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CATCH STRUCTURE AND DYNAMICS OF ANTILLEAN "Z" TRAPS ON A CORAL REEF: INTERACTION BETWEEN TRAP CHARACTERISTICS AND FISH BEHAVIOUR

Thesis submitted by
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in May 1995

Thesis submitted for the research Degree of Master of Tropical Marine Ecology and Fisheries Biology in the Department of Marine Biology at James Cook University of North Queensland

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ABSTRACT

This study experimentally evaluated a number of factors affecting the structure, dynamics and variability in catches from Antillean "Z" traps deployed on fringing coral reefs at Orpheus Island (central Queensland coast). The aim was to develop methodologies to improve the use of traps as a fishing device and a sampling tool for different target species. The effects of trap characteristics (mesh size), presence of bait, bait type and frequency, soak time and the prior residence of individuals in traps were assessed, in terms of total catches and species composition. Using direct diver-observations and video technology, the effects of these manipulations on the attractiveness of traps to different species, the number of fish entering the traps and escapement were distinguished. The generality of the patterns observed was assessed repeating experiments at two locations. Cattle Bay (Trial 1) and Pioneer Bay (Trial 2).

Catch rates and final catches were consistently higher in large-meshed traps (42 mm hexagonal mesh) compared with small-meshed traps (12.5 mm square mesh), and for traps baited with pilchards (*Sardinops neopilchardus*) compared with the use of fish oil. The same pattern was observed during both trials, although overall catches were twice as high at Cattle Bay, compared with Pioneer Bay. During the second trial, baited traps did not perform better than traps with no bait. Also, similar total catches were registered in rebaited traps and traps baited only once, suggesting a minor role of bait on catches at this location. The magnitude of the effects of these different trapping procedures on catch rates and final catches was species-specific. Catches were dominated by four species: *Siganus doliatus* (Siganidae), *Lutjanus carponotatus* (Lutjanidae), *Plectropomus maculatus* and *P.leopardus* (Serranidae). These were affected differently by the mesh size, with *S.doliatus* caught almost entirely in large-meshed traps, *L.carponotatus* caught mainly using pilchards for bait, and the coral trout species not significantly affected by any of the treatments. There appeared to be a trend in the composition of fish families trapped. Herbivorous fish appeared at the beginning of the soak period when large predatory species were absent. More predatory species could have progressively entered traps to prey on the smaller fish species that are being accumulated over the soak period.

Differences in catches were the result of different behavioural responses of fishes to traps at different stages in the trapping process. Diver-observations and video analysis indicated that different catch rates in different treatments were not closely related to the number of fish attracted to the traps, but reflected species-specific differences in the likelihood of fish entering or escaping from traps. An experiment in which the presence of *S.doliatus* in traps was manipulated, indicated that catches were affected by visual communication between fish inside and outside large-meshed traps. Greater numbers of *S.doliatus* entered large-meshed traps in which *S.doliatus* had been placed experimentally. On the other hand, *L.carponotatus* was more likely to enter traps baited with pilchards, and the presence of small fish in traps at the beginning of the soak period resulted in a greater catchability of coral trout.

Knowledge of these species-specific fish-fish and fish-trap behavioural responses provides considerable scope for designing trapping protocols for targeting particular species. High variability in catches may be an unavoidable consequence of species-specific behaviour patterns and may limit their utility as a sampling tool for measuring changes in relative populations densities.

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STATEMENT ON SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Marina Santurtun *(Date)*

CHAPTER I

GENERAL INTRODUCTION

Fish traps have been the principal artisanal method of fishing in many tropical regions of the world (Munro, 1983). Traps remain in popular use in the Caribbean and the Pacific contributing a very large part of the catch (Munro *et al.*, 1971). The kinds of traps in use vary between and within geographical regions. Munro *et al.*, (1971), described three types of traps present in the Caribbean, the Antillean "Z" trap used in Jamaica and the Great Antilles, the Cuban "S" trap and the Chevron trap used mainly in Puerto Rico and the Virgin Islands. These traps were once built of a variety of natural materials (mainly wood and cane), however, wire was introduced during the early 1920's. In the Pacific region, and specifically in Australia, aboriginals are known to have used stone walls to trap and contain fish which were driven into them (Walters, 1987). Within Australia, rectangular and cylindrical traps are used for collecting mainly snapper and emperor, respectively (Anon, 1968; Clark, 1984; Sainsbury, 1990). In other tropical areas of the Pacific such as New Caledonia (Kulbicki & Mou-Tham, 1987), Papua New Guinea (Dalzell & Aini, 1987), and New Zealand (Crossland, 1976) traps have been used experimentally as fishing gear. Despite the long period of use there is considerable scope for improving the design, baiting and deployment of traps to improve catches of target species.

In addition to the use of traps as a fishing gear, traps have good characteristics for use in the assessment of fish stocks, providing information on abundance, population structures and movements (Davies, 1989, Sheaves, 1992). Traps have been used extensively in the Caribbean as sampling devices for quantitative and qualitative studies of coral reef fish communities under different fishing regimes (Wolf & Chislett, 1974; Parrish, 1982; Koslow *et al.*, 1988; Recksiek *et al.*, 1991). They have been used for collecting information necessary for management of fisheries in Florida (Taylor & McMichael, 1983; Sutherland & Harper, 1983) and in the Pacific (Dalzell & Aini, 1987; Kulbicki & Mou-Tham; 1987). In Australia, trap based fisheries (North-West Shelf fishery and Northwestern Australia) have been examined to assess their effectiveness in harvesting fish (Moran & Jenke, 1989; Sainsbury, 1990; Whitelaw *et al.*, 1991). This technique has also been recently used as a sampling tool on the Great Barrier Reef with the purpose of estimating densities of reef fish (Davies, 1989; Newman, 1990; Williams *et al.*, 1992). Traps offer several advantages over other sampling methods used in fish stock assessment. In contrast to trawling, it is a "non-destructive" sampling device that can potentially provide a large number of live fish for mark-recapture estimates of population size, growth and movement (Davies, 1989). Furthermore, they can be used in coral reef areas, where trawlers cannot operate because of the complex topography and can be deployed with minimum disturbance to the habitat. Traps can be used to target fish species that are not amenable to visual census techniques, including schooling and deep water species. Traps also provide point sampling units for assessing abundance of species simultaneously at a number of locations.

Because of the use of traps as a sampling tool for studying fish populations in tropical regions, studies have been directed toward gaining a better understanding of trap performance. This has been studied in terms of how long traps are deployed (soak period), time of deployment (lunar phase) (Munro *et al.*, 1971; Newman, 1990), distance to the reef and substrate on which traps are set, (Sylvester & Dammann, 1972; Parrish, 1982; Luckhurst & Ward, 1987), depth at which traps are set (Craig, 1976; Newman, 1990) and direction of main tidal currents in relation to the funnels (Munro *et al.*,1971; Campbell *et al.*,1987). Also, the design of traps has received considerable attention. The effectiveness in catching fish has been assessed for different trap shapes (Whitelaw *et al.*, 1991), funnel type and shape (Luckhurst & Ward, 1987), mesh size (Wolf & Chislett, 1974; Olsen *et al.*, 1978; Stevenson & Stuart-Sharkey, 1980; Luckhurst & Ward, 1987; Newman, 1990) and different baits used (Sylvester & Dammann, 1972; Munro, 1974; Stevenson & Stuart-Sharkey, 1980; Campbell *et al.*, 1987; Newman, 1990). Few generalisations have emerged, with effects of the factors dependent upon the species concerned and the local species composition. The common problem found in all previous studies was the high variability in catch rates and catch composition recorded for identical traps, which affects the accuracy and precision of density estimates.

As fish traps are passive collectors, catch rates and catch composition depend on the behavioural response of the fish in the presence of the trap and its occupants (Luckhurst & Ward, 1987; Karnofsky & Price, 1989). Davies (1989) demonstrated that trap efficiency in catching fish was species-specific. Depending on the target species considered in each of the fisheries or sampling studies, the sampling methods should be tailored to take account of these specific behavioural characteristics in relation to traps. While catches may be improved by changing such things as trap design (e.g. mesh size) or the bait used, very little is known of the behavioural mechanisms involved. Without such information, improvements can be only achieved on a trial-and-error basis. High variability in catch rates may relate to behavioural interactions within and among the species being caught and changes in the behaviour of fish as a result of changing trap design and deployment. An assessment of the importance of these factors can only be addressed using direct dive observations or underwater video techniques (Campbell *et al*, 1987).

This study examines the structure and dynamics of fish catches using Antillean "Z" traps on the fringing reefs of Orpheus Island (central Great Barrier Reef). The aims of this study were:

1.- To examine the structure and dynamics of fish catches in traps with different mesh sizes using different baits.

2.- To examine the attractiveness of the different trap design and bait combinations by measuring the aggregation of individuals around them.

3.- To describe fish behaviour in the vicinity of different traps, including a description of rates of ingress and escapement.

4.- To evaluate the effect of the presence of a certain species in the trap on the subsequent ingress of conspecifics.

The thesis is divided into two main sections: 1) the influence of traps using different mesh sizes and bait types on the accumulation and final catches over different soak periods (Chapter II) and 2) an examination of the attractiveness of traps and fish behavioural interactions that influence rates of capture (Chapter III). A final section (Chapter IV) presents the discussion of the previous results and the thesis conclusions.

CHAPTER II

INFLUENCE OF BAIT AND MESH SIZE ON CATCH STRUCTURE AND DYNAMICS USING ANTILLEAN "Z" TRAPS

2.1. INTRODUCTION

Bait type and mesh size are two factors which can be easily modified to improve catches. However, few workers have examined the effect of these factors on catch and the underlying mechanisms. Munro (1974) proposed a simplistic theoretical model for catches based on rates of ingress (entry) and egress (escapement) in baited and unbaited traps. Initial rates of ingress are higher in baited traps than in unbaited ones, due to the immediate effect of bait as an attractant for certain species. Once the bait is depleted, the rates of ingress to these traps drop off and ingress rates reach similar levels to those registered in unbaited traps. Also, escapement rates increase sharply. Catch rates decline as a consequence of these two factors. Munro (1974) concluded that optimum soak times (the fishing time of the trap at which the catches are highest) for baited traps were shorter than for unbaited traps. Easily dispersed baits, and consequently low longevity baits, will be very effective trapping fish while they last. Baits that last longer are usually related to lower catch rates and longer fishing periods that the very effective ones (Campbell *et al.*, 1987). Rates of ingress and consequently trap catches were closely related to the effectiveness of the bait in attracting fishes to the vicinity of the trap and their subsequent capture (Campbell *et al.*, 1987). The different studies that have monitored and modelled the cues that lead fish to enter and escape from traps have been directed to the multispecific trappable stock (Dews *et al.*, 1987). However, it is known that rates of ingress/egress are species specific and also the optimum soak time varies from one species to another (Munro, 1974; Davies, 1989).

The composition of the catch will change depending on the soak time. Some species are replaced by others, while abundance of others remain constant during that same soak time. Davies (1989) observed how herbivorous species (scarids and siganids) appeared in traps at the beginning of the soak period while large predatory species (*Plectropomus* spp.) appeared after two days soak. A detailed study of the snapper fishery in Western Australia (Moran & Jenke, 1989) stressed the importance of soak time for catch build-up. Maximum catches were reached after 30 minutes soak, after which escapement rates were very high. Long periods of soak resulted in high quality and low quantity of the snappers, which suggested that there was a very high turn-over in the composition of the fish in the trap. Determining the optimum soak time for target species is an important part of maximising the efficiency of sampling and catching in traps.

Different mesh sizes used in traps have been suggested to influence catch by increasing the size of fish retained (Luckhurst & Ward, 1987; Newman, 1990), by being perceived as shelters (Luckhurst & Ward, 1987) and by presenting more obvious funnel apertures resulting in higher escapements (Luckhurst & Ward, 1987). In other studies, recruitment to the trap fishery has been related to fish behavioural changes (Hartsuijker & Nicholson, 1981) and to higher vulnerability to the traps as a result of an increase in fish size (Smith & Tyler, 1975) rather than to the mesh size used.

The aims of this section were to establish:

1.- How the catch is accumulated over the soak period in terms of rates at which different species are caught in traps made with different mesh sizes and using different baits. This was measured by regular diver counts of the fish in the traps.

2.- Whether bait type and mesh size caused differences in final catch composition and catch rates for abundant species.

3.- Whether patterns observed at one location and time are likely to be repeatable in space and time.

4.- Whether a continuous supply of bait caused different final catch composition and catch rates from traps baited only once.

2.2. MATERIAL AND METHODS

2.2.1. STUDY SITES AND HABITAT

Two trapping trials were carried out during two consecutive years at Orpheus Island. Orpheus Is. is a member of the Palm Island group, on the Central Great Barrier Reef (18°35'S, 146°28'E), located 80 km north of Townsville (Queensland) and 13 km from the mainland (Fig.2.1.). The first trial took place in Cattle Bay between 7 October 1993 and 9 January 1994 over a total of 26 days. Cattle Bay is situated at the north-western part of the island. The second trapping trial was carried out at Pioneer Bay, located on the western part of the island. This took place between 21 June and 24 November 1994 over a total of 42 days. Both locations were situated in a Marine Park protected area (Zone B) where the abundance of fish was expected to be at its highest. Previous studies located on the northern part of Cattle Bay (Iris point) recorded high catches of a variety of species (Davies, 1989; Newman, 1990). Both Cattle and Pioneer Bay are protected from strong southeast and easterly winds which are predominant during winter.

The first trapping trial extended over approximately 1 km along half the southern part of Cattle Bay, where the habitat was relatively uniform. In the shallower parts, the substratum was dominated by hard-branched corals (*Acropora* spp. and *Montipora* spp.) and soft corals (Alcyonarians). The reef slope was characterised by relatively flat and stable areas of coral rubble with some microatolls. Small patches of mangroves (*Rhizophora* sp.) are located at the northern part of the sampling site.

In the second trial, traps were deployed over approximately 1.2 km along the southern part of Pioneer Bay. This location was characterised by a 400 m wide reef flat which was exposed during spring tides. The inner part of the flat consisted of fine and very fine sand, coral rubble and some dead microatolls. A 100-metre wide band of coral rubble and some living colonies surrounded the inner sandy areas. Living corals such as *Porites* sp., *Goniastrea* sp., and Alcyonarians form the outer part of this reef flat. On the southern part of the inner reef flat was located an area of mangrove (*Rhizophora* sp.) (Parnell, 1987). The substratum of the sites were dominated by hard-branched and soft corals at the shallower reef flat areas and the deeper reef slope was characterised by vast areas of coral rubble changing progressively to sand-muddy bottoms at the deepest parts.

The fish fauna found at both sampling locations at Orpheus Is. was typical of inshore reefs. On the reef flat, small sand-inhabiting fish such as gobies (Gobiidae), lizardfish (Synodontidae) and stingrays (Dasyatidae) were very abundant. Near the band of coral rubble, small damselfishes (Pomacentridae) and wrasses (Labridae) were numerous. The number of fish species was highest in the living coral zone, where damselfishes and wrasses dominated. Other families represented were groupers (Serranidae), snappers (Lutjanidae) and a few species of grunts (Haemulidae: *Diagramma pictum*) and sweetlips (Lethrinidae: *Lethrinus nebulosus*), butterflyfish (Chaetodontidae), and fusiliers (Caesionidae). Surgeonfishes (Acanthuridae) and big schools of small parrotfish (Scaridae) were observed feeding on the coral or algae. Nocturnal fish reef species were also abundant at Orpheus island: cardinal fishes (Apogonidae), squirrelfishes (Holocentridae) and moray eels (Muraenidae).

2.2.2. GENERAL DESCRIPTION OF THE TRAPS

The traps used in this study were built based on the characteristics of the Antillean "Z" traps described by Munro *et al.* (1971) and Munro (1983), but with a number of variations. They were constructed using angle iron frames welded together to adjust the "Z" shape. Galvanised hexagonal and square wire meshes (42 mm and 12.5 mm, respectively) were cut and tucked together with galvanised tie wire and were used for building walls, roof and floor enclosures of the different meshed traps. These mesh "boxes" were later stringed to the iron frames with galvanised tie wires (Davies, 1989) (Fig.2.2.).

Traps were built with two straight funnels laced with galvanised tie wire to the concave end of the large diagonals on opposite sides of the trap. The ellipse-shaped funnels had an outer aperture of approximately 350 mm x 200 mm, reducing to 250 mm x 150 mm in the inner funnel. Traps had two doors on opposite ends to the funnels to facilitate being emptied and rebaited. The traps were 1.80 m long, 0.84 m wide and 0.50 m deep, respectively. These Antillean "Z" traps with a volume of 0.756 m^3 were almost half the size of those used by Davies (1989) in his study at the same island.

2.2.3. SAMPLING DESIGN

TRIAL 1: Cattle Bay

A sampling program was carried out to determine the effects of two factors, mesh size and bait type on the catch dynamics. A fixed factor orthogonal sampling design was adopted (Fig.2.3a.). The first factor was mesh which had two levels: Large mesh (42 mm hexagonal mesh) and small mesh (12.5 mm square mesh). The second factor was bait type, with two different baits being used: frozen Western Australia blue pilchards (*Sardinops neopilchardus*) and fish oil. It was necessary to replicate the 4 different treatment combinations through time. During any one soak period, 4 traps, each of them representing one treatment combination, were set in the early morning for two days soak time. A total number of 52 hauls (13 replicates per treatment) were carried out between October 1993 and January 1994.

The soak time period (between setting and hauling the traps) was set at 2 days based on previous observations. Davies (1989), using larger "Z" traps, different mesh sizes and horseneck funnels, estimated an optimum soak time of 3 days for *Lutjanus carponotatus*. This was determined by measuring the time taken for catches to asymptote. Longer soak periods of 3.5 days were calculated for *Plectropomus* spp. and *Siganus doliatus*. However, due to the straight funnels used in this study and the possible higher escapement through them (Luckhurst and Ward, 1987), a shorter soak time of 2 days was chosen.

To control for any possible lunar effects on catch rates (Munro *et al.*, 1974; Newman, 1990), traps were only deployed during new or full moon periods. Traps were set in the early morning in a randomised sequence, to avoid any confounding effect due to spatial or temporal factors. Traps were set as far as possible from one another within the limits of the sampling area (at least 60 m.) in an attempt to ensure independence among replicates (Eggers *et al.*, 1982). All traps were set along the reef flat or at the beginning of the reef slope at depths ranging from 6 to 10 metres with divers repositioning the traps to ensure that they were sited in a flat and stable substratum as close as possible to massive corals (<1 m.) in the opposite side from which the main tidal currents were coming. Traps were orientated so that the funnels faced these tidal current.

At the end of the 2 days soak time, traps were manually hauled on board and the catch was identified at the species level whenever possible. Standard and total lengths were recorded. The nomenclature is based on Randall *et al.* (1990). The catch was released far from where traps were hauled (i.e. out of the sampling area). A new trial was initiated that same morning with the traps for every treatment combination being moved to other random locations, within the sampling area, separated by at least 100 metres from the previous one to avoid fish learning behaviour (i.e. learning to escape from traps) and two sites being used twice.

Traps of different mesh sizes were baited with approximately 800 grams of chopped pilchards (10-11 fish) placed in a perforated plastic container. This bait produced high catches in previous studies (Whitelaw *et al.*, 1991). An artificial bait was used for the other baited traps. Ten chopped pilchards were placed in a plastic container and completely cover with 750 millilitres of edible vegetable oil. This mixture was left in a closed container for no less than two days after which the oil was strained and a sponge was dipped in the oily substance and placed in the holed plastic container which was then hung inside the traps.

TRIAL 2: Pioneer Bay

As in the previous trial, traps were deployed in a sampling exercise designed to examine the effects of two factors (mesh size and bait type) on the number of fish and number of species caught, catch-composition and cumulative catch. An orthogonal sampling design was used (Fig. 2.3b.) to determine the combination of mesh size and bait that maximised catch for particular species. Also as in the previous trial, two levels of mesh size were used: large mesh (42 mm hexagonal mesh) and small mesh (12.5 mm square mesh). However in this trial, the two different kinds of bait were tested in addition to a new level of unbaited traps. The same baits, frozen Western Australia pilchards (*Sardinops neopilchardus*) and fish oil were used. In this trial, the effect of extending the soak period one day was also examined. This was suggested from the results of the previous trial at Cattle Bay. Catches of *L.carponotatus* in traps soaked for 2 days seemed to decrease markedly after 30 hours soak probably due to the high escapement through straight funnels, however, catches of *S.doliatus* and *Plectropomus* spp. were still increasing after two days soak.

The 6 different treatments were replicated through time, with at least 6 traps representing treatments deployed at haphazard locations during any one time. From June to November, a total number of 75 hauls was achieved. A different number of replicates of each treatment (ranging from 11 to 14, Fig.2.3b.) were carried out.

Effect of rebaiting the traps

From July to September, an additional rebaiting treatment was carried out to examine the effects of a daily supply of fresh bait on catch rates and catch composition. As before, two levels of mesh size were used: large mesh (42 mm hexagonal mesh) and small mesh (12.5 mm square mesh). Two different kinds of bait were tested: frozen Western Australia pilchards (*Sardinops neopilchardus*) and fish oil.

Four different treatments were replicated through time, with at least 2 traps, each of them representing one of the treatments, deployed at random locations during any one trial. From July to September, a total number of 16 hauls were achieved.

Each of the treatment combinations were baited when the trial started, then they were baited again before the overnight soak on the second day (i.e. after 36 hours) and on the third day (i.e. after 60 hours). Divers rebaited the traps positioning their bodies intercepting the open doors to prevent any fish from escaping, and then hung a new bait tube in each of the treatment combinations and removed the old one. After the 3 days soak period, traps were hauled, catch identified, measured and released. That same morning, a new rebaiting trial was started in a new random location within the limits of the sampling area.

2.2.4. UNDERWATER COUNTS

During all trapping programs (section 2.2.3.), underwater counts of trapped fish were carried out using SCUBA to examine catch composition and build-up through the soak period. That is, counts of number of fish and number of species caught for the different treatment combinations of mesh and bait. Catch build-up can be defined as how the total number of individuals and the species composition of the catch develops during the period that the trap is fishing. Direct counts were made on the multispecific catch (total number of fish regardless of species) and on four target species known to be abundant in the area, readily caught in traps and of importance to the recreational fishery: *Lutjanus carponotatus, Plectropomus leopardus* and *Plectropomus maculatus* (*Plectropomus* spp.) and *Siganus doliatus*.

During trial 1 at Cattle Bay and for each soak period, catch was identified and counted at four different times of the day between 7:30 a.m. and 5:00 p.m. Counts were carried out during the 1st hour, 3rd hour, 5th hour, and 7th hour (day 1) and during 24th hour, 26th hour, 28th hour, and 30th hour (day 2) of the soak period. At each of the four times, fish numbers and species in each treatment combination were noted before moving to the next one, so that the four treatments were sampled for each period. At the end of this trial a total of 380 underwater counts were achieved.

During trial 2 at Pioneer Bay and for rebaited traps, during each day's soak period, two daily inspections of each of the treatments were randomly made by divers during the early morning (7:30 a.m. to 8:00 a.m.) and late afternoon (5:00-5:30 p.m.). Thus, at the end of the soak period inspections were carried out during the 1st hour, 7th hour, 24th hour, 30th hour, 48th hour and 54th hour. At each inspection period, catches in each of the six treatments and four rebaiting treatments were counted and identified. At the end of the trial a total number of 376 underwater fish counts were achieved for the six treatments and 105 counts for the rebaiting trial. For those traps used for the rebaiting treatments, during the afternoon of the second and third days of the soak time and before the underwater counts started, new baits were set in the traps.

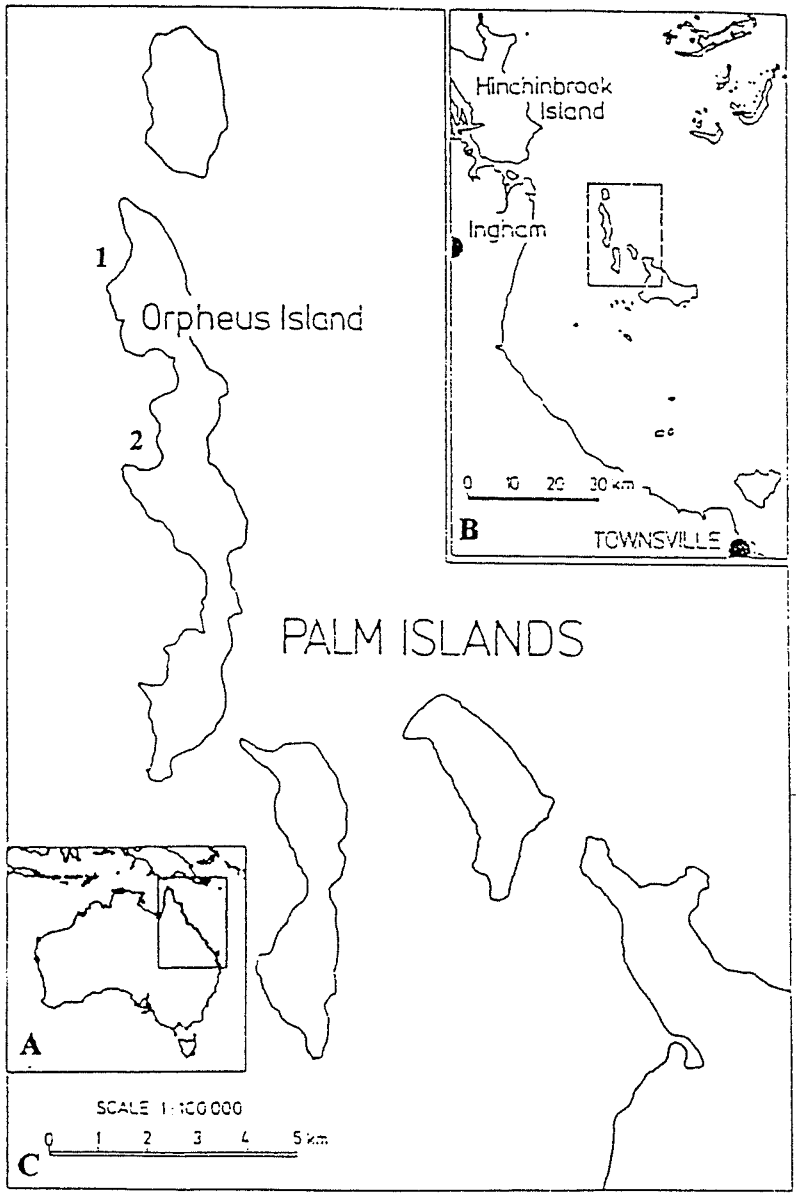


Fig.2.1. Map of Australia (A) showing the coast of Queensland (B) and Orpheus Island (C). The two sampling locations at Orpheus Island are also indicated. **1**= Trial 1: Cattle Bay; **2**= Trial 2: Pioneer Bay.

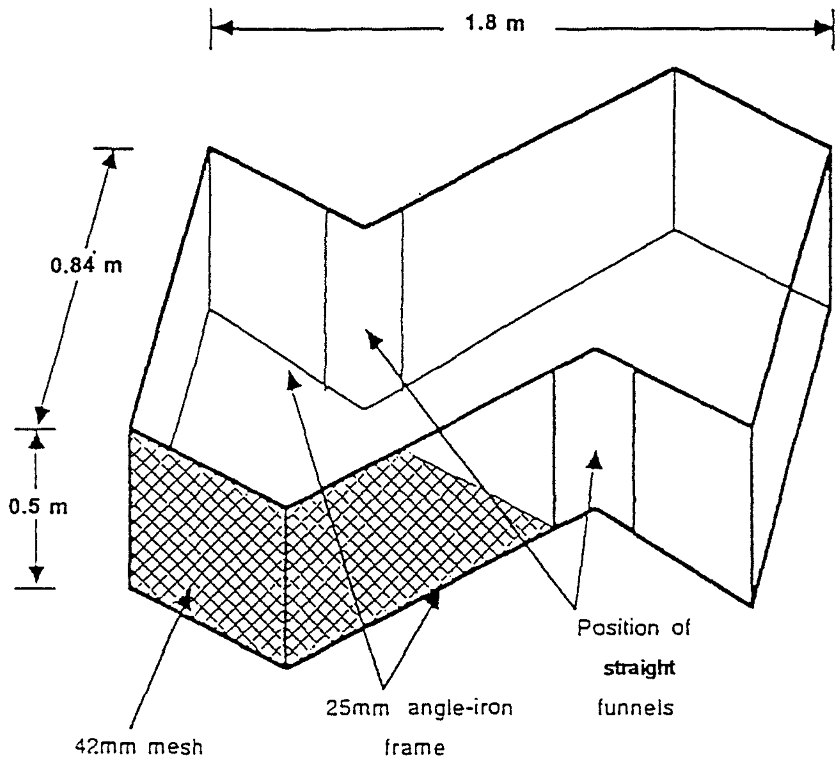


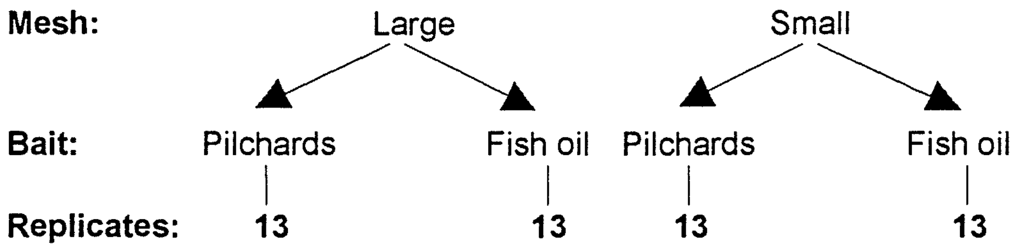
Fig.2.2. Diagram of Antillean "Z" trap with large mesh. The positions of the funnels are indicated. From Davies (1989). Figure 2.

Fig.2.3.

(a).Orthogonal sampling design with two-fixed factors (Mesh size and Bait type) for traps deployed at Cattle Bay (Trial 1). The number of replicates carried out for each treatment is indicated. Each trap was deployed for 2 days.

TRIAL 1

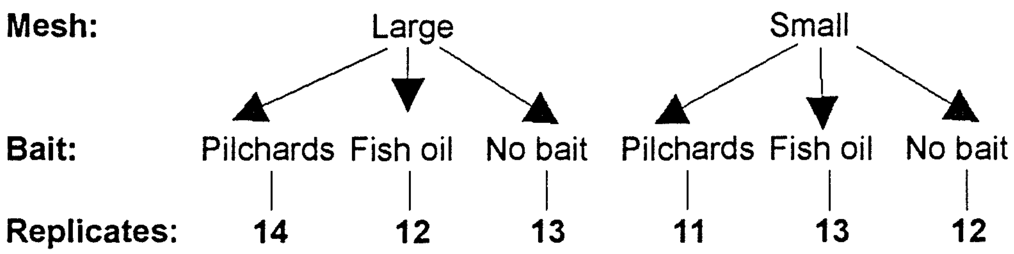
(CATTLE BAY)



(b). Orthogonal sampling design with two-fixed factors (Mesh size and Bait type) for traps deployed at Pioneer Bay (Trial 2). The number of replicates carried out for each treatment is indicated. Each trap was deployed for 3 days.

TRIAL 2

(PIONEER BAY)



2.2.5. DATA ANALYSIS

The mean number of fishes at the time of hauling up the trap (final catch), the number of species and the mean number of target species, were analysed by using a two-way analysis of variance for each trial. In both cases, data were transformed by log (x+1) to reduce deviations from the normal distribution and to achieve homogeneity of variances. A significance level of $P=0.05$ was used for all data analyses. Before the analysis of variance was carried out, data was tested for homogeneity of the variances using Cochran's test (Winer, 1971). After the analysis of variance, comparison of means of significant treatments were carried out using *a posteriori* test: Ryan's Q-test (Day & Quinn, 1989).

When transformations of the data did not result in homogeneity of variances, randomised ANOVA tests were used to assess whether patterns in data were likely to have appeared by chance (Manly, 1991). In these tests, the significance level of a test statistic is calculated by randomly reordering the data. The mean number of *S.doliatus* caught in both trials was analysed using this test. Although homogeneous variances are not a condition in this test, data was log (x+1) transformed in an attempt to reduce heterogeneous variances. For the second trial, it was necessary to reduce the number of replicates of each treatment to 11 to balance the design. In this way, eleven replicates were chosen randomly and the randomised ANOVA test was carried out. In the summary of the results of all ANOVA tests, transformed data is presented. Probability levels of the randomised ANOVA tests are given in percentages. Catch rates of traps with different mesh sizes were compared using two-tailed t-tests assuming equal variances (Zar, 1987). Also, the final number of fish and number of species caught in traps baited only once and traps baited three times were compared using a t-test for treatments in which more replicates were obtained (Zar, 1987).

Fisher's exact test for a two-tailed hypothesis was used for analysing length-frequency distributions of target and most abundant species for which there were enough individuals caught. This test is considered to work well for examinations of 2x2 contingency tables because in the calculation of the distribution of probabilities, probabilities of more extreme contingency tables, in the same direction in which the original distribution table is extreme, are used (Zar, 1987). Size classes were pooled into two for each of the species considered. In this way at least one individual was represented in one size class. Different size classes, depending on the species considered, were used for these tests depending on the species under consideration (i.e. total length of *L.carponotatus* and *L.sebae* were divided into 0-<30 cm and ≥30 cm size classes and total lengths of *Plectropomus* spp. were grouped into another two size classes 0-<40 cm and ≥40 cm; for *S.doliatus*: 0-<20 cm and ≥20 cm size classes were used). Tukey-type multiple comparison tests of proportions of size classes of target and most abundant species were carried out to discern how length frequencies differed (Zar, 1987).

2.3. RESULTS

A total of 230 fish from thirty species and fifteen families were captured in twenty-six days of trapping during the first trial. Overall, a mean number of 2.2 fish/trap/day (s.e.=±0.2) were captured. For the second trial, 222 fish from 43 species and 21 families were yielded over 42 days of trapping at Pioneer Bay (Appendix I & II). The overall catch rate was of 1.0 fish/trap/day (s.e.=± 0.1).

2.3.1. EFFECT OF MESH SIZE ON THE OVERALL CATCH

In both trials, large-meshed traps were consistently more effective catching fish than small mesh ones accounting numerically for 68.7% of the total catch in trial 1 and 74.3% of total catch in trial 2 (Fig.2.4). There was a significant effect of mesh size on number of individuals caught during the two trials, with the number of fish caught in large-meshed traps significantly higher than in small mesh traps for both trials (Tab.2.1.). Catches followed an increasing trend over the whole soak period with slight decreases in mean number of fish during daylight hours of the soak period (Fig.2.4.). For both trials, after the first overnight soak periods, an increase in number of fish was recorded in both mesh sizes. After the second overnight soak period and for traps deployed at Cattle Bay during trial 1, catches appeared to level off and mean numbers remained fairly constant in both meshed traps. Catches in large-meshed traps deployed at Pioneer Bay showed a slight drop in mean numbers at the end of the soak period. During the first trial, the rate of catch build-up in large-meshed traps, as measured by the average number of fish in the traps over 48 hours soak time, was approximately twice as fast as the small-meshed traps while for the second trial catch rates were approximately three times faster. There was a significant difference between catch rates of different mesh sizes deployed at Cattle Bay ($t=-3.170$, d.f.=50, $P<<0.05$) and at Pioneer Bay ($t=3.334$, d.f=73, $P<<0.05$).

2.3.2. EFFECT OF BAIT TYPE ON THE OVERALL CATCH

For both trials, traps baited with pilchards showed a consistently higher mean average catch than traps using fish oil (Fig.2.5). In addition, in trial 2 the mean values of the catch in unbaited traps were consistently higher than catches in traps using fish oil. The catch was significantly higher in traps baited with pilchards during the first trial (Tab.2.1). For the second trial, higher numbers of fish were captured in traps baited with pilchards than in unbaited traps and traps baited with fish oil, however, no significant differences in mean numbers of fish were detected by Ryan's Q-test (Tab.2.2.). As for different meshed traps, the greatest rise in number of fish trapped was observed after the first overnight soak period (i.e. 24 hours). For both trials, mean catches in baited and unbaited traps (trial 2) followed a similar pattern to that of the mean catch in meshed traps over the different soak periods (Fig.2.5.) although the mesh factor appeared to have a greater effect on the number of fish caught than the bait types used.

2.3.3. CATCH DYNAMICS OF TARGET SPECIES

Mean number of target fish captured showed different trends for both mesh sizes and baits through the different soak periods. For both trials, *Siganus doliatus* was the species with the highest mean number of individuals captured in large-meshed traps. The most significant feature was that virtually no *S.doliatus* were captured in small-meshed traps during the different soak periods used in both trials (Fig.2.6.). There was a significant effect of mesh size in the number of *S.doliatus* caught in meshed traps for both trials (Tab.2.3). After the first 24 hours of the soak period of trial 1, only one *S.doliatus* was captured in this treatment. For trial 1, and from the variance range (Tab.2.3.) there was some evidence that the level of variation in number of *S.doliatus* changed over the different treatments.

During the first trial, mean catches of *S.doliatus* showed an increasing trend in both bait treatments. However, for the second trial, catches of *S.doliatus* decreased in traps baited with fish oil and in unbaited traps. In this same trial, an increasing trend in *S.doliatus* catches was observed in traps with pilchards through all the soak period. Catches of this species in unbaited traps were comparatively higher (Fig.2.6.). However, bait type appeared not to have a significant effect on the final number of *S.doliatus* caught in traps for each of the trials. Catch rates of *S.doliatus* caught in different meshed traps at Cattle Bay and Pioneer Bay were significantly different ($t=4.578$, d.f=50, $P<<0.05$ and $t=2.631$, d.f=73, $P<<0.05$, respectively)

In the first trial, a comparatively higher number of *L.carponotatus* were caught in large-meshed traps (Fig.2.7). *L.carponotatus* reached a maximum catch after 30 hours soak in large-meshed traps, while in small-meshed traps the highest mean number of fish was registered during 24 hours of soak. For both mesh sizes, catches decreased after the last overnight soak. However, during the trial at Pioneer Bay a comparatively higher number of *L.carponotatus* was caught in small-meshed traps than in large ones. From the ANOVA results, the mean number of *L.carponotatus* caught in traps deployed at Cattle and Pioneer Bay did not differ significantly in traps with different mesh sizes (Tab.2.4). During trial 2, a continuous decreasing trend in mean numbers was recorded in large-meshed traps after the morning of the second day. For both mesh sizes, mean catches decreased during this trial over the daylight hours of the soak period, increasing after overnight soaks (Fig.2.7.). Catch rates of *L.carponotatus* in traps with different mesh sizes deployed during trial 1 and trial 2 did not differ ($t=1.503$, d.f.=50, $P>>0.05$ and $t=0.615$, d.f.=73, $P>>0.05$).

During each trial, the mean catches of this species were higher in traps baited with pilchards than in traps baited with fish oil and in unbaited traps (trial 2). However, no significant effect of bait on mean numbers of *L.carponotatus* was found for trial 1, while bait had a significant effect on the number of *L.carponotatus* caught in the traps deployed at Pioneer Bay (Tab.2.4.). The multiple comparison of means could not make a clear distinction amongst the different baits on numbers of this species.

For both trials the final number of *Plectropomus* spp. caught did not differ significantly between traps with different mesh sizes (Tab.2.5.). During the first trial, mean numbers of *Plectropomus* spp. were higher in small-meshed traps for the first 6 hours of the second day soak. Mean catches of this species were comparatively low. The maximum average catch was recorded in large-meshed traps at the end of the soak. During the second trial, catches of *Plectropomus* spp. showed an increasing trend at the end of the soak period in both mesh sizes with slightly lower catches in 12.5 mm square mesh traps (Fig.2.8.). The catch rates of this species did not differ significantly between traps with different mesh sizes at Cattle Bay ($t=1.002$, d.f=50, $P>>0.05$) and Pioneer Bay ($t=0.480$, d.f.=73, $P>>0.05$).

For both trials, mean number of *Plectropomus* spp. were maintained at very low numbers in baited and unbaited traps (trial 2). Bait did not have an effect on number of *Plectropomus* spp. caught at the end of the soak period of each of the trials (Tab.2.5). During the first trial, catches in traps using pilchards slightly decreased after the morning of the second day of the soak period and increased again after the overnight soak period. During the second trial, the highest number of *Plectropomus* spp. was found in unbaited traps, with catches increasing from the end of the second day of the soak time until the end of the soak period (Fig.2.8.).

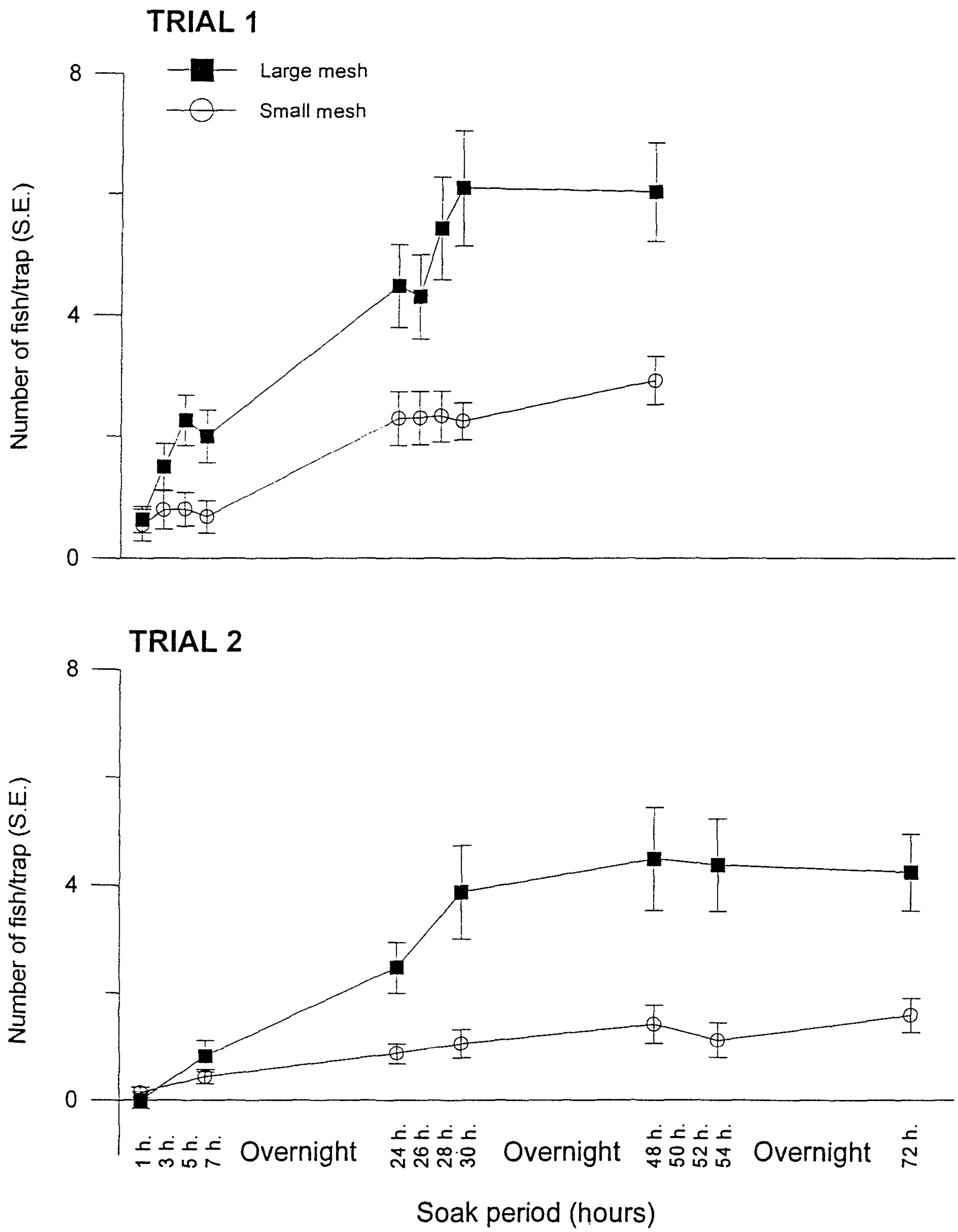


Fig.2.4. Mean number of fish captured in different meshed traps during each trial. (Error bars represent standard errors)

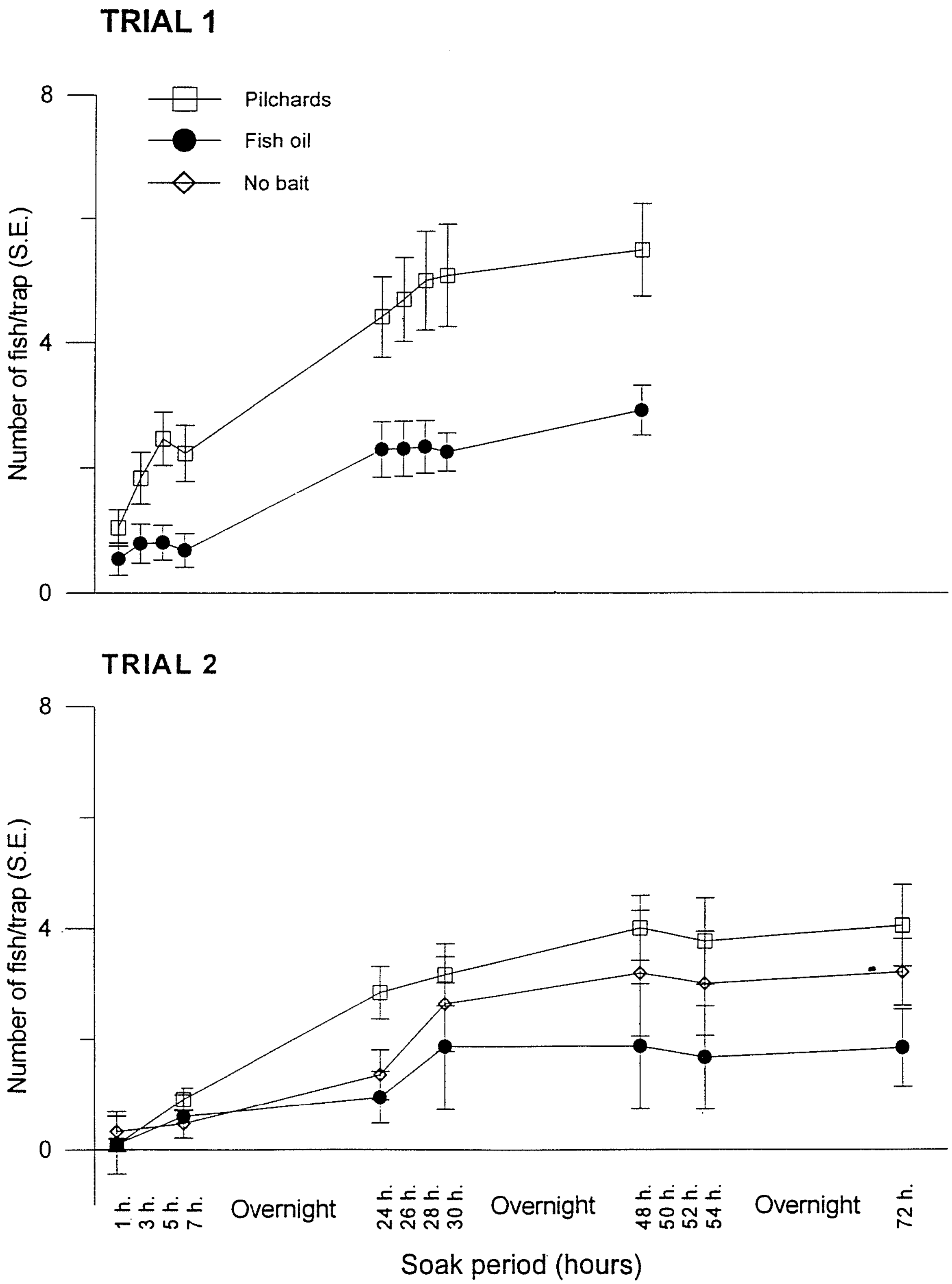


Fig.2.5 Mean number of fish captured by different baits during each trial.
(Error bars represent standard errors)

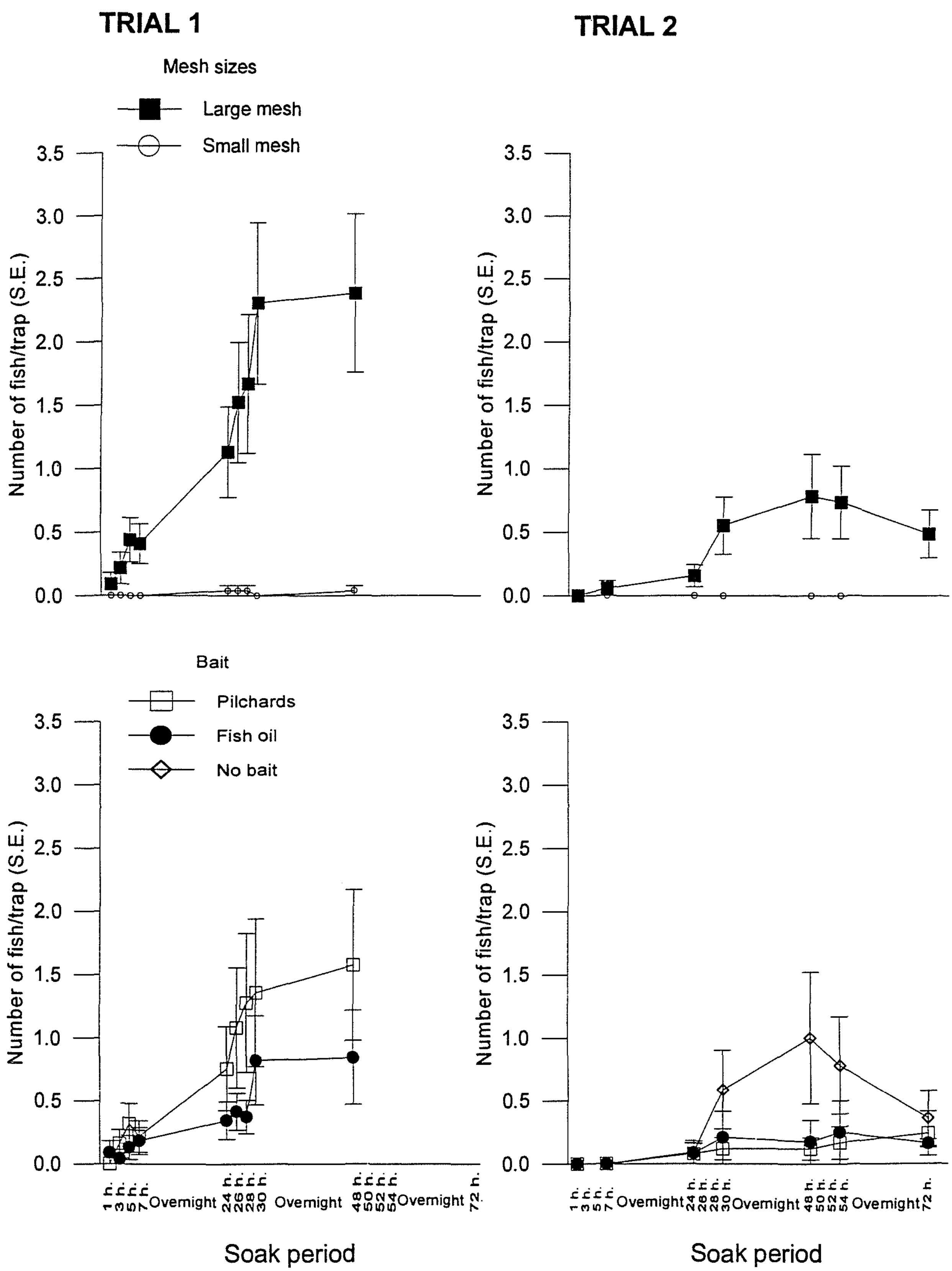


Fig.2.6. Mean number of *S.doliatus* captured in traps during each trial.
(Error bars represent standard errors)

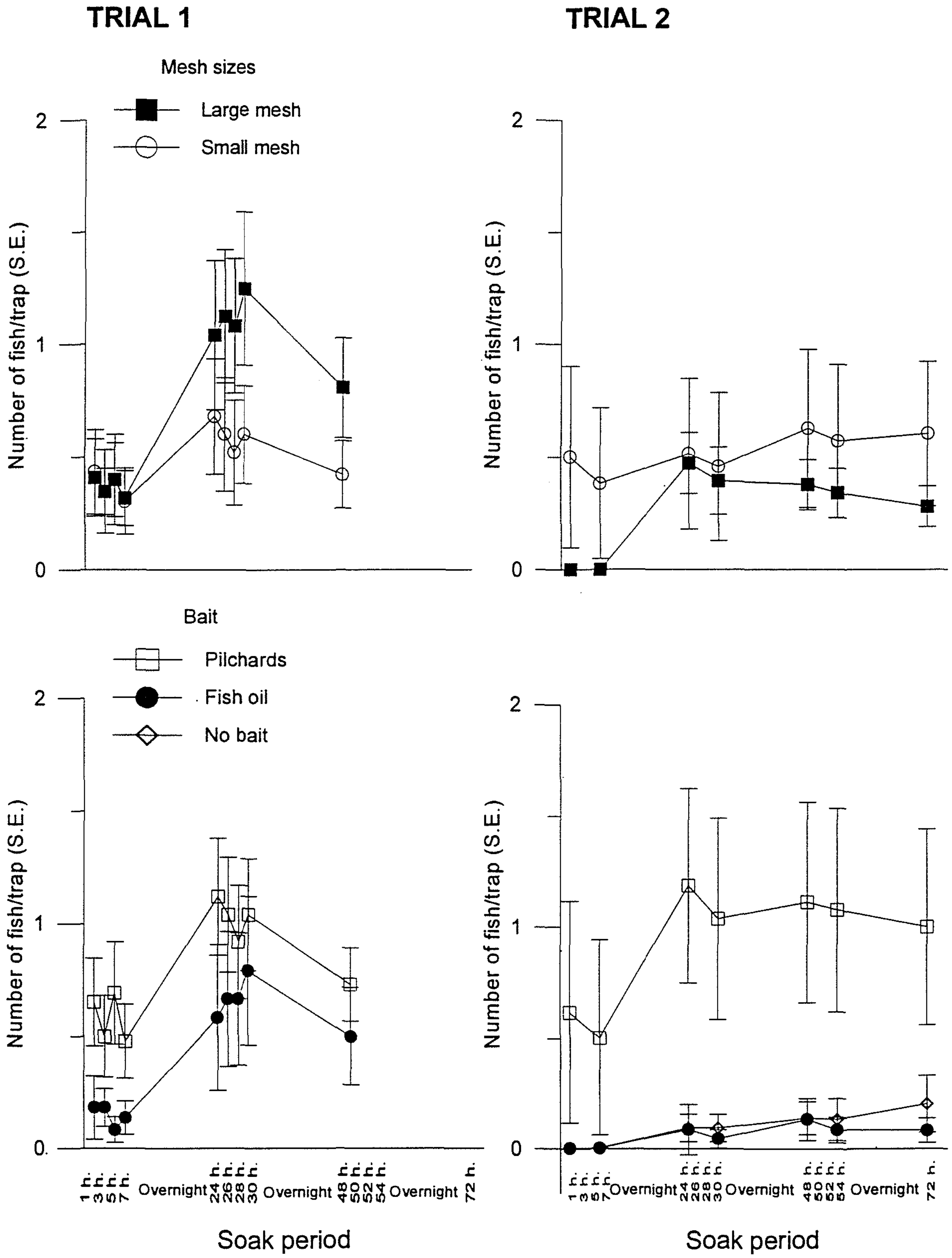


Fig.2.7. Mean number of *L.carponotatus* captured in traps during each trials.
(Error bars represent standard errors)

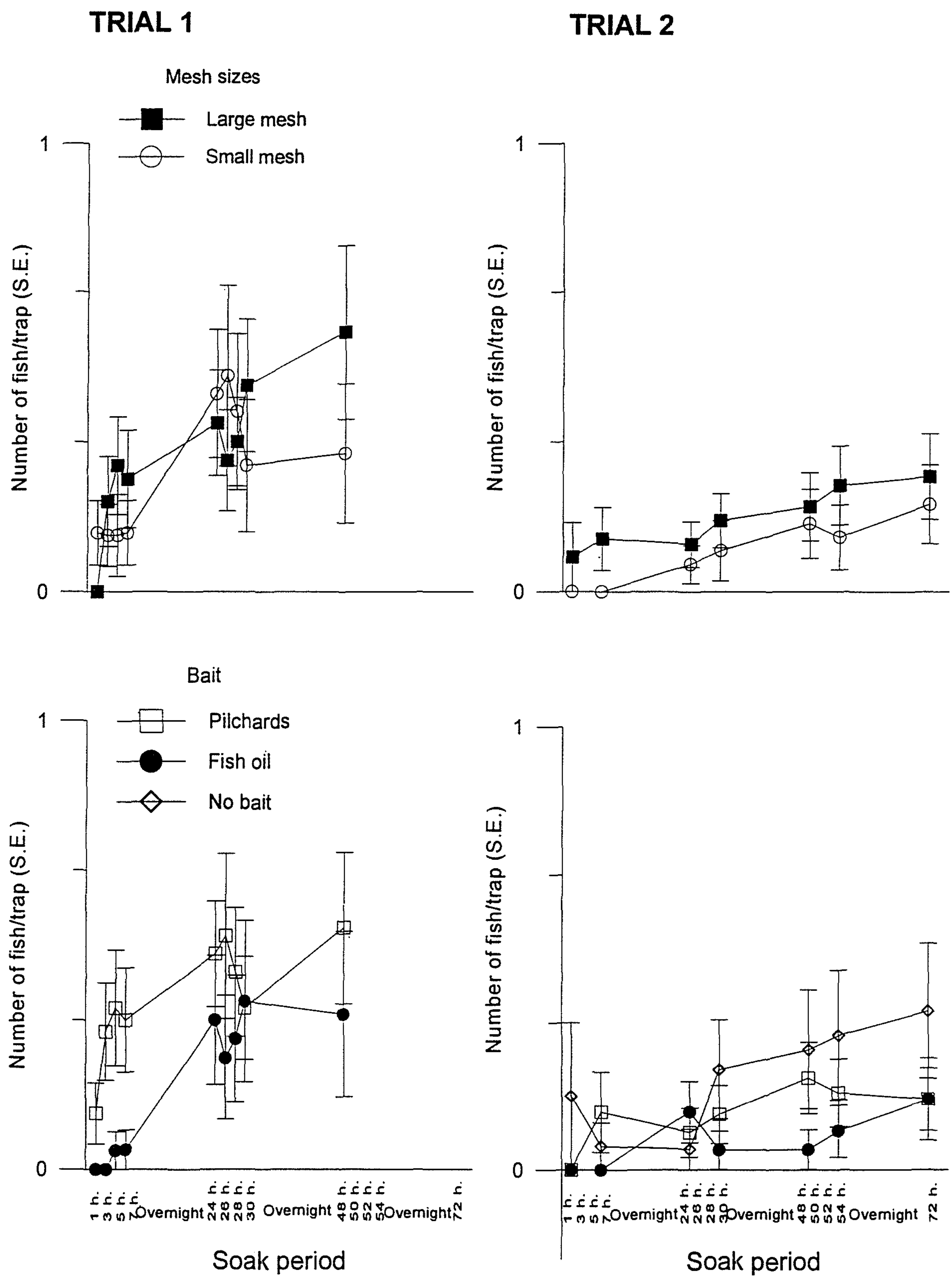


Fig.2.8. Mean number of *Plectropomus* spp. captured in traps during each trial.
(Error bars represent standard errors)

Table.2.1 Results of two-way ANOVA of number of individuals yielded in traps. (*) Denotes significant at 0.05 probability level.

Source of variation	TRIAL 1 : Cattle Bay Number of fish d.f.	MSS	F	P	TRIAL 2: Pioneer Bay Number of fish d.f.	MSS	F	P
Mesh (M)	1	0.7292	10.02	0.0027*	1	0.8931	8.369	0.0051*
Bait (B)	1	0.5269	7.24	0.0098*	2	0.6062	5.681	0.0052*
M x B	1	0.0031	0.043	0.8383	2	0.0128	0.121	0.8864
Residuals	48	0.0727			69	0.1067		

Table.2.2 Results of Ryan's Q-test for multiple comparison of means of significant factors from the ANOVA (TRIAL 2). Underlined proportions were not significantly different.

	BAIT
Individuals	<u>Pilchards Unbaited Fish oil</u>
Species	Pilchards> <u>Unbaited Fish oil</u>

Table.2.3 Results of randomised ANOVA on number of *S.doliatus* caught during both trials. (*) denotes significant at 5% level.

Source variation	TRIAL.1: Cattle Bay Number of *S.doliatus* d.f.	MS	F	P (%)	TRIAL 2: Pioneer Bay Number of *S.doliatus* d.f.	MS	F	P(%)
Mesh(M)	1	1.645	22.70	0.02*	1	0.2261	7.75	0.58*
Bait(B)	1	0.0907	1.25	35.76	2	0.0073	0.25	81.30
MxB	1	0.0474	0.65	50.84	2	0.0073	0.25	80.54
Error	48	0.0724			60	0.0291		

Variance range as % of error MS= 231.86   270.02
Sig.level for variance= 0.10%   20.64%

Table.2.4 Results of the ANOVA on the number of *L.carponotatus* caught in traps during both trials. (*) denotes significant at 0.05 level.

Source of variation	TRIAL 1: Cattle Bay Number of *L.carponotatus* d.f.	MSS	F	P	TRIAL 2: Pioneer Bay Number of *L.carponotatus* d.f.	MSS	F	P
Mesh (M)	1	0.1002	2.49	0.1211	1	0.0085	0.421	0.5254
Bait (B)	1	0.0795	1.97	0.1663	2	0.0927	0.0137	0.0137*
M x B	1	0.1094	2.71	0.1057	2	0.0036	0.179	0.8367
Residual	48	0.0402			69	0.0203		

Table.2.5. Results of the ANOVA on the number of *Plectropomus* spp. caught in traps during both trials. (*) denotes significance at 0.05 level.

	TRIAL 1: Cattle Bay *Plectropomus* spp.				**TRIAL 2: Pioneer Bay *Plectropomus* spp.**			
Source variation	**d.f.**	**MSS**	**F**	**P**	**d.f.**	**MSS**	**F**	**P**
Mesh (M)	1	0.0419	1.08	0.3036	1	0.00469	0.222	0.6442
Bait (B)	1	0.0683	1.76	0.1907	2	0.01580	0.746	0.4781
MxB	1	0.0052	0.13	0.7183	2	0.00296	0.140	0.8696
Residual	48	0.0388			69	0.02119		

2.3.4. FAMILY AND SPECIES COMPOSITION OF THE CATCH

Effect of mesh size

During the first trial, small-meshed traps captured 72 fish from 17 species and 12 families while at the end of the second trial 57 fish from 19 species and 12 families were caught in these traps. Large-meshed traps caught 158 fish from 25 species and 14 families and 165 fish from 34 species and 17 families, respectively. Of the 30 species captured in the first trial, 12 were common to both mesh sizes. At the end of the experiments, large-meshed traps caught 13 species not present in small-meshed traps. Five fish species were caught exclusively in small-meshed traps: *Epinephelus ongus*, *Apogon compressus*, *Thalassoma lunare*, *Myripistis murdjan* and *Dischistodus prosopotaenia.* Ten of the 43 fish species captured during the second trial were common to both mesh sizes. Twenty-four species were captured exclusively in large-meshed traps while small-meshed traps captured 11 species which were unique in these traps (App I & II). From the ANOVA results (Tab.2.6.), there was a significant effect of mesh on the number of species caught. A significantly higher number of species were caught in large-meshed traps than in small ones.

The most abundant fish family caught in large-meshed traps during the first trial was Siganidae, followed by families Lutjanidae and Serranidae. In small-mesh traps the most abundant fish family was Holocentridae followed by Serranidae. During the second trial in large-mesh traps, the families Pomacanthidae and Siganidae contributed the highest numbers to the catch. Lutjanidae was the family with most individuals captured in small-meshed traps. Also, in these traps, family Serranidae contributed greatly to the catch (Tab.2.7.).

Effect of bait type

For each of the trials, traps baited with pilchards captured a total number of 140 fish (60.9%) from 26 species and 15 families and 101 fish (45.5%) from 31 species and 16 families, respectively. From the results of the two-way factor ANOVA (Tab.2.6.), at the end of trial 1, a significantly higher number of species were caught in traps baited with pilchards. In the first trial, 16 species were common for both baits. Nine species were caught exclusively in traps baited with pilchards while 4 species (*Chaetodon rainfordi, Amlyglyphidodon curacao*, *Scolopsis bilineatus* and *Thalassoma lunare)* were caught exclusively in traps using fish oil. At the end of trial 2, a significantly higher number of species were caught in traps baited with pilchards than in traps baited with fish oil and unbaited traps. However, no significant differences in number of species were found between the two latter ones (Tab.2.2). In the first trial, traps baited with fish oil captured 90 fish (39.1%) from 21 species and 13 families while during the second trial, 46 fish (20.7%) from 19 species and 12 families were caught. Unbaited traps captured 75 fish (33.8%) from 21 species and 15 families. During the second trial, nineteen species were caught in both baited and unbaited traps. Fourteen species were caught exclusively in traps baited with pilchards. Five species: *Epinephelus malabaricus*, *Cheilinus fasciatus*, *Chaetodon melannotus*, *Apogon compressus* and *Orectolobus ornatus* were caught only in traps using fish oil. *Lutjanus sebae* and *Caesio cuning* were common species captured in both baited traps. *Canthigaster valentini* and *Neoglyphidodon melas* were captured exclusively in unbaited traps (App. III & IV)

At the end of the first trial and in traps baited with pilchards, catch was dominated by the families Siganidae and Serranidae. The family Lutjanidae was the most abundant family by numbers during the second trial. During the first trial, the family Siganidae and Serranidae were the most abundant families by numbers caught in traps baited with fish oil while Chaetodontidae and Pomacanthidae constituted the largest part of the catch for this bait during the second trial. The most abundant families by numbers caught in unbaited traps were Pomacanthidae and Serranidae (Tab.2.7).

2.3.5. CONTRIBUTION OF THE TARGET SPECIES TO THE CATCH COMPOSITION

At the end of the first trial, more than fifty percent of the catch was constituted by the target species (*Lutjanus carponotatus, Plectropomus* spp. and *S.doliatus*) while during the second trial, target species constituted less than one quarter of the total catch. For both trials, *S.doliatus* and *L.carponotatus* were the most numerically abundant species caught in traps. *Plectropomus* spp. was the third most abundant species trapped at Cattle Bay, while in traps set at Pioneer Bay, it was the fourth most abundant species caught.

Effect of mesh size

At the end of the first trial, the catch of small-meshed traps was dominated by *L.carponotatus* while this species comprised a very small percentage of the catch in the second trial. In large-meshed traps, for each of the trials, the most abundant target species was *S.doliatus*. The contribution of *Plectropomus* spp. caught in small-meshed traps to the final catch for each of the trials was close to 3%, while in large-meshed traps more than twice the number of *Plectropomus* spp. were caught in the first trial. For the second trial a slightly higher number of *Plectropomus* spp. were caught in large-meshed traps (Fig.2.9.).

Effect of bait type

For the target species in for the first trial, *S.doliatus* made up the highest contribution by numbers to the catch in traps baited with pilchards and fish oil. During the second trial, numbers of this species were higher in unbaited traps than in baited ones, being the second most abundant species in number yielded by these traps. For the first trial, catches of *L.carponotatus* constituted the second highest proportion of the catch in traps baited with pilchards and fish oil while for the second trial *L.carponotatus* was the most numerically abundant target species caught in traps baited with pilchards. For those baited traps set at Cattle Bay, *Plectropomus* spp. was the most rarely captured target species in both baited traps while for traps set in Pioneer Bay, catches of this species were equally low for both bait types. The number of *Plectropomus* spp. yielded by unbaited traps was higher than in baited ones at this location (Fig.2.10.).

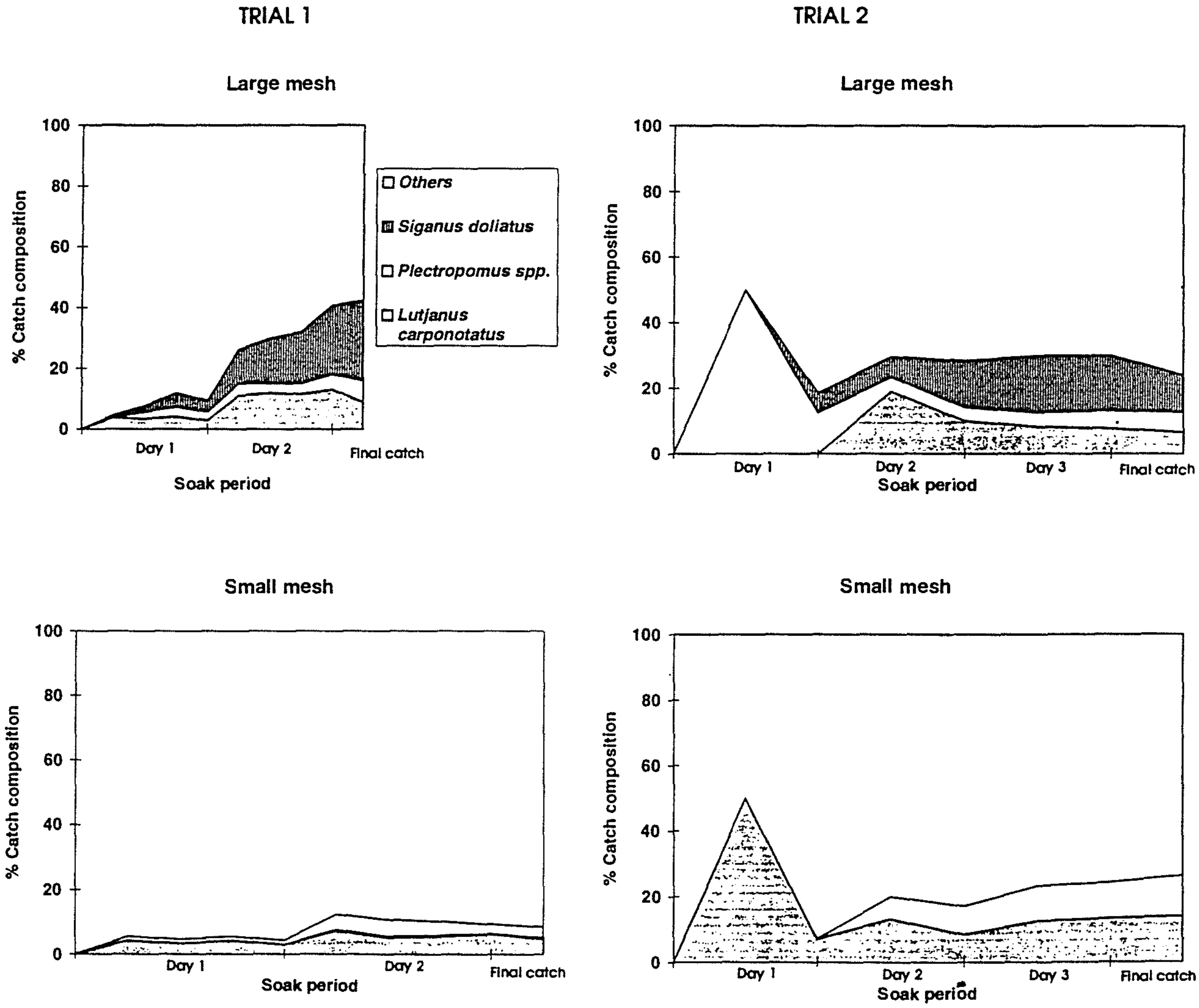


Fig.2.9. Percentage of the catch of different meshed traps deployed at Cattle Bay (Trial 1) and Pioneer Bay (Trial 2) contributed by the target species over the different soak periods.

TRIAL 1

TRIAL 2

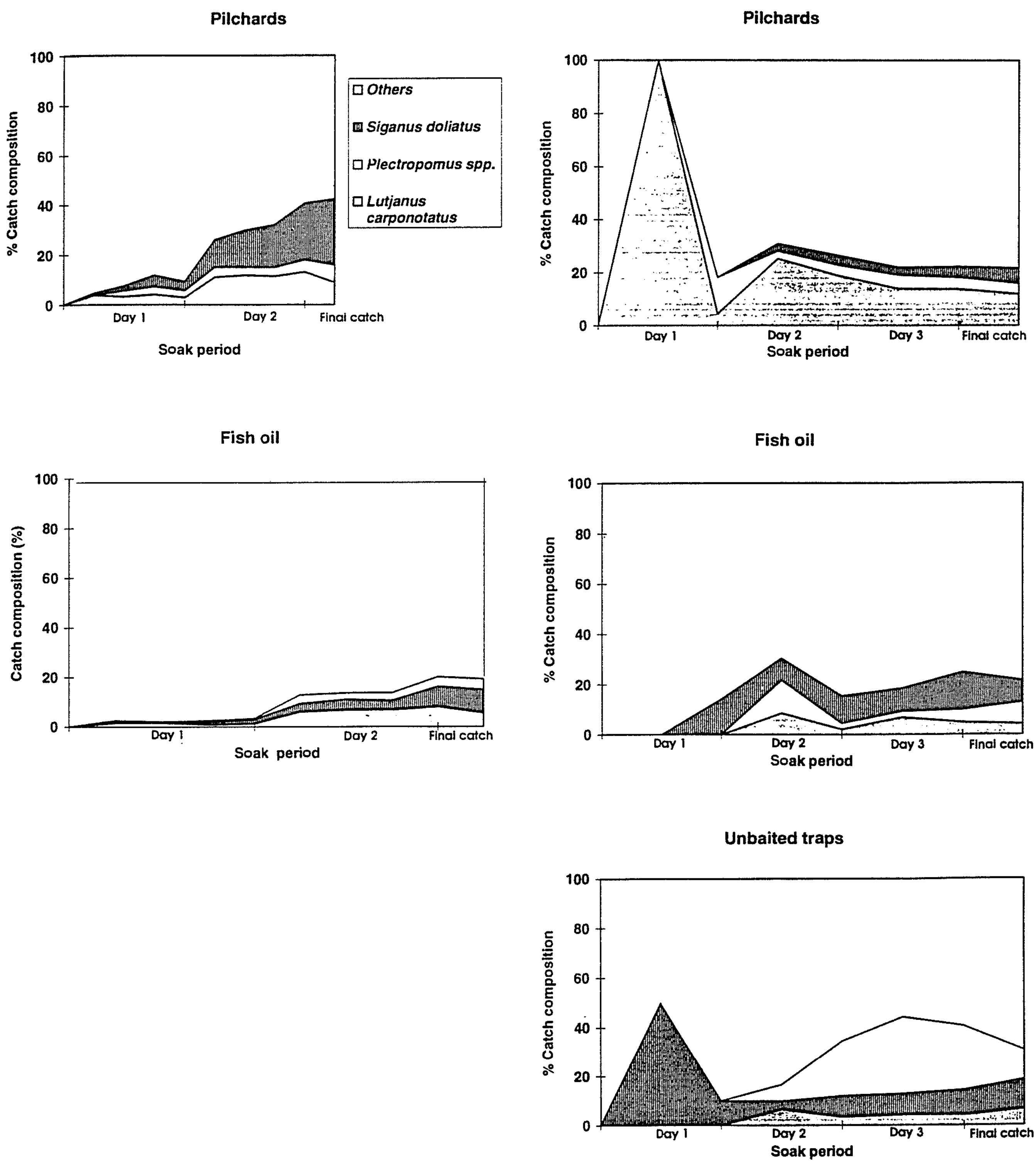


Fig.2.10. Percentage of the catch of baited and unbaited traps deployed at Cattle Bay (Trial 1) and Pioneer Bay (Trial 2) contributed by the target species over the different soak periods.

Table.2.6 . Results of Two-way Analysis of Variance testing for the effect of mesh and bait on number of fish and number of species captured in traps at Orpheus Island. Data was transformed by log(x+1); (*)indicates significant at 0.05 level.

	TRIAL 1: Cattle Bay Number of species				TRIAL 2: Pioneer Bay Number of species			
Source of variation	d.f.	MSS	F	P	d.f.	MSS	F	P
Mesh size (M)	1	0.5319	12.45	0.0009*	1	0.3070	5.095	0.0272*
Bait (B)	1	0.4125	9.65	0.0032*	2	0.4895	8.123	0.0007*
M x B	1	0.0036	0.085	0.7749	2	0.0221	0.367	0.6939
Residual	48	0.0427				0.0602		

Table.2.7. Family composition of the catch of the end of the soak period for traps deployed at Cattle Bay (Trial 1) and Pioneer Bay (Trial 2)

	TRIAL 1				TRIAL 2			
	Large mesh numbers	% of catch	Small mesh numbers	% of catch	Large mesh numbers	% of catch	Small mesh numbers	% of catch
Lutjanidae	30	13.04	12	5.22	23	10.36	20	9.01
Serranidae	26	11.30	13	5.65	18	8.11	14	6.31
Siganidae	67	29.13	1	0.43	27	12.16	-	-
Labridae	3	1.30	5	2.17	5	2.25	2	0.90
Holocentridae	3	1.30	15	6.52	5	2.25	4	1.80
Pomacanthidae	7	3.04	1	0.43	29	13.06	1	0.45
Chaetodontidae	2	0.87	-	-	11	4.95	-	-
Scaridae	-	-	-	-	5	2.25	-	-
Nemipteridae	4	1.74	4	1.74	14	6.31	-	-
Lethrinidae	5	2.17	1	0.43	8	3.60	2	0.90
Pomacentridae	2	0.87	3	1.30	-	-	2	0.90
Haemulidae	1	0.43	-	-	2	0.90	2	0.90
Acanthuridae	-	-	-	-	9	4.05	-	-
Apogonidae	-	-	8	3.48	-	-	4	2.29
Caesidae	-	-	-	-	1	0.45	1	0.57
Tetraodontidae	1	0.43	-	-	-	-		
Balistidae	6	2.61	8	3.48	5	2.25	2	0.90
Centropomidae	1	0.43	1	0.43	1	0.45	-	-
Muraenidae	-	-	-	-	-	-	2	0.90
Hemigaleidae	-	-	-	-	1	0.45	-	-
Orectolobidae	-	-	-	-	1	0.45	-	-
TOTALS	158	68.70	72	31.30	165	74.32	57	25.68

	TRIAL 1				TRIAL 2					
	Pilchards number	% of catch	Fish oil number	% of catch	Pilchards number	% of catch	Fish oil number	% of catch	No bait number	% of catch
Lutjanidae	28	12.17	14	6.09	35	15.77	3	1.35	5	2.25
Serranidae	26	11.30	13	5.65	12	5.41	6	2.70	14	6.31
Siganidae	44	19.13	24	10.43	8	3.60	5	2.25	14	6.31
Labridae	5	2.17	3	1.30	5	2.25	1	0.45	1	0.45
Holocentridae	8	3.48	10	4.35	-	-	5	2.25	4	1.80
Pomacanthidae	1	0.43	7	3.04	4	1.80	7	3.15	19	8.56
Chaetodontidae	1	0.43	1	0.43	-	-	8	3.60	-	-
Scaridae	-	-	-	-	1	0.45	-	-	4	1.80
Nemipteridae	5	2.17	3	1.30	6	2.70	4	1.80	4	1.80
Lethrinidae	3	1.30	3	1.30	8	3.60	-	-	2	0.90
Pomacentridae	2	0.87	3	1.30	1	0.45	-	-	1	0.45
Haemulidae	1	0.43	-	-	3	1.35	-	-	1	0.45
Acanthuridae	-	-	-	-	8	3.60	-	-	1	0.45
Apogonidae	4	1.74	4	1.74	-	-	3	1.35	1	0.45
Caesidae	-	-	-	-	1	0.45	1	0.45	-	-
Tetraodontidae	1	0.43	-	-	-	-	-	-	1	0.45
Balistidae	10	4.35	4	1.74	5	2.25	2	0.90	-	-
Centropomidae	1	0.43	1	0.43	1	0.45	-	-	-	-
Muraenidae	-	-	-	-	2	0.90	-	-	-	-
Hemigaleidae	-	-	-	-	1	0.45	-	-	-	-
Orectolobidae	-	-	-	-	-	-	1	0.45	-	-
TOTALS	140	60.87	90	39.13	101	45.50	46	20.72	75	33.78

2.3.6. LENGTH COMPOSITION OF THE CATCH

The effect of mesh on the selectivity of size classes was examined in relation to the total length of the target species and most abundant species to two different mesh sizes. Fisher's exact tests for two-tailed hypotheses were used.

The absence of *S.doliatus* caught in small-meshed traps during the first and second trials did not allow the former test (Fig.2.11). The length frequency data of *Pomacanthus sexstriatus* were not considered because of the absence of this species in small-meshed traps deployed during the second trial (Fig.2.12b). Fisher's exact test was carried out on frequencies of size classes of *L.sebae* caught during the second trial (Fig.2.12a) and *Plectropomus* spp. and *L.carponotatus* caught in both trials (Fig.2.13 & 14). No significant differences were found in the distribution of the two size classes of *Plectropomus* spp. for both mesh sizes during the first trial ($n=24$, $m_1=4$, $m_2=9$, $f_{12}=3$, $f_{crit}=-,4$) and during the second one ($n=16$, $m_1=5$, $m_2=6$, $f_{12}=0$, $f_{crit}=-,4$). Length frequency of *L.carponotatus* caught in different meshed traps during the first trial was found to be significantly different ($n=33$, $m_1=7$, $m_2=12$, $f_{12}=3$, $f_{crit}=\geq 4,11$). The total length of *L.carponotatus* and *L.sebae* caught during the second trial were found not to differ significantly ($n=16$, $m_1=5$, $m_2=8$, $f_{12}=2$, $f_{crit}=0,5$) and ($n=20$, $m_1=5$, $m_2=8$, $f_{12}=3$, $f_{crit}= -, 5$) between the two mesh sizes.

The results of the Tukey-type test for multiple comparison of proportions of size classes for *L.carponotatus* caught during the first trial showed that there was no significant difference in the distribution of large size classes (≥30 cm) and small size classes (0-<30 cm) in both meshed traps (large and small mesh). However, size distributions differed significantly in the frequency with which they were caught. A summary of the results is presented in Tab.2.8.

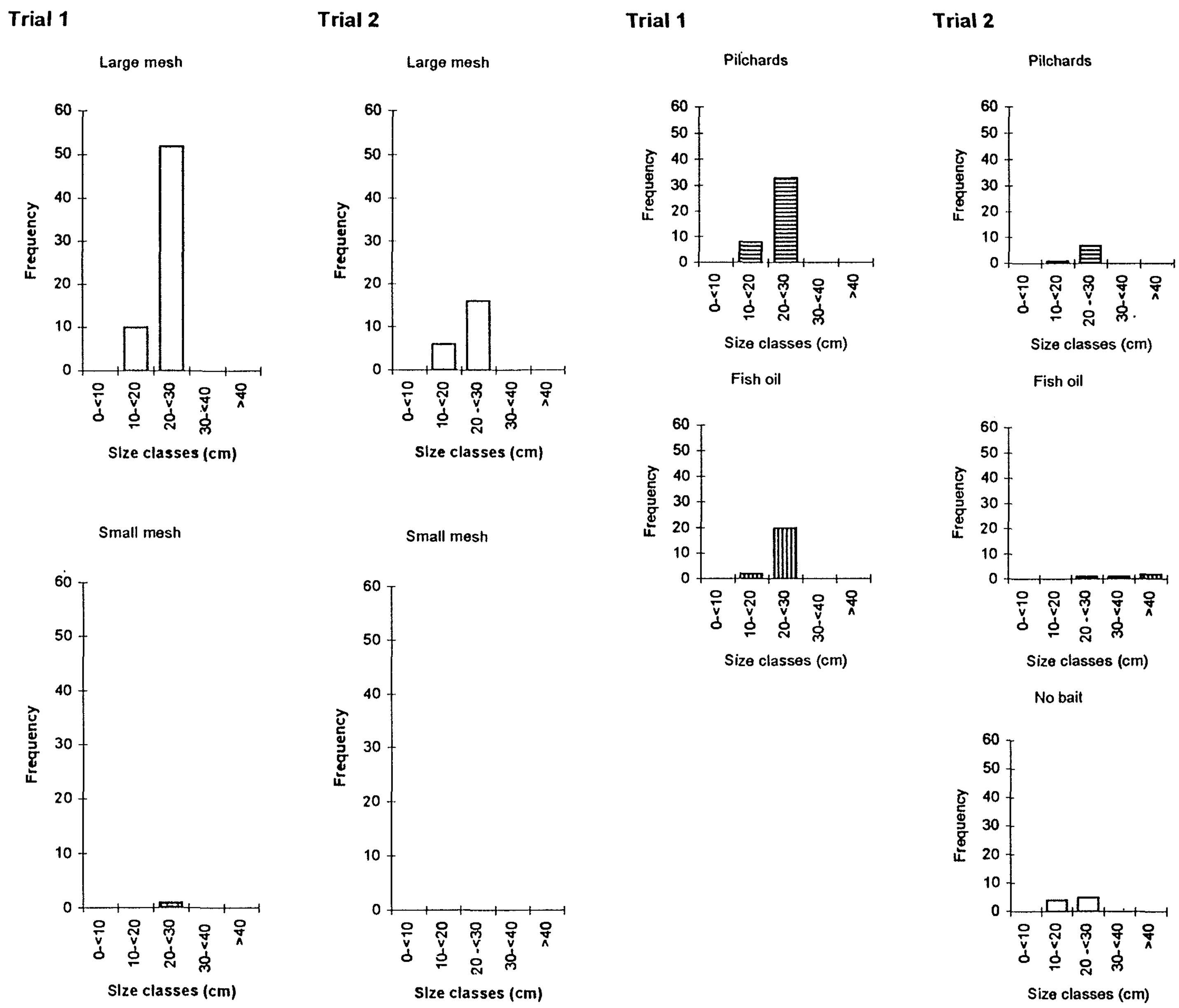


Fig.2.11. Length frequency of *S. doliatus* (cm) caught in traps deployed at Cattle Bay (Trial 1) and Pioneer Bay (Trial 2). Five size classes are shown in the figures although only two were considered in the statistical analysis.

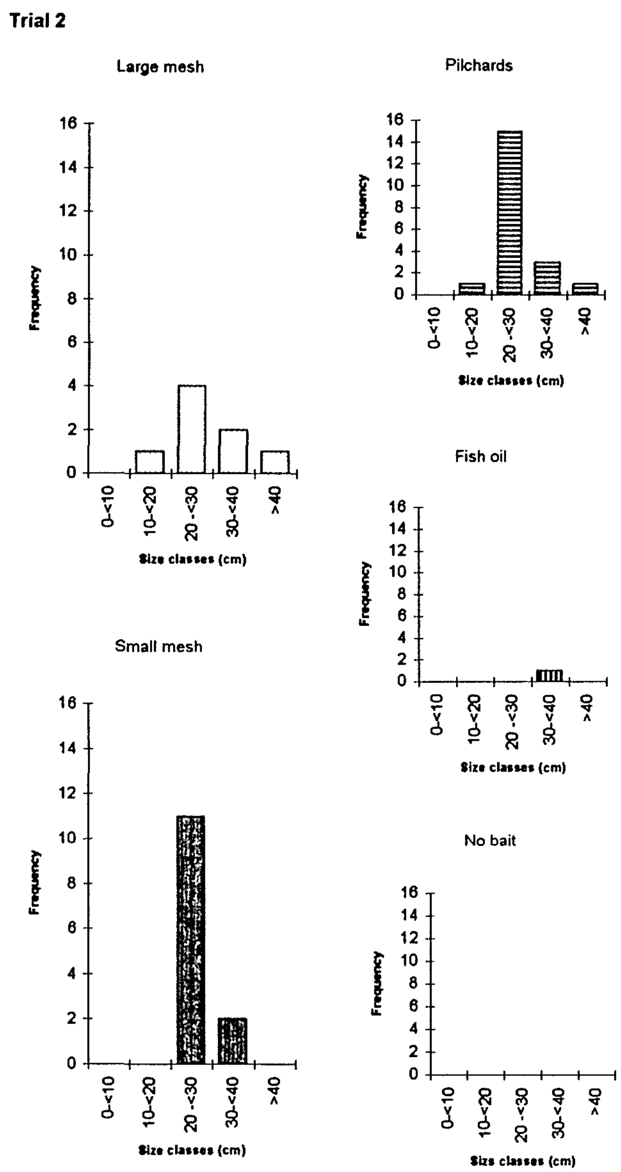


Fig.2.12a. Length frequency of *Lutjanus sebae* (cm) caught in traps deployed at Pioneer Bay (Trial 2). As before, five size classes are shown.

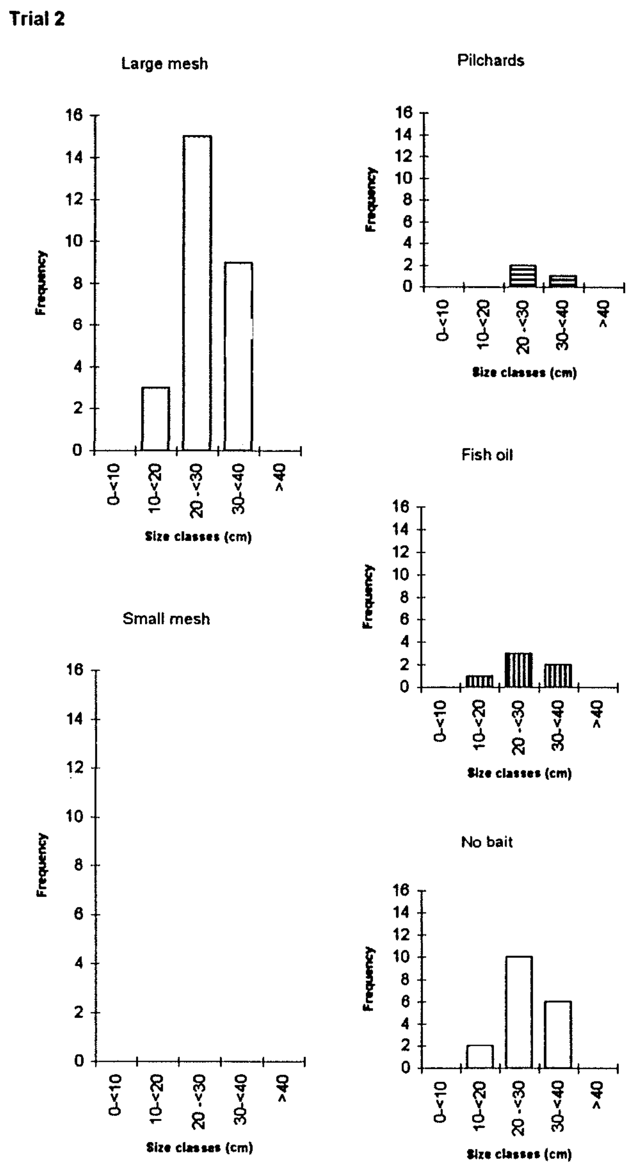


Fig.2.12b. Length frequency of *Pomacanthus sexstriatus* (cm) caught in traps deployed at Pioneer Bay (Trial 2). Five size classes are shown.

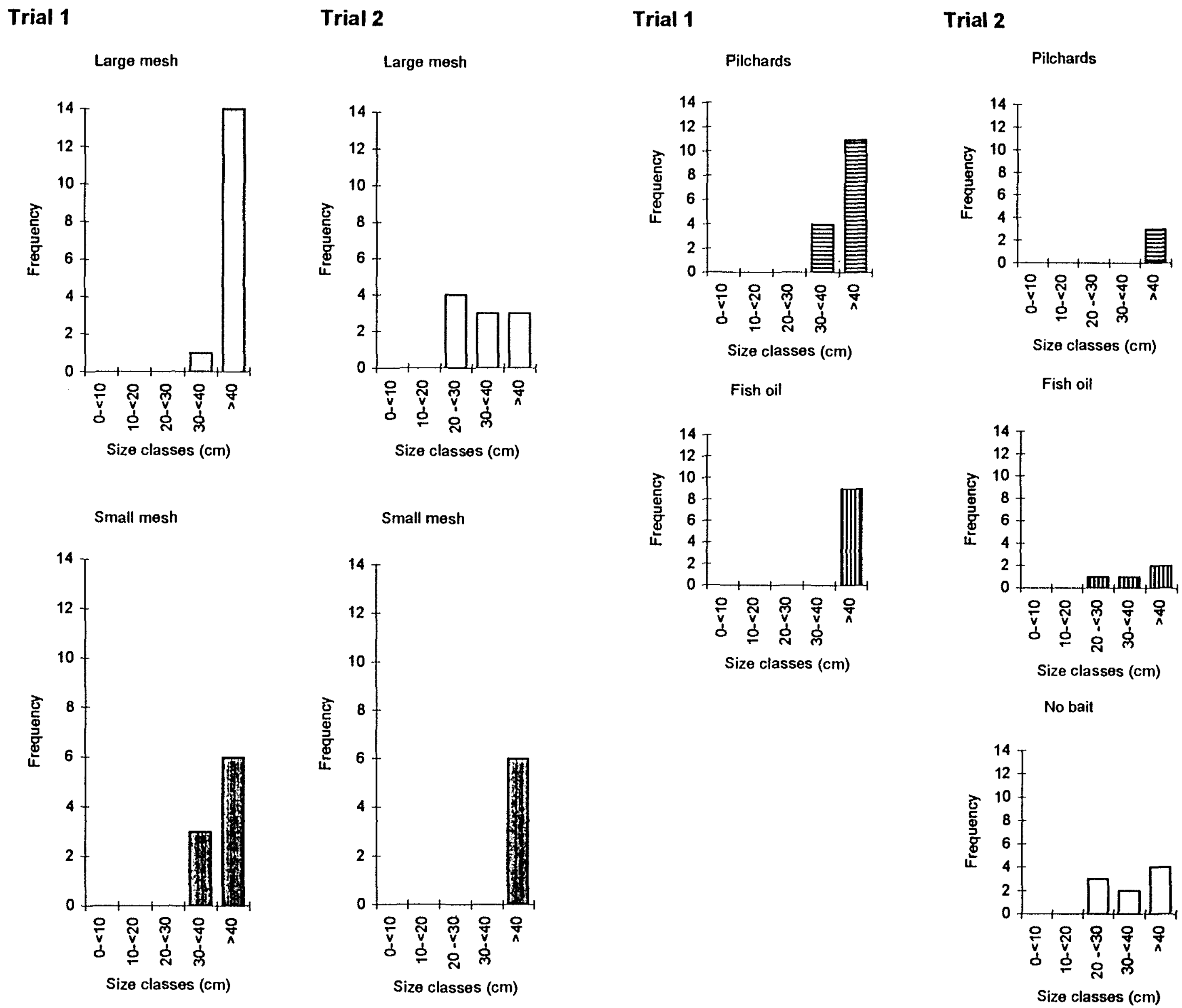


Fig.2.13. Length frequency of *Plectropomus spp.* caught in traps deployed at Cattle Bay (Trial 1) and Pioneer Bay (Trial2). Five size classes are shown in the figure although only two were used in the statistical analysis

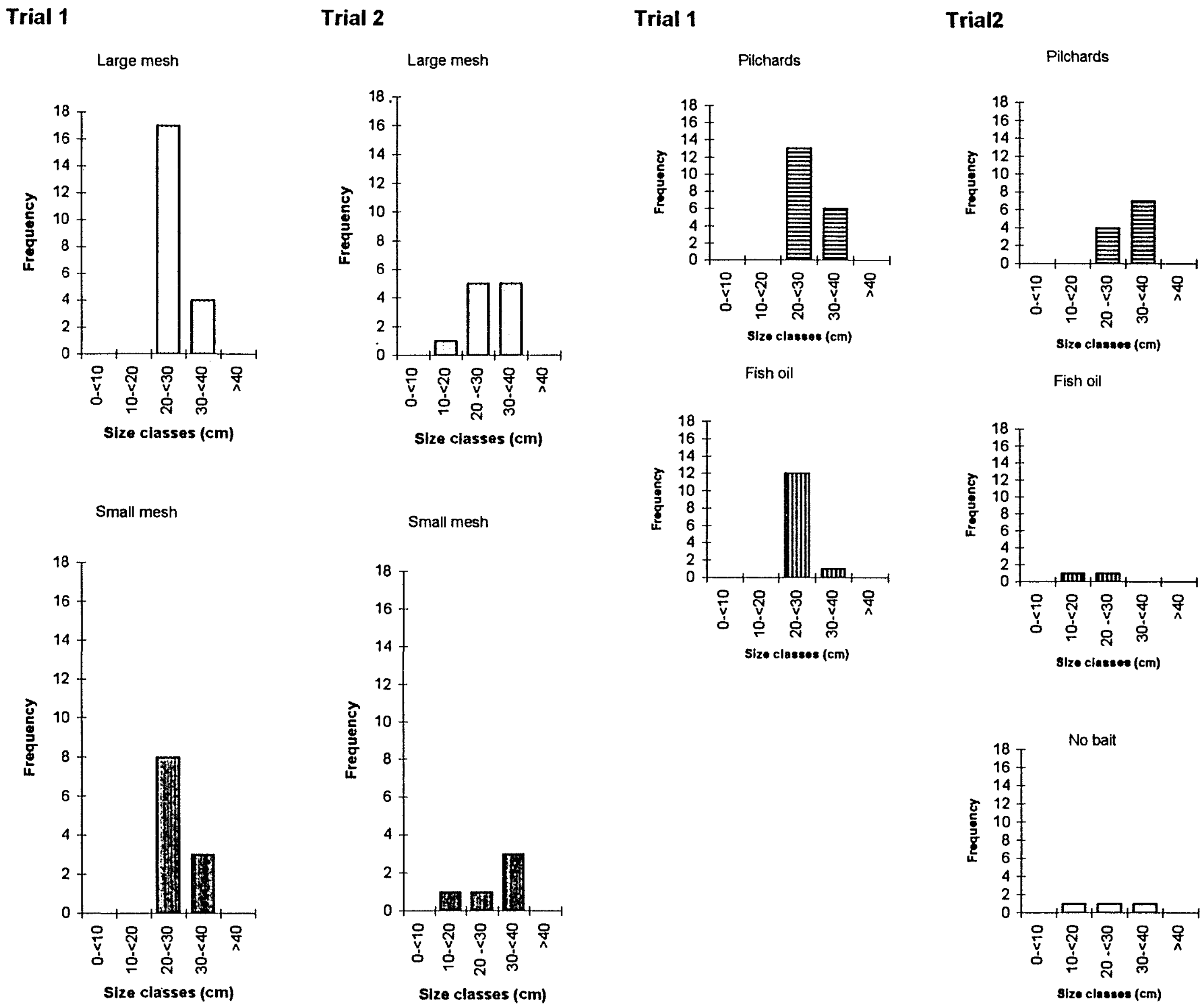


Fig.2.14. Length frequency of *L.carponotatus* (cm) caught in traps deployed at Cattle Bay (Trial1) and Pioneer Bay (Trial 2). Five size classes are shown in the figures although only two were used in the statistical analysis.

Table.2.8. Results of the Turkey-type test for multiple comparison of size class proportions for *L. carponotatus* caught during the first trial. L=Large, S=Small. Underlined proportions were found to be not significantly different.

Size classes	**Mesh size**
0-<30 cm	Small Large
≥30 cm	Small Large

L (0-<30) S(0-<30) > L(≥30) S(≥30)

2.3.7. EFFECT OF REBAITING ON THE OVERALL CATCH

At the end of the rebaiting experiments, 45 fish from 20 species and 12 families were caught, making an overall catch mean of 0.9 fish/trap/day (s.e.=±0.1).

Effect of mesh size on catch rates and final catch

Large-meshed traps again yielded a consistently higher number of fish than the small meshed ones. For both mesh sizes, catches followed an increasing trend over the whole soak period with a slight decrease in mean numbers in large-meshed traps during daylight hours of the soak period. During the first 24 hours of the soak period, catches in rebaited traps with large mesh appeared to be higher than those in large-meshed traps baited only once. However, after 24 hours soak, catches in both types of traps were maintained at comparable levels (Fig.2.15.). Catch rates of both mesh types were compared and no significant differences were found ($t=1.754$, $d.f.=14$, $P>>0.05$). When catches of small-meshed traps rebaited with pilchards were compared to the catches of small-meshed traps baited once with pilchards, no differences in the mean final catches were found ($t=0.726$, $d.f.=17$, $0.2<P<0.5$).

Effect of bait type on catch rates and final catch

As for traps baited with pilchards during trial 1 and 2, traps rebaited with pilchards showed a consistently higher mean catch than traps baited with fish oil. However, when the catch rates of traps rebaited with pilchards and fish oil were compared no significant differences were found ($t=1.452$, $d.f.=14$, $P>>0.168$). Catches followed the same trend as that in meshed traps with mean catches slightly decreasing during daylight hours of the soak while they increased after the overnight soak periods. When rebaited traps were compared to traps baited once, catches appeared to be higher during the first day of the soak period, with catches reaching comparable levels over the rest of the soak time (Fig.2.16.). Fish seemed to appear in traps rebaited with fish oil during the second day of the soak period and catches increased for the rest of the soak time. Values of the final catch were comparable to those reached in traps baited once with fish oil. A constant supply of fresh bait did not affect catch rates and final catches of traps placed in shallow water, however, higher numbers of traps are needed to draw conclusions on the role of rebaiting traps.

Catch dynamics of the target species in rebaited traps

No *L.carponotatus* were present in small-meshed traps until the second day of soak and then catches increased until the end of the soak period. In large-meshed traps, catches of this species reached a maximum value after the first day of soak, then catches followed a decreasing trend until the end of the soak period. *L.carponotatus* were absent in traps rebaited with fish oil at the end of the soak period and in traps rebaited with pilchards the catches were higher after the first overnight soak period (Fig.2.17). Comparable numbers of *S.doliatus* were caught by both mesh types. Catches of this species were nil during the first and second day of soak, with individuals of this species appearing in all rebaited traps at the end of the soak period. Traps rebaited with pilchards yielded no *S.doliatus* (Fig.2.17.). Large-meshed traps caught markedly higher number of *Plectropomus* spp. than small-meshed traps. As for traps baited only once, rebaited traps showed increasing catches over the whole soak period. However, catches in small-meshed traps decreased after the overnight soak period of the second day levelling off at the end of the soak. Catches of *Plectropomus* spp. were higher in traps rebaited with fish oil at the beginning of the soak period while in traps rebaited with pilchards, catch started increasing after the first day of soak until the end of the soak period (Fig.2.17).

PIONEER BAY

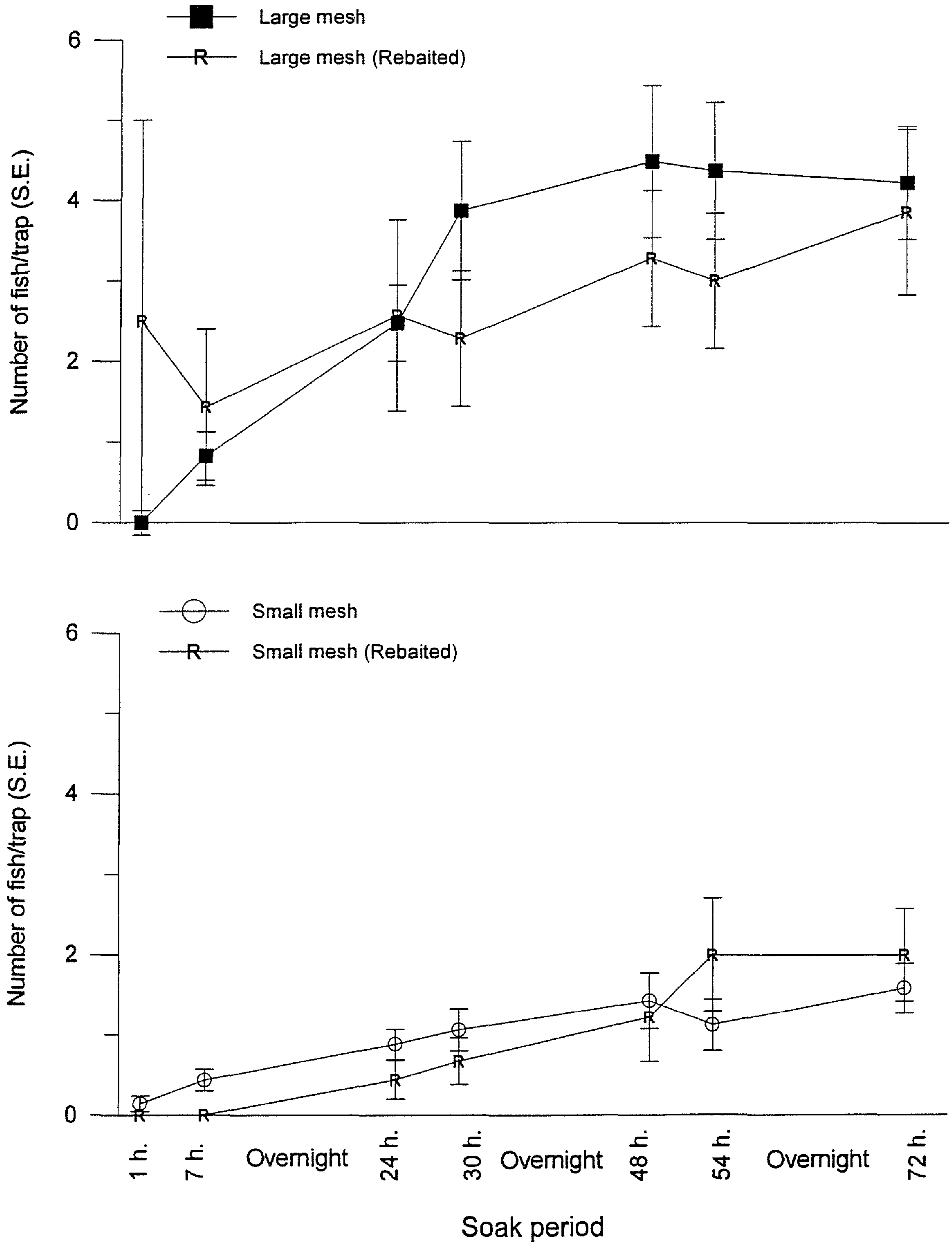


Fig.2.15. Mean number of fish caught in rebaited traps and in traps baited once (Mesh sizes
(Error bars represent standard errors)

PIONEER BAY

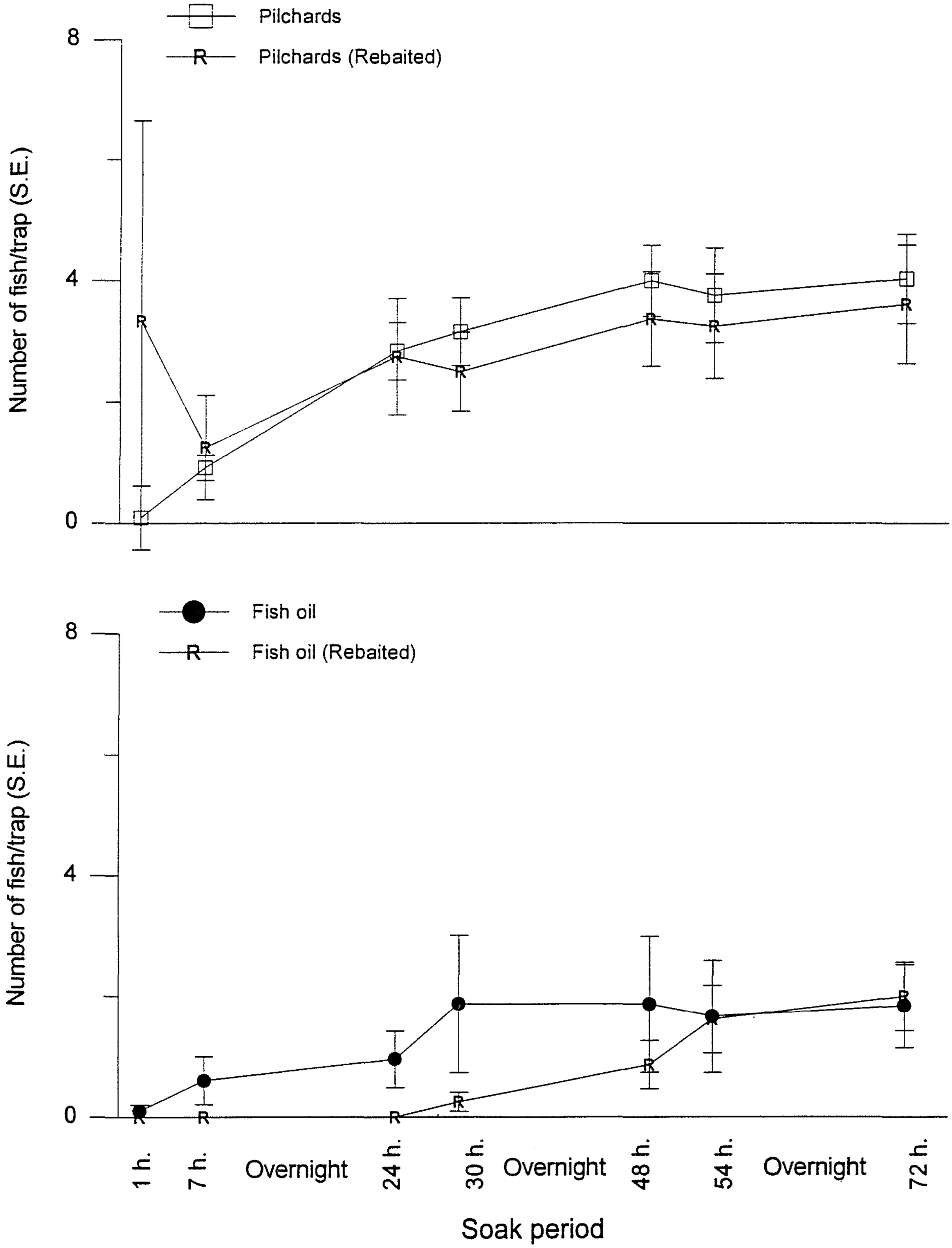


Fig.2.16. Mean number of fish caught in rebaited traps and in traps baited once (Bait types)
(Error bars represent standard errors)

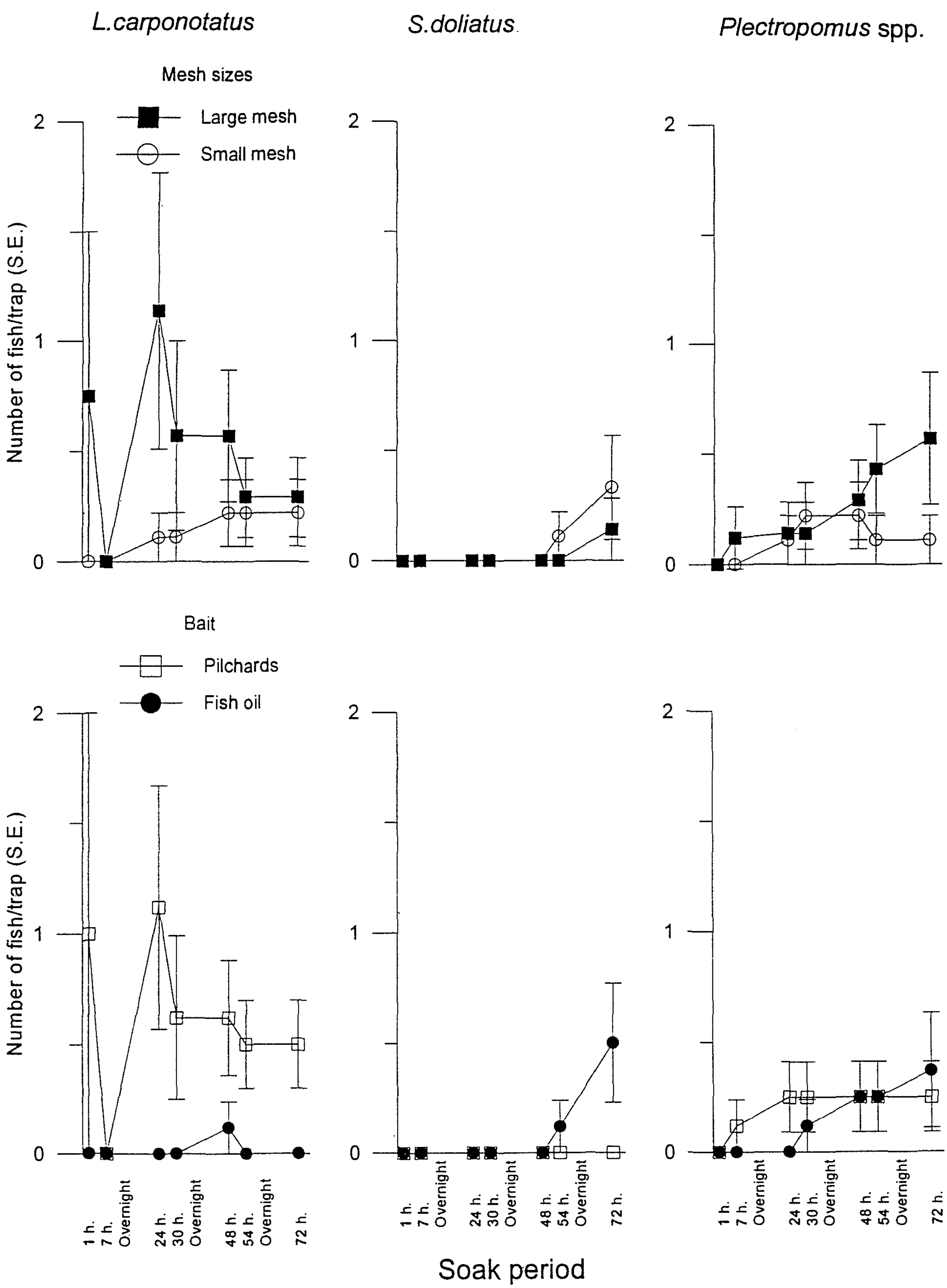


Fig.2.17. Mean catches for different meshed and baited traps during the rebaiting experiments. (Error bars represent standard errors)

Family and species composition in rebaited traps

During the rebaiting experiment carried out at Pioneer Bay, large-meshed traps caught a total of 27 individuals from 13 species and 9 families. Small-meshed traps captured 40% of the total catch. The catch belonged to 11 species and 8 families. Four fish species were caught in both large- and small-meshed traps: *L.carponotatus*, *Plectropomus* spp., *S.doliatus* and *Lethrinus nebulosus*. Large-meshed traps caught 9 species which were not found in small-meshed traps (Tab.2.9). When species numbers caught in small-meshed traps rebaited with pilchards were compared to species numbers caught in small-meshed traps baited once with pilchards, no significant differences in species numbers were found ($t=1.611$, d.f.$=17$, $0.1<P<0.2$).

Individuals from the family Serranidae made up the highest percentage of the catch in large-meshed traps at the end of the rebaiting experiment. The most abundant fish family caught in small-meshed traps was the family Lutjanidae (Table.2.10.). *Plectropomus* spp. was the most trapped target species in all rebaited traps. *S.doliatus* was the second most abundant species caught in small-meshed traps during the rebaiting experiment (Fig.2.18.).

Traps rebaited with pilchards caught 29 fish (64.4%) from 14 species and 8 families. Sixteen individuals from 8 species and 6 families were caught in traps rebaited with fish oil. Two fish species were common to both baited traps: *Plectropomus* spp. and *Epinephelus malabaricus*. However, traps rebaited with pilchards captured 12 species not present in traps rebaited with fish oil. These latter traps yielded exclusively 6 fish species (Tab.2.9.). Members of the family Serranidae and Lutjanidae were the most numerically abundant caught in traps rebaited with pilchards. The family Apogonidae, Serranidae and Siganidae comprised the largest part of the catch in traps rebaited with fish oil (Tab.2.10.). *S.doliatus* was the target species caught in highest numbers in traps rebaited with fish oil while *L.carponotatus* was the most abundant species caught in traps rebaited with pilchards (Fig.2.18).

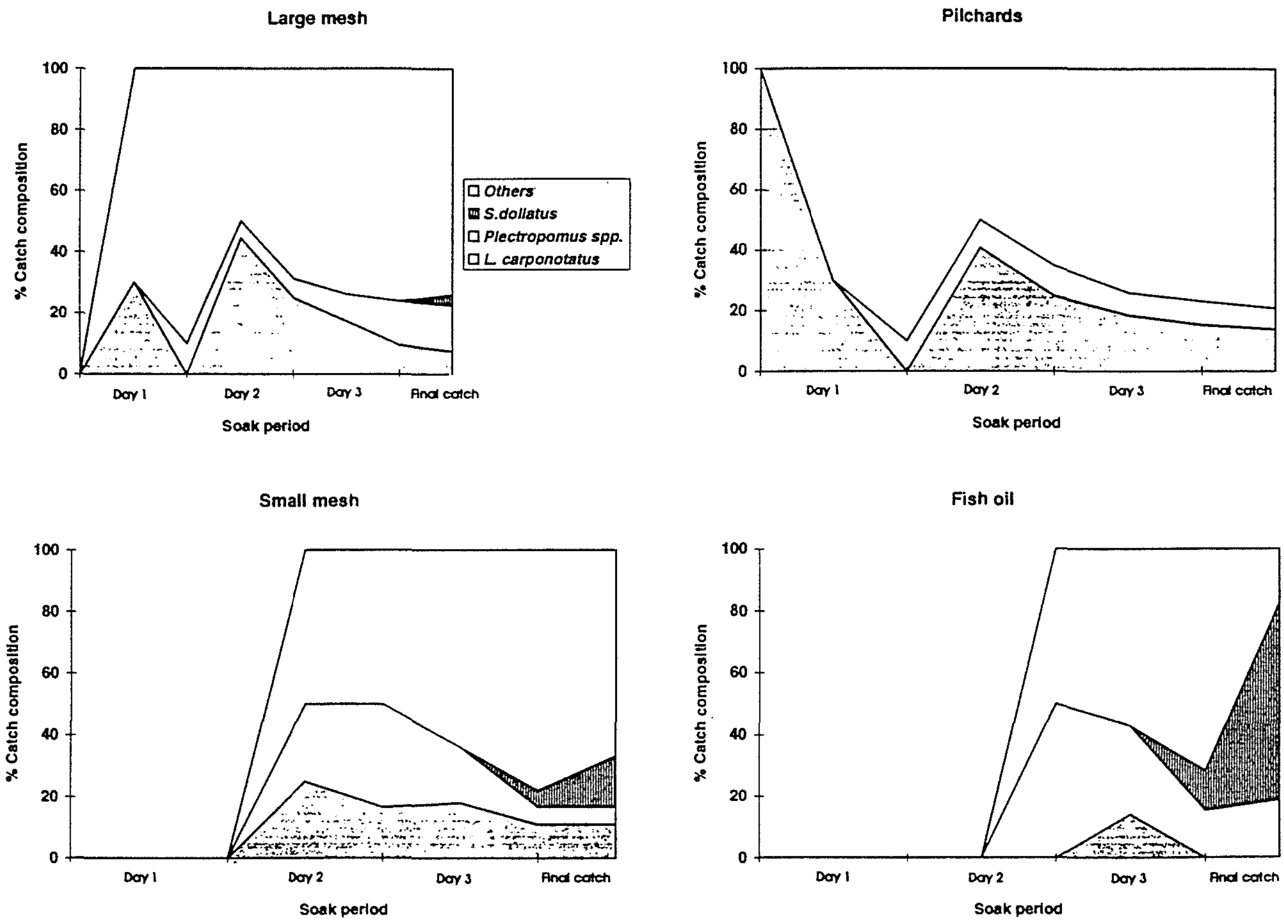


Fig.2.18. Percentage of the catch in rebaited traps deployed at Pioneer Bay contributed by the target species over 3 days of soak period.

Table. 2.9. Family and species composition of the catch at the end of the soak period for rebaited traps deployed at Pioneer Bay.

	Rebaited traps				Rebaited traps			
	Large mesh numbers	% of catch	Small mesh numbers	% of catch	Pilchards number	% of catch	Fish oil number	% of catch
Lutjanidae	4	8.89	3	6.67	7	15.56	-	-
Lutjanus carponotatus	**2**	**4.44**	**2**	**4.44**	**4**	**8.89**	-	-
Lutjanus sebae	2	4.44	-	-	2	4.44	-	-
Lutjanus fulvus	-	-	1	2.22	1	2.22	-	-
Serranidae	10	22.22	2	4.44	8	17.78	4	8.89
Plectropomus spp	**4**	**8.89**	**1**	**2.22**	**2**	**4.44**	**3**	**6.67**
Epinephelus ongus	1	2.22	-	-	1	2.22	-	-
Epinephelus malabaricus	2	4.44	-	-	1	2.22	1	2.22
Epinephelus quoyanus	3	6.67	-	-	3	6.67	-	-
Cromileptes altivelis	-	-	1	2.22	1	2.22	-	-
Siganidae	1	2.22	3	6.67				
Siganus doliatus	**1**	**2.22**	**3**	**6.67**	-	-	**4**	**8.89**
Labridae			-	-				
Choerodon schoenleinii	2	4.44	-	-	2	4.44	-	-
Pomacanthidae	1	2.22	1	2.22	1	2.22	1	2.22
Pomacanthus sexstriatus	-	-	1	2.22	-	-	1	2.22
Chaetodontoplus meredithi	1	2.22	-	-	1	2.22	-	-
Nemipteridae								
Scolopsis monogramma	1	2.22	-	-	-	-	1	2.22
Lethrinidae								
Lethrinus nebulosus	1	2.22	2	4.44	3	6.67	-	-
Pomacentridae								
Pomacentrus brachialis	-	-	1	2.22	-	-	1	2.22
Haemulidae								
Diagramma pictum	6	13.33	-	-	6	13.33	-	-
Apogonidae	-	-	5	11.11	-	-	5	11.11
Apogon fuscus	-	-	1	2.22	-	-	1	2.22
Apogon moluccensis	-	-	4	8.89	-	-	4	8.89
Muraenidae								
Gymnothorax spp.	-	-	1	2.22	1	2.22	-	-
Hemigaleidae								
Triaenodon obesus	1	2.22	-	-	1	2.22	-	-
TOTALS	**27**	**60.00**	**18**	**40.00**	**29**	**64.44**	**16**	**35.56**

Table.2.10. Family composition of the catch at the end of the soak period in rebaited traps deployed at Pioneer Bay

	Rebaited traps			
	Large mesh numbers	% of catch	Small mesh numbers	% of catch
Lutjanidae	4	8.89	3	6.67
Serranidae	10	22.22	2	4.44
Siganidae	1	2.22	3	6.67
Labridae	2	4.44	-	-
Pomacanthidae	1	2.22	1	2.22
Nemipteridae	1	2.22	-	-
Lethrinidae	1	2.22	2	4.44
Pomacentridae	-	-	1	2.22
Haemulidae	6	13.33	-	-
Apogonidae	-	-	5	11.11
Muraenidae	-	-	1	2.22
Hemigaleidae	1	2.22	-	-
TOTALS	**27**	**60.00**	**18**	**40.00**

	Rebaited traps			
	Pilchards number	% of catch	Fish oil number	% of catch
Lutjanidae	7	15.56	-	-
Serranidae	8	17.78	4	8.89
Siganidae	2	4.44	-	-
Labridae	1	2.22	1	2.22
Pomacanthidae	1	2.22	1	2.22
Nemipteridae	-	-	1	2.22
Lethrinidae	3	6.67	-	-
Pomacentridae	-	-	1	2.22
Haemulidae	6	13.33	-	-
Apogonidae	-	-	5	11.11
Muraenidae	1	2.22	-	-
Hemigaleidae	1	2.22	-	-
TOTALS	**29**	**64.44**	**16**	**35.56**

2.4. DISCUSSION

This study identified a number of factors that influence the overall size and composition of catches using Antillean "Z" traps, including mesh size, bait type and baiting frequency. By monitoring the accumulation of catches in different treatments it was possible to identify treatment combinations and soak times that maximise overall catch for particular target species.

Mesh size

On the basis of previous studies, catches in small-meshed traps were expected to be higher in weight and numbers than in large-meshed traps for two reasons: Firstly, they may retain a larger range of fish sizes (Wolf & Chislett, 1971; Stevenson & Stuart-Sharkey, 1980). Secondly, they are supposed to have a stronger visual impact underwater, appearing more attractive as shelters to fish (Munro, 1974; Luckhurst & Ward, 1987). However, during this study, catches were significantly greater in large-meshed traps than in small ones for the total number of fish and total number of species. The rabbit fish *S.doliatus*, was caught almost exclusively in large-meshed traps. This pattern was robust to sampling at different locations and times.

The reasons for higher catches in large-meshed traps are uncertain. There could be greater escapement from small-meshed traps because of the greater contrast between the cage material and the opening of the funnel (Luckhurst & Ward, 1987). This would explain the lower catches and decreasing catch rates of some species over the soak period (e.g. *L.carponotatus*). However, underwater observations suggest that this can only be applied to some species. Alternatively, small-meshed traps may decrease the amount of conspecific attraction and consequently decrease catches. However, the way in which fish perceive traps is a matter for speculation. A decrease in conspecific attraction cannot explain nil catches of *S.doliatus* in small-meshed traps at the beginning of the soak period. In this study, it appeared that the strong underwater silhouette of small-meshed traps seemed to "confuse" herbivorous fish, especially *S.doliatus*. This species was observed to simply avoid entering small-meshed traps. In the following chapter, conspecifc attraction experiments of

S.doliatus in different mesh traps are discussed. Newman (1990) argued that the strong visual outline of small-meshed traps underwater makes the identification and counting of catches difficult for divers, but this was not a problem in this study.

Bait type

Bait type was also important, with use of pilchards resulting in the largest multispecific catches and a greater diversity of fish species in catches. *L.carponotatus* were caught in significantly higher numbers in traps baited with pilchards. This bait has been successfully used in commercial fisheries of North-Western Australia due to the high oil content and disintegration when feeding, which causes a larger bait plume effect (Whitelaw *et al.*, 1991). The decreasing catch rates of *L.carponotatus* in traps with pilchards after a few hours of the soak period may be due to the depletion of the bait and subsequently an increase in escapement rates (Munro *et al.*, 1971). The absence of a significant effect of bait on the numbers of *L.carponotatus* in traps deployed at Cattle Bay may have been caused by differences in the extension of the bait flux due to different current regimes (Campbell *et al.*, 1987) and differences in the local density of fish (pers.obs.).

The other bait used in this study, fish oil, was considered to have a higher oil content than pilchards and act over a longer period. This bait was expected to start fishing at lower rates than pilchards, but last longer after the pilchards were depleted. However, its attractiveness did not seem to be strong enough to affect the trap success. This could be due to the absence of bait particles in the bait plume.

Unbaited traps registered comparable total catches to those traps baited with pilchards, supporting previous studies in which no differences in catches between unbaited and baited traps were found, once the bait was depleted (High & Ellis, 1973; Munro *et al.*, 1971; Stevenson & Stuart-Sharkey, 1980). Although a significant bait effect was found on total number of fish, bait does not seem to be a major factor determining high catches for some species (*S.doliatus* and *Plectropomus* spp.). Also, no significant differences between final catches in rebaited traps and traps baited once suggested that bait did not have a large effect on traps set in shallow water. However, it appears to be a necessary attractant in traps deployed in deeper waters (Wolf & Chislett, 1974; Sainsbury, 1990). Further studies on the role of rebaiting with a higher number of traps are needed to identify any possible difference between rebaited traps and traps baited once on catch rates and total catches.

Catch rates over soak periods

Total catch rates appeared to increase at the end of the two day soak period (Cattle Bay), particularly for *S.doliatus,* suggesting that the soak period was not long enough for the traps to reach their saturation time (Munro, 1974). Longer soak periods of 4.5 days for the total catch and of 3.5 days for *S.doliatus*, were proposed by Davies (1989) when larger traps with horseneck funnels were deployed at the same island. On the other hand, total catches and catches of *S.doliatus* at Pioneer Bays levelled off and started decreasing at the end of the 3 day soak time. In these cases, the time to reach the asymptotic catch appeared to be shorter than that calculated by Davies (1989). Besides differences in fish abundance expected in the different locations used in both studies, the differences in optimum soak periods for the total catch appeared to be caused by the higher rates of ingress and egress events of the multispecific stock, and particularly of *L.carponotatus,* expected in the traps with straight funnels used in this study when compared to those in the horse-neck funnels used in Davies's study (1989) (Luckhurst & Ward, 1987). The differences in optimum soak times for *S.doliatus* appeared to be caused by real differences in abundance of *S.doliatus* between the locations used in this study (Cattle Bay and Pioneer Bay) and Davies' location (Iris point) rather than higher escapements from traps with straight funnels. Underwater observations carried out during each trial (Chapter II) showed very low numbers of *S.doliatus* escapements. On the contrary, when trapped its paired conspecific stayed outside the trap and subsequently entered the trap. This conspecific behaviour has been commonly observed in herbivorous fish species at different locations and times (Munro *et al.*, 1971; Luckhurst & Ward, 1987; Davies, 1989; Whitelaw *et al.*, 1991).

Optimum soak period for *Plectropomus* spp. may be longer than 3 days as catches increased over time with highest catches at the end of the soak period. More extended soak periods may be a result of the increasing numbers of smaller fish trapped through the soak period acting as an incentive (live bait) for large piscivorous to enter these traps (Munro *et al.*, 1971; Sylvester & Dammann, 1972; Stevenson, 1978; Davies, 1989).

Family-composition of catch

There appeared to be a trend in the composition of fish families caught in traps, with herbivorous fish appearing at the beginning of the soak period when no large predators are trapped with progressively more piscivorous fish entering traps towards the latter stages of the soak period (Munro, 1974, Dalzell & Aini, 1987, Davies, 1989; Koslow *et al.*, 1988). Predatory species could be entering traps to prey on the smaller fish species that have accumulated (Davies, 1989). At the end of the soak period, higher proportions of herbivorous fish families (Siganidae, Pomacanthidae) occurred in large-meshed traps regardless of bait while predatory fish families (Serranidae and Lutjanidae) occurred in higher proportions in small-meshed traps regardless of bait. Low numbers of herbivorous species in small-meshed traps determined the differences in catch composition between traps and must be considered when this species group is targeted.

Size-composition of catch

There were few clear effects of trapping on the size composition of the catches. The only significant result of the length analysis might have been confounded by the low number of size classes distinguished. Apart from the different mesh sizes and consequently, different fish size retention, Hartsuijker & Nicholson (1981) suggested that recruitment to the trap fishery is more related to behavioural changes with the size of the fish. If mesh size was considered as determining length at first capture, similar values for that length were expected to be found at the lower sizes of the different species with similar body morphology. A study carried out at Pedro Bank (Jamaica) showed that this did not occur. Smith & Tyler (1975) argued that fish vulnerability to the trap was a result of an increase in size and subsequently, the lack of available shelter. However, this increase in vulnerability may be restricted to those fish species in which home range varies with fish size. Larger numbers of fish need to be targeted if conclusions are to be drawn from the sizes of fish caught in traps.

Conclusions

The different target species showed marked differences in catch rates and final catches within each location due to species-specific behaviour in relation to different mesh sizes and baits (Summary Table). Most notable among these were the high rates of escapement for *L.carponotatus* when bait was depleted, negative relationship between *S.doliatus* and small-meshed traps and an increase in numbers of *Plectropomus* spp. when small prey fish were present. The optimum soak period for maximum catch was species-specific for both locations. Differences in catch rates and final catches of target species between locations were caused mainly by the supposed different abundances of species at each location. Total catch rates (2.2 fish/trap/day at Cattle Bay and 1.0 fish/trap/day and 0.9 fish/trap/day (rebaited traps) at Pioneer Bay) in this study were lower than those obtained in previous studies at the same island: Davies (1989) caught 4.52 fish/trap/day and Newman (1990) caught 3.84 fish/trap/day. Variation in catch rates between studies appeared to be caused by the different trap volume (High & Ellis, 1973), funnel shapes (Luckhurst & Ward, 1987), soak period (Davies, 1989) and fish abundances in the different locations used (Campbell *et al.*, 1987). For the multispecific stock, the highest effectiveness in catching fish of large-meshed traps and traps baited with pilchards was consistent between locations (Cattle Bay and Pioneer Bay) and soak periods (2 days and 3 days, respectively) (Summary Table). Also, similar patterns in total catch rates and family catch composition were found in traps of those characteristics at the two locations in Orpheus Island. Final catches, composition and catch rates resulted from the different behavioural response of fish to the traps. This is examined in detail in the following chapter.

Summary Table. Sampling design for maximum catches of the multispecific catch and target species. (-) indicates any of the two mesh sizes and bait types.

	Mesh size	Bait type	Rebaiting	Soak time(days)
(1) **Overall catch**	Large	Pilchards	No	3
(2) ***S.doliatus***	Large	-	No	2
(3) ***L.carponotatus***	-	Pilchards	No	1
(4) ***Plectropomus* spp.**	-	-	No	>3

CHAPTER III

FISH BEHAVIOUR IN RELATION TO ANTILLEAN "Z" TRAPS: A DIRECT OBSERVATIONAL APPROACH

3.1. *INTRODUCTION*

Fish behaviour may be one of the most important factors determining the final catch in traps. High variability in the catches from fish traps, both in terms of quantity and composition, can potentially be attributed to the different responses of reef fish species to the gear itself and interactions among individual fish. The performance of the traps is based on a sequence of events consisting of fish arrival at the trap, their entry into the trap and their possible egress from the trap (Campbell *et al.*, 1987). The relative importance of these processes can only be determined from direct observations. The number of fish caught may or may not be a good indicator of their abundance in the vicinity of the trap.

When baited traps are used, the number of fish arrivals and consequent aggregation around traps may be influenced by the spread of the bait plume downstream (Whitelaw *et al.*, 1991) and also by the sensorial ability of different fish and whether they respond to the bait as food. Alternatively, when unbaited traps are used, the attractiveness of the traps may be related to their desirability as shelter sites or presence of other fish already in the traps (Luckhurst & Ward, 1987). Once in the vicinity of the trap, the success of the trap performance may depend on the interaction between the trap itself and the fish behavioural response to it. Hence, there is no single reason for fish to aggregate around traps or for them to enter the trap (High & Ellis, 1973).

In one of the first underwater studies of traps three factors were identified as affecting the likelihood that an individual fish will enter a trap. These were curiosity, reaction to individuals in distress, or entry to prey on other small fishes already trapped. Campbell *et* *al.* (1987) identified a further set of factors affecting ingress, such as bait-flux due to currents and the direction in which the trap funnels faced. Complex relationships between the physical trap characteristics and fish morphology are responsible for trap selectivity, and the failure to catch certain species (Newman, 1990). Trap designs, funnel shape, trap shape, mesh size and fish body configuration are just some aspects of the failure (Newman, 1990). Whether the fish is territorial or home ranging, solitary or schooling will strongly influence the probability of fish entering traps (Luckhurst & Ward, 1987). If traps are set by chance in the living or hunting territory of individuals, the chances of catching those fish are enhanced. The presence of a particular fish in the trap may enhance or deter the entrance of other individuals depending on their behaviour. Munro *et al.*, (1971) suggested that intraspecific attraction such as schooling behaviour had a major effect on catch composition. Traps that already contain fish have a greater chance of new ingresses if fish out of the trap are positively associated to fish already trapped (High & Ellis, 1973; Parrish, 1982; Luckhurst & Ward, 1987; Davies, 1989; Newman, 1990). However, the chance of new ingress is decreased if fish out of the trap are negatively associated to fish already trapped (i.e.interspecific relationships: predator-prey and territoriality) (Craig, 1976; Campbell *et al.*, 1987; Luckhurst & Ward, 1987). Highly variable catches in traps, and in passive gears in general (i.e. hook and line), is due to high intra-interspecific variation in fish behaviour (Luckhurst & Ward, 1987).

Feeding activities of trapped fish increases the dispersion of bait particles and the resulting bait plume may further increase the number of fish attracted to the trap. Luckhurst & Ward (1987) observed that many fish did not feed from bait when just trapped, however, Campbell *et al.* (1987) observed fish like emperors (lethrinids) and snappers (lutjanids) feeding at the bait as soon as trapped. Rate of egress registered on traps is also closely related to bait depletion (Munro *et al.*, 1971, Campbell *et al.*, 1987). As stated by Munro *et al.* (1971) escapement rates increased after bait depletion and they are closely related to the number of fish present in traps.

Rates of ingress and escapement may relate to fish behavioural responses to traps of different mesh sizes (Luckhurst & Ward, 1987). The strong visual impact of traps with a small mesh size was speculated to be one of the factors affecting high turnover in fish numbers. Fish were attracted to small mesh traps but they were able to distinguish the funnel opening more easily than in large mesh ones and so escaped in higher numbers. Munro (1974) also pointed out that the complex visual contours of wooden traps could be the reason that these traps captured more fish than those with steel frames.

The behavioural response of fish to traps is interesting and useful for assessing the capture efficiency of any kind of trap and the characteristics of individual species which affect its catchability (Karnofsky & Price, 1989). The importance of a knowledge of fish behaviour in providing a better understanding of how gear operates is essential in all work related to fish traps. In this way the optimum soak times which could maximise the catch of the target species may be assessed.

In this study, trap performance is examined with a focus on behavioural changes in response to a particular gear, and to intraspecific interactions among individuals. Diver observations and video techniques are used to directly measure fish aggregations around traps, ingress and egress under different conditions of mesh size and bait.
The specific aims of this study were to :

1) examine the relationship between number of fish in the area surrounding traps of different characteristics and the subsequent catch.

2) assess rates of ingress and escapement of the target species into/from different traps in relation to the fish inside and outside traps.

3) evaluate the effect of 13 mm square mesh and 42 mm hexagonal meshed traps in determining the attractiveness of *Siganus doliatus* to traps.

4) study the effect of the presence of *Siganus doliatus* on the subsequent ingress of a conspecific and other species into traps

3.2. MATERIALS AND METHODS

3.2.1. *SAMPLING DESIGN: TRAP ATTRACTIVENESS*

TRIAL 1: Cattle Bay

Four traps, each one representing a different treatment combination, were set in the early morning as described in the previous chapter. Underwater observations were carried out at different times of the day using SCUBA to determine the relationship between catch and the aggregation of fish around traps, and to directly record fish entering and escaping from the trap. During each day's soak period, traps were observed at four different times between 7:30 a.m. and 5:00 p.m. (Fig.3.1.). At each of the four times, a single trap for each treatment was observed for fifteen minutes before moving to the next one, so that the four treatments were sampled for each sampling period. The four daily observations were separated from one another by about 90 to 120 minutes. A total of 94 hours were spent observing traps in situ. Thus 376 behavioural observations of 15-minutes duration were carried out.

Direct observations were made on the four target species *(L.carponotatus*, 2 *Plectropomus* spp., and *S.doliatus*). The diver was positioned at about 5 m distance from the trap where both entry funnels could be clearly seen as well as being able to observe the area in an approximately 2 metre radius from the trap. A 2-metre distance was chosen arbitrarily as a measure of "availability" of "trappable" fish, where interactions among fish or between fish and the trap might determine catches (Campbell *et al.*, 1987). Another factor was that an area larger than 2 metres could not always be observed due to poor visibility at some sites.

Once the diver was in place, number of fish and species in the trap were recorded. Every time a fish moved through the sampling area around the trap, it was registered and identified. Every two minutes, any significant behaviour such as feeding from bait, aggressive interactions among fish inside the trap or between fish inside and out of the trap were recorded. All sizes of fish sighted within this area around the trap were considered potentially "trappable" within the limits of the mesh size.

The time that a fish spent within 2-metres of the trap was also recorded as was the duration and frequency of any kind of reaction to the fish already trapped to the fish outside the trap (e.g. swimming together or away from other fish). When a fish entered the trap, the time at which it entered and the time it took the fish to get in (i.e. time at which it was first sighted in the trap surrounds) were also noted. Every time that a fish escaped from the trap, the time at which this occurred was registered and whether the fish remained within 2-metres radius around the trap or went away immediately.

TRIAL 2: Pioneer Bay

From 21 June to 21 November a behavioural study was carried out at Pioneer Bay to assess in more detail how fish respond to baited and unbaited traps with different mesh sizes. An underwater video-camera was set outside one of the traps representing one treatment combination (see previous chapter) for a three day soak period (Fig.3.2). The traps monitored were determined by a random sequence in an orthogonal sampling design with two-fixed factors (mesh size and bait type). As in trial 2, two levels of mesh size were used: large mesh (42 mm hexagonal mesh) and small mesh (12.5 mm square mesh). Two different kinds of bait were used: pilchards and fish oil in addition to an unbaited treatment. A total of 115 hours of video recordings were obtained for all 6 treatments.

In the early morning of the first day of the soak after setting the trap, divers proceeded to position the camera. A colour digital Panasonic WV-CL350 camera inside a waterproof housing was used for all underwater recordings. The housing was anchored to the substratum by a concrete block with an aluminium/steel attachment which was screwed to the housing. The camera was positioned approximately 3 metres from the trap, perpendicular to the long axis of the trap. From this point, both trap funnels, the interior of the trap and the immediate area surrounding the trap were included in the camera field. An underwater cable of more than 80 metres connected the camera to a video deck (Hitachi VHS recorded) and to the batteries for the power supply placed on a barge moored in the vicinity of the trap site. All video footage was recorded onto VHS tapes for further analysis.

During the early morning of the last day's soak, the camera was retrieved from the water, and the trap was hauled up, emptied and the catch counted and identified to species level when possible. Total and standard lengths of each fish were recorded. That same morning, a new trap, representing a different treatment combination, was placed in a new location within the sampling area. Divers placed the trap assuring the position of the funnels to the main tidal current as well as the proximity of the trap to a massive coral. The video-camera was reset, focused on both trap funnels and the surrounding area. Recordings of the new treatment started as soon as the trap and camera were set.

Each of the treatment combinations were recorded twice a day for 90 minutes during each of the three days soak. Video camera recordings started in the early morning of the first day soak (7:00-8:30 a.m.) and a second recording was carried out during the late afternoon (4:30-6:00 p.m). Video recordings were carried out throughout the soak period with occasional extra recording hours during midday and early afternoon periods.

The early morning and late afternoon recording times were chosen due to the higher activity of the two target species (*Lutjanus carponotatus* and *Plectropomus* spp.) at that time of the day as registered in a previous study carried out at Orpheus island using the same traps (pers.obs.). Thus, more behavioural displays were expected to be observed during these hours.

Video recordings were analysed in terms of fish numbers and time spent by individual fish in the 2 metre area surrounding the trap at that observation time. Frequency and duration of any significant behaviour of the fish outside the trap in relation to the catch (e.g. swimming together, inspections of the mesh or chasing smaller fish inside the trap) and any ingress and egress in/from the traps were noted.

3.2.2. *EXPERIMENTAL DESIGN: INTRASPECIFIC INTERACTIONS IN* **Siganus doliatus**

The attractiveness of a trap and the likelihood of ingress may increase once conspecifics have entered the trap. Also, the ability to perceive conspecifics inside traps may depend on the physical structure of the trap, including mesh size. An experiment was carried out to determine the effect of mesh size and the presence of *S.doliatus* on the additional catch of this species and catch composition. Traps were set in a two-way orthogonal design with two fixed factors: mesh size and *S.doliatus*. The factor mesh size with two levels: large mesh (42 mm hexagonal mesh) and small mesh (12.5 mm square mesh), and the factor *S.doliatus* with another two levels: presence of *S.doliatus* and absence of *S.doliatus*. At least four traps, one for each treatment combination, were set for 3 days soak time. At the end of 24 days of the study a total of 10 replicates for each treatment combination were achieved and more than 240 records of fish at the experimental traps were deployed.

Divers ensured that the position of the traps was on a flat substratum, close to massive corals with the funnels facing into the main tidal current. They then proceeded to place one *S.doliatus* in each of the two appropriated treatments, one with small mesh and one with large mesh. These fish were marked by clipping one dorsal spine. They were kept on board for less than 30 minutes in a dark container with a continuous flux of water before being placed in the traps.

After three days soak, traps were hauled, emptied and the catch was counted, identified to species level (when possible) and standard and total lengths were recorded to the nearest millimetre. After this, fish were released well away, at least 200 metres, from the place they were caught. A new set of experimental traps was placed at a new location within the sampling area that same morning. Divers repositioned the traps and also placed new *S.doliatus* in the traps. The new set of traps was left in the water for another 3 days soak period.

Two daily inspections of the manipulative experimental traps were carried out everyday of the soak period. The first inspections was carried out early in the morning (8:00-8:30 a.m.)

and the second during the late afternoon (4:30-5:00 p.m.). During each inspection, number of fish and species inside the traps were recorded.

3.3. *DEFINITION OF TERMS AND ASSUMPTIONS*

Unless specified, data from underwater observations carried out during trial 1 and video-camera recordings obtained during trial 2 were used in all the analyses. *In situ* observations of ingress and escapement recorded during underwater observations of trial 1 and video-recording of trial 2 are named as "observed ingress" and "observed escapement".

The term "net ingress" refers to all fish known to have entered the traps between countings. This net ingress was calculated as the sum of all increases in the number of fish between consecutive observations. When ingress is recorded in this manner, fishes which entered and escaped during the period between countings or fish which were replaced by a conspecific could not be accounted for. Therefore, "net ingress" has to be considered as a minimum estimate of the real ingress to traps. During the first study, time between counts varied between 90 and 120 minutes but during the second study observations were separated in time by 9 hours.

The loss in number of fish between consecutive countings due to escapement, predation or unknown causes was considered as "net escapement". When egress is recorded in this manner, fishes which disappeared due to predation during the period in between counts could not be accounted for. Again, time between observations means that this must be considered as a minimum estimate of actual escapement.

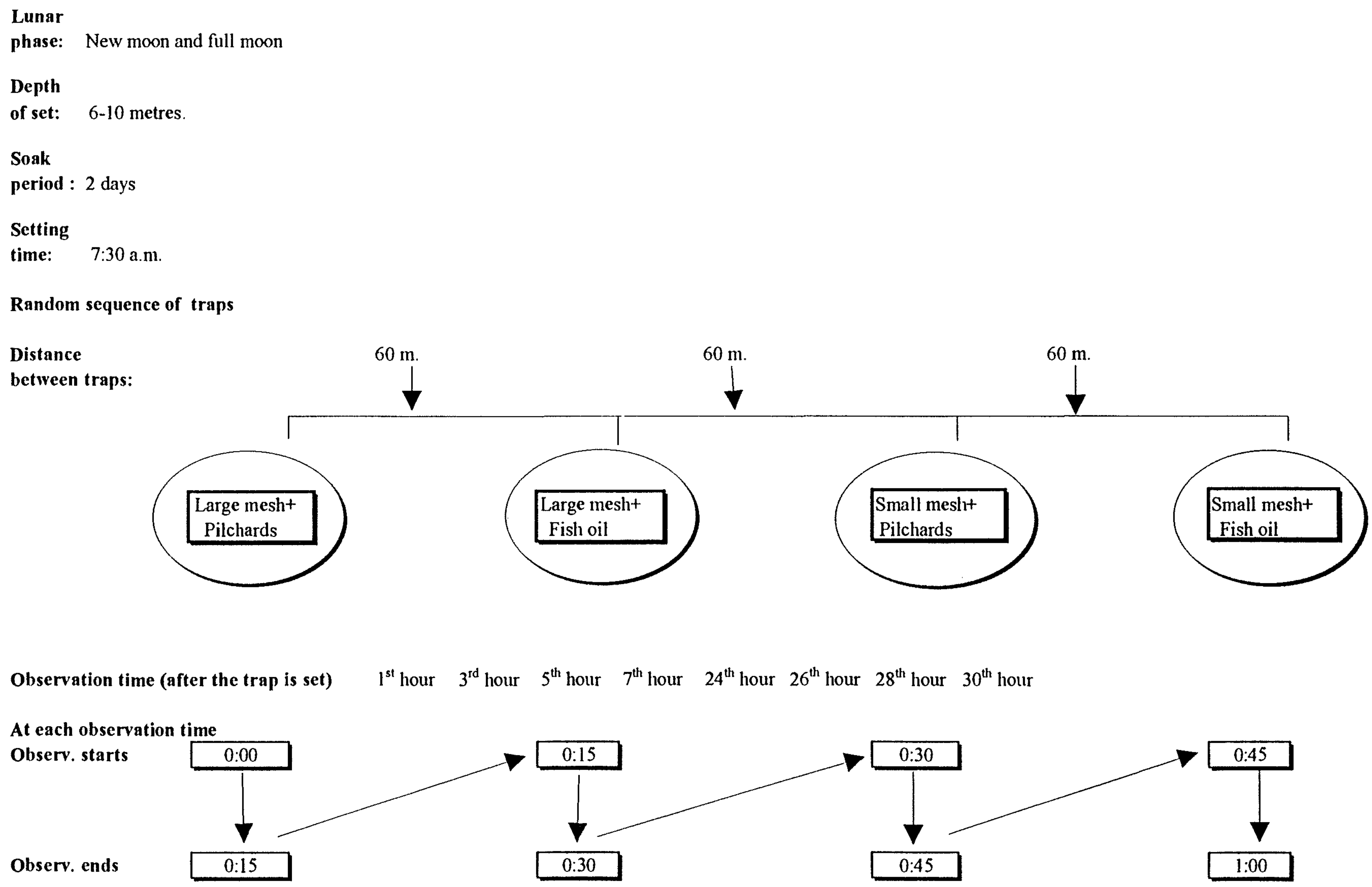
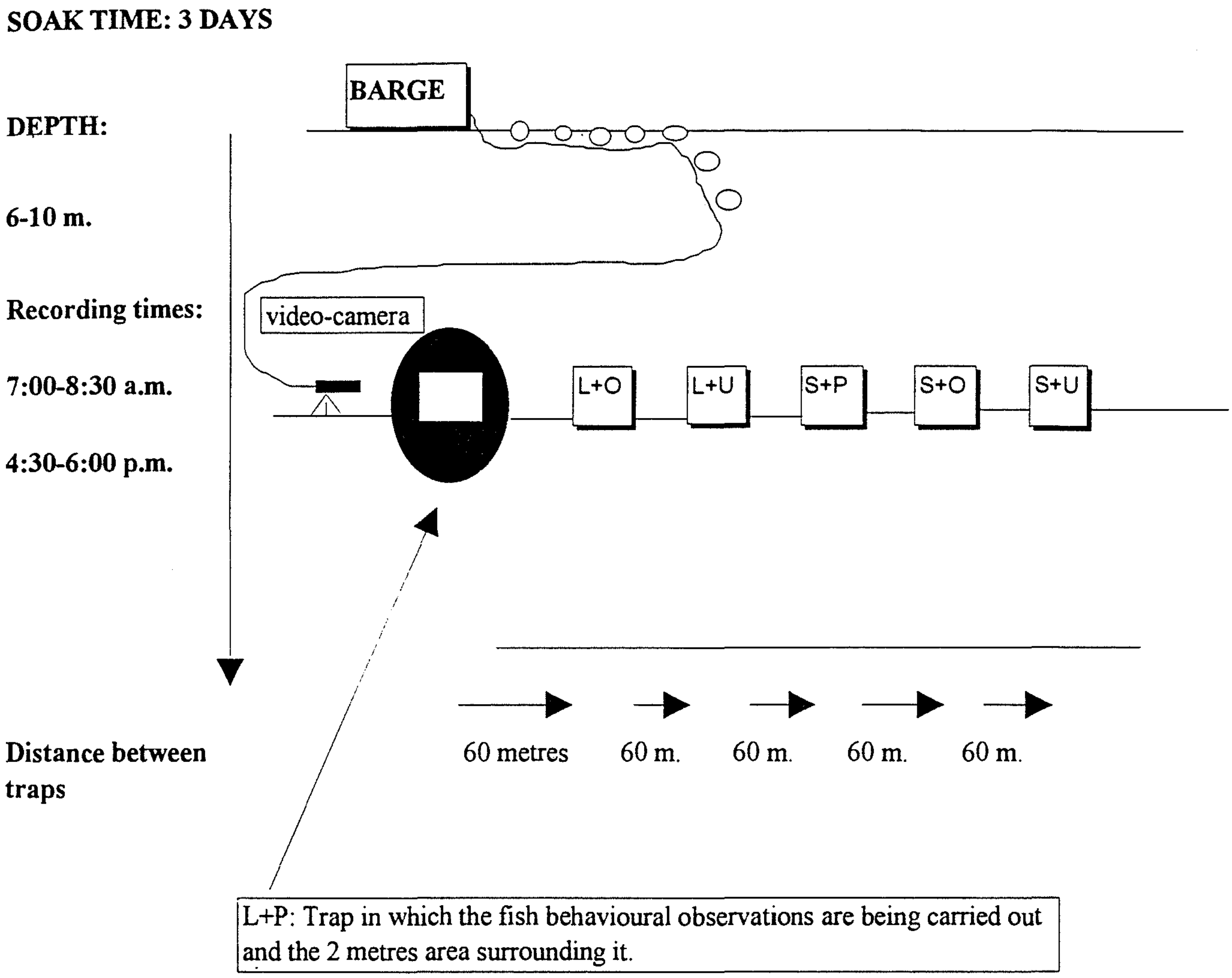


Fig. 3.1. Example of the underwater observations carried out in traps deployed at Cattle Bay (TRIAL 1)



After 3 days soak a new trap is set.

Fig.3.2. Example of how the video recordings were carried out at Pioneer Bay (Trial 2).
L+P= Large mesh + Pilchards, L+O= Large mesh + Fish oil, L+U= Large mesh + No bait
S+P= Small mesh +Pilchards, S+O= Small mesh + Fish oil, S+U= Small mesh + No bait

3.4. *DATA ANALYSIS*

Prior to any parametric statistical analysis, homogeneity of variances was tested using Cochran's test (Winer, 1971). Data was log (x+1) transformed if the results of the Cochran's test suggested it necessary (Zar, 1987). For both trials, two-factor analysis of variance were carried out on the total number of fish observed in the 2 metre area surrounding traps at each observation time. Numbers of *S.doliatus* and *L.carponotatus* observed during the second trial were too small to carry out any statistical analysis and number of *Plectropomus* spp. was examined with some of the bait levels not being represented in the analysis (Tab.3.1.). The relationship between the number of fish outside the traps and the catch at the end of each observation was studied by using correlation coefficients. When data obtained from these bivariate populations was far from normal, Spearman's ranked correlations were used (Conover, 1971; Zar, 1987).

Because of the non-normality and heteroscedasticity of the data or time spent by the target species in the 2 metre area surrounding traps at each observation time, this was examined using a randomised two-factor analysis of variance. For trial 1, the number of replicates was reduced to 10 in order to have an equally replicated design. For trial 2, an unreplicated randomised ANOVA with 5,001 randomizations was carried out on the total time spent around traps by *Plectropomus* spp.

Net ingress and escapement estimates were compared by a two-factor analysis of variance. For *S.doliatus,* this was examined using a randomised two-factor analysis of variance in which 5,001 randomizations were carried out. Observed ingress and egress were correlated with the number of fish in the 2 metre area surrounding the trap and inside the traps at the moment of the event by using Spearman's ranked correlations, due to the non-normality of the data.

Data from manipulative experimental traps was examined using a two-factor analysis of variance on final number of individuals, species, number of *S.doliatus* and number of siganids (Family Siganidae) captured in traps. T-tests were used to compare catch rates between the different treatments.

Total lengths were compressed into 2 size classes to avoid expected frequencies less than 1and less than 20% of the expected frequencies lower than 5 (Zar,1987). Length frequency distributions of target and most abundant species was analysed using two-tailed Fisher's exact tests (Zar, 1987). Total lengths of *S.doliatus* were examined using χ^2-homogeneity tests with Yate's corrections. Tukey-type multiple comparison tests among proportions were used to look for significant differences (Zar, 1987).

3.5. *RESULTS*

3.5.1. *TRAP ATTRACTIVENESS*

During both trials, a highly variable number of fish was registered around traps over the observation periods (Fig.3.3). During the first day soak, for both trials, the number of fish in the 2-metre area surrounding traps of different mesh sizes was similar. A decline in fish numbers was registered at the end of the soak period in trial 1, for both mesh sizes. However, at Pioneer Bay, numbers seemed to increase after the second day soak and only decreased in small-meshed traps at the end of the soak period. For all traps at each location, number of fish appeared to follow a decreasing trend at the end of the 2 day soak period.

The bait treatments differed in their apparent attractiveness to fish (Fig.3.3.). Numbers appeared to be higher near unbaited traps than in baited ones. Also, traps baited with fish oil seemed to attract very similar and even more fish than pilchards (Fig.3.3). However, for each trial, the total number of fish in the 2-metre area surrounding traps did not differ significantly between traps at any observation time (Tab.3.1.). Overall, traps with different mesh sizes attracted comparable numbers of fish at the end of both trials.

The effects of the different treatments on the attraction of fish appeared to be species specific. For both trials, the number of *S.doliatus* appeared to be higher outside large-meshed traps than in small ones (Fig.3.4.). Bait did not seem to have an effect on the numbers of this species gathered around traps with very similar numbers of ***S.doliatus*** observed around baited and unbaited traps. The only significant differences between large- and small-meshed traps on the numbers of *S.doliatus* was found during the morning of the first day soak of trial 1 (Tab.3.1.). From the ANOVA results (Tab.3.2.) ***S.doliatus*** observed at Cattle Bay during the first day soak spent significantly longer time around large-meshed traps. As expected, these times varied greatly due to differences between individuals observed at each trap.

Plectropomus spp. were observed in higher numbers around small-meshed traps, during trial 2 (Fig.3.4.). For the different baits, the highest number was observed in unbaited traps followed by traps baited with fish oil and pilchards. However, the ANOVA test did not discern any significant difference between numbers, or the time spent, in the 2- metre area surrounding the traps (Tab.3.1. & Tab.3.2.). During the observations at Cattle Bay, mean numbers of this species appeared to be very similar for both mesh sizes and baits. Thus, the ANOVA results did not show any significant effect of mesh size and baits on numbers (Table.3.1.). The time spent in close proximity to the trap was similar for all different traps at any observation time. The only difference between treatments was found in the time spent in the 2-metre area surrounding large- and small- meshed traps during the early morning observation of the second soak day (Tab.3.2.).

Comparable numbers of *Lutjanus carponotatus* were observed at each location in the 2-metre area surrounding traps with different mesh sizes and baits (Fig.3.4.) and consequently no significant differences on numbers (Tab.3.1) or time spent in this close area were found at Cattle Bay (Tab.3.2.). No *L.carponotatus* were observed in the unbaited trap surrounds at Pioneer Bay. However, in all cases very low numbers of this species were observed in the 2-metre area surrounding traps at this location.

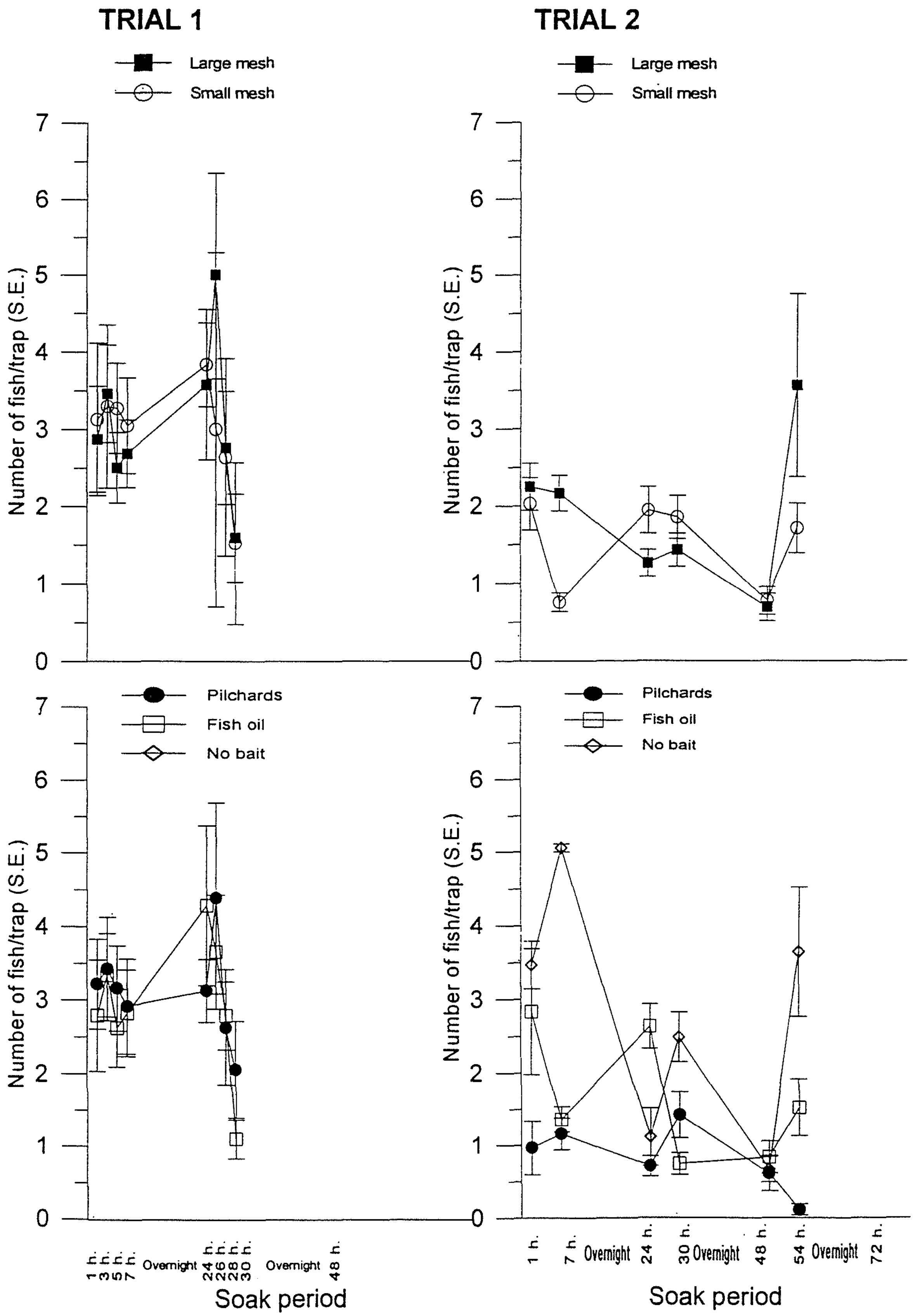


Fig.3.3. Mean number of fish observed in the 2 metres area surrounding traps at locations. (Trial 1:Cattle Bay and Trial 2: Pioneer Bay) (Error bars represent standard errors)

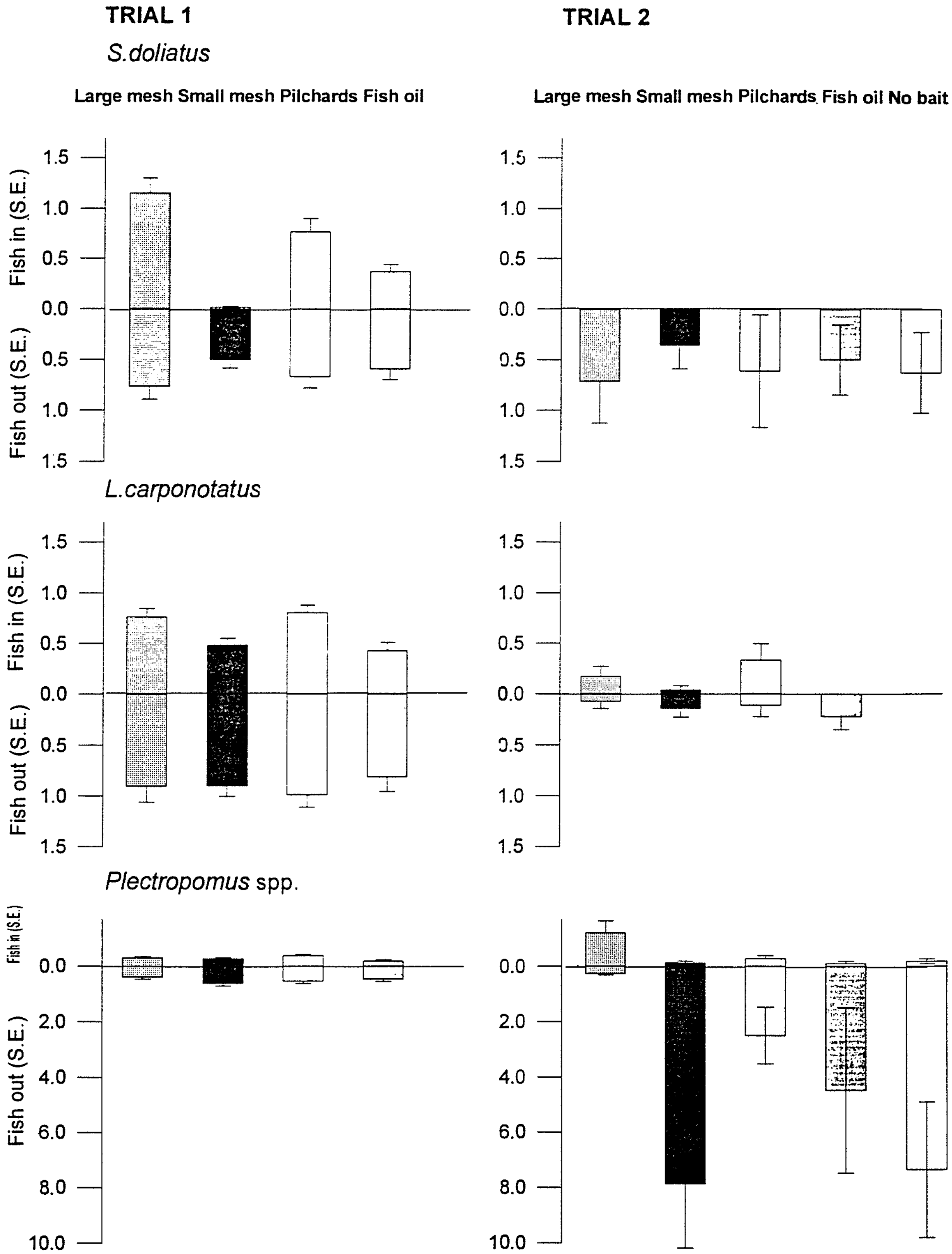


Fig.3.4. Mean number of target species inside and outside traps at the observation moment. (Error bars represent standard errors)

Table.3.1 Results of ANOVA tests of the effect of mesh size and bait on total numbers of fish, *S.doliatus*, *L.carponotatus* and *Plectropomus* spp. observed around traps at each observation time.(*) denotes significance at 0.05 probability level. Bait levels considered on ANOVA tests of Trial 2 are indicated near the bait factor (P=Pilchards, O=Fish oil and U=No bait). For Trial 1 only the morning and late afternoon observations were considered.

		Total numbers							
		TRIAL 1				TRIAL 2			
DAY 1		d.f.	MS	F-ratio	P	d.f.	MS	F-ratio	P
Morning	Mesh(M)	1	0.01908	0.117	0.7377	1	0.12726	0.458	0.5747
(P+U)	Bait (B)	1	0.07526	0.461	0.5081	1	0.64560	2.324	0.2669
	M x B	1	0.01488	0.091	0.7674	1	0.09236	0.332	0.6279
	Residuals	43	0.16331			2	0.27780		
Afternoon	Mesh(M)	1	0.00066	0.005	0.9433	1	0.09799	0.592	0.4749
(P+O)	Bait (B)	1	0.00107	0.009	0.9278	1	0.00732	0.044	0.8416
	M x B	1	0.00278	0.022	0.8839	1	0.20380	1.233	0.3040
	Residuals	41	0.12569			7	0.16563		
DAY 2									
Morning	Mesh(M)	1	0.04323	0.363	0.5563	1	0.01910	0.037	0.8544
(P+O+U)	Bait (B)	1	0.00479	0.040	0.8440	2	0.32895	0.642	0.5546
	M x B	1	0.00622	0.052	0.8227	2	0.19076	0.372	0.7020
	Residuals	46	0.11915			7	0.51230		
Afternoon	Mesh(M)	1	0.02898	0.290	0.5990	1	0.09990	0.754	0.4577
(P+O+U)	Bait (B)	1	0.07261	0.726	0.4082	2	0.12556	0.947	0.4800
	M x B	1	0.03658	0.365	0.5552	2	0.32950	3.993	0.1427
	Residuals	42	0.10009			3	0.13260		
DAY 3									
Morning	Mesh(M)					1	0.11150	0.343	0.6676
(O+U)	Bait (B)					1	0.09584	.0.295	0.6879
	M x B					1	0.27278	0.839	0.5356
	Residuals					4	0.32496		
Afternoon	Mesh(M)					1	0.04335	0.051	0.8385
(O+U)	Bait (B)					1	0.00484	0.006	0.9454
	M x B					1	0.0013	0.002	0.9717
	Residuals					3	0.85452		

		S.doliatus				*L.carponotatus*			
		TRIAL 1				TRIAL 1			
DAY 1		d.f.	MS	F-ratio	P	d.f.	MS	F-ratio	P
Morning	Mesh(M)	1	2.02890	6.36	0.0155*	1	0.00020	0.004	0.9516
(P+U)	Bait (B)	1	0.00212	0.007	0.9361	1	0.01120	0.177	0.6805
	M x B	1	0.12780	0.401	0.5368	1	0.12650	1.995	0.1650
	Residuals	43	0.31900			43	0.06340		
Afternoon	Mesh(M)	1	0.02100	0.378	0.5484	1	0..01820	0.216	0.6492
(P+O)	Bait (B)	1	0.00450	0.082	0.7797	1	0.09570	1.133	0.2933
	M x B	1	0.00830	0.150	0.7043	1	0.00100	0.012	0.9129
	Residuals	41	0.05560			41	0.0844		
DAY 2									
Morning	Mesh(M)	1	0.09880	0.170	0.6861	1	0.00440	0.050	0.8264
(P+O+U)	Bait (B)	1	0.01561	0.027	0.8721	1	0.00230	0.026	0.8732
	M x B	1	0.03912	0.067	0.7990	1	0.04100	0.460	0.5084
	Residuals	46	0.57990			46	0.08920		
Afternoon	Mesh(M)	1	0.141	2.924	0.0947	1	0.05670	1.530	0.2229
(P+O+U)	Bait (B)	1	0.0869	1.803	0.1866	1	0.00470	0.127	0.7271
	M x B	1	0.0007	0.016	0.9018	1	0.00470	0.127	0.7271
	Residuals	42	0.0482			42	0.03700		
DAY 3									
Morning	Mesh(M)								
(O+U)	Bait (B)								
	M x B								
	Residuals								
Afternoon	Mesh(M)								
(O+U)	Bait (B)								
	M x B								
	Residuals								

		Plectropomus spp.							
		TRIAL 1				TRIAL 2			
DAY 1		d.f.	MS	F-ratio	P	d.f.	MS	F-ratio	P
Morning	Mesh(M)	1	0.16040	2.875	0.0967	1	0.51480	-1.855×10^{14}	1
(P+U)	Bait (B)	1	0.02280	0.409	0.5325	1	0.15660	-5.642×10^{15}	1
	M x B	1	0.09420	1.689	0.2002	1	0.15660	-5.642×10^{15}	1
	Residuals	46	0.05580			1	-2.77×10^{17}		
Afternoon	Mesh(M)	1	0.00250	0.170	0.6869	1	0.73590	7.349	0.0535
(P+O)	Bait (B)	1	0.00110	0.075	0.7879	1	0.17760	1.774	0.2537
	M x B	1	0.00690	0.457	0.5099	1	0.17760	1.774	0.2537
	Residuals	42	0.01520			4	0.10010		
DAY 2									
Morning	Mesh(M)	1	0.11950	2.786	0.1024	1	0.35770	1.088	0.3317
(P+O+U)	Bait (B)	1	0.00010	0.002	0.9622	2	0.09850	0.300	0.7502
	M x B	1	0.00060	0.015	0.9034	2	0.00450	0.014	0.9861
	Residuals	43	0.04290			7	0.32890		
Afternoon	Mesh(M)	1	0.00340	0.125	0.7293	1	0.26270	2.685	0.1998
(P+O+U)	Bait (B)	1	0.02270	0.816	0.3813	2	0.07110	0.727	0.5526
	M x B	1	0.00740	0.268	0.6129	2	0.30140	3.080	0.1874
	Residuals	41	0.02780			3	0.09780		
DAY 3									
Morning	Mesh(M)					1	0.12290	0.384	0.6047
(O+U)	Bait (B)					1	0.02160	0.068	0.8215
	M x B					1	0.08270	0.258	0.6670
	Residuals					2	0.32040		
Afternoon	Mesh(M)					1	0.15750	1.135	0.3649
(O+U)	Bait (B)					1	0.48810	3.516	0.1575
	M x B					1	0.15750	1.135	0.3649
	Residuals					3	0.13880		

Table.3.2 Randomized ANOVA results of the effect of mesh size and bait on time spent by target species in the 2 metre area surrounding traps at every observation time. (*) denotes significance at 0.05 probability level.

		S. doliatus				*L. carponotatus*				*Plectropomus spp.*							
		TRIAL 1				TRIAL 1				TRIAL 1				TRIAL 2			
		(Randomized ANOVA)				(Randomized ANOVA)				(Randomized ANOVA)				(Unreplicated ANOVA)			
DAY 1		d.f.	MS	F-ratio	P (%)	d.f.	MS	F-ratio	P (%)	d.f.	MS	F-ratio	P (%)	d.f.	MS	F-ratio	P (%)
Morning	Mesh(M)	1	1.701	6.06	**2.90***	1	0.009	0.02	88.48	1	2.007	2.01	12.36	1	0.041	0.02	100
	Bait (B)	1	0.121	0.43	46.24	1	0.440	0.83	35.86	1	0.382	0.04	94.52	1	0.929	0.53	55.04
	M x B	1	0.121	0.43	47.62	1	0.093	0.18	68.94	1	0.178	0.18	70.46	1	1.737		
	Residuals	36	0.281			36	0.528			36	0.996						
		Variance range=261.87				Variance range=137.17				Variance range=121.38				Variance range not possible			
		Sig.level of variance=5.22%				Sig.level of variance=54.14%				Sig.level of variance=56.42%							
Afternoon	Mesh(M)	1	1.701	6.06	**2.60***	1	0.366	0.49	49.08	1	0.328	0.35	54.52	1	0.875	1.22	33.06
	Bait (B)	1	0.121	0.43	46.96	1	1.137	1.51	21.26	1	0.172	0.18	65.92	1	0.438	0.61	100
	M x B	1	0.121	0.43	48.22	1	0.228	0.30	58.04	1	0.235	0.25	59.78	1	0.719		
	Residuals	36	0.281			36	0.755			36	0.949						
		Variance range=254.99				Variance range=88.89				Variance range=92.79				Variance range not possible			
		Sig.level of variance=5.86%				Sig.level of variance=67.34%				Sig.level of variance=67.24%							
DAY 2																	
Morning	Mesh(M)	1	0.400	0.38	53.38	1	0.024	0.03	86.82	1	5.992	5.23	**3.06***	1	8.542	25.38	10.36
	Bait (B)	1	0.037	0.04	85.96	1	0.171	0.21	64.92	1	0.7401	0.65	46.1	2	1.183	3.52	71.96
	M x B	1	0.850	0.81	36.06	1	0.772	0.93	33.58	1	3.553	3.1	9.54	2	0.3366		
	Residuals	36	1.057			36	0.832			36	1.146						
		Variance range=40.87				Variance range=153.33				Variance range=145.01				Variance range not possible			
		Sig.level of variance=96.56%				Sig.level of variance=11.04%				Sig.level of variance=13.86%							
Afternoon	Mesh(M)	1	0.773	0.92	29.36	1	0.381	1.16	28.08	1	0.287	0.51	36.02	1	4.045	3.98	39.78
	Bait (B)	1	0.767	0.91	29.62	1	0.003	0.01	92.08	1	0.231	0.41	44.04	2	1.015	1.00	100
	M x B	1	0.585	0.70	47.82	1	0.000	0.00	97.36	1	0.229	0.41	53	2	1.015		
	Residuals	36	0.840			36	0.329			36	0.564						
		Variance range=143.03				Variance range=84.98				Variance range=148.95				Variance range not possible			
		Sig.level of variance=54.66%				Sig.level of variance=59.84%				Sig.level of variance=75.40%							
DAY 3																	
Morning	Mesh(M)													1	1.552	1	100
	Bait (B)													1	1.552	1	100
	M x B													1	1.552		
	Residuals																
														Variance range not possible			
Afternoon	Mesh(M)													1	0.040	0.02	100
	Bait (B)													1	0.929	0.53	55.04
	M x B													1	1.737		
	Residuals													Variance range not possible			

3.5.2. *RELATIONSHIP BETWEEN FISH AGGREGATIONS AROUND TRAPS AND CATCH.*

Total number of individual fish inside and outside traps

There was no obvious relationships between the final catch and the total numbers of fish outside the different treatments at any location (Fig.3.5.). At each location, a comparable total number of fish was observed in the 2-metre area surrounding meshed traps, however, the final catch traps differed significantly between these traps (see previous chapter) being higher in large-meshed traps for a comparative number of fish outside them. The number of fish in the 2-metre area surrounding baited traps deployed at Cattle Bay followed a similar pattern with comparable numbers of fish outside these traps but significantly different catches in traps baited with pilchards. For those traps deployed at Pioneer Bay numbers of fish in the 2-metre area surrounding unbaited traps appeared to be higher than near baited traps. However, as for the results of Cattle Bay, traps baited with pilchards appeared to drive larger numbers of fish inside them. This indicates no clear relationships between catches in different traps and number of fish aggregated around them. When the catch and the number of fish outside the traps were examined over the whole soak period, some relationships appeared. At Cattle Bay, the catch was positively correlated to the number of fish observed in the 2-metre area surrounding large- and small-meshed traps and traps baited with pilchards. In contrast, at Pioneer Bay a negative relationship between catch and number of fish outside unbaited traps was found (Table.3.3). For all relationships, the values of the coefficient of determination (r^2) were very low, the highest value being 0.28.

Target species in the 2-metre area surrounding traps and target species trapped

At each location, a comparable number of each target species observed in the 2-metre area surrounding the trap resulted in comparatively different catches (Fig.3.4). In general, the numbers of *L.carponotatus* and *S.doliatus* observed outside traps deployed at Cattle Bay was higher than at Pioneer Bay. But within each of the locations, the number of these target species in the 2-metre area surrounding traps of different mesh sizes and bait types was very similar resulting in different catches in each different trap. At Pioneer Bay, the number of *Plectropomus* spp. observed in the closest proximity of small-meshed traps was comparatively the highest, however, the conspecific catch in those traps was the lowest at that observation time. No relationships between the number of fish aggregated around different traps and their conspecific catch seemed to appear from these observations.

When these variables are examined over the whole soak period some relationships appeared. At Cattle Bay, positive relationships were found between the number of *S.doliatus* inside different meshed traps and traps using pilchards and numbers of this species outside these traps. The maximum value of the coefficient of determination (r^2) was 0.04 (Tab.3.3). At Pioneer Bay, the absence of *L.carponotatus* inside and outside unbaited traps and traps baited with fish oil did not allow examination of the relationship between these variables. At Cattle Bay, these variables present positive relationships in large-meshed traps and traps baited with pilchards. As before, values of the coefficient of determination were very low (r^2=0.04) (Tab.3.3) .

At Cattle Bay, numbers of *Plectropomus* spp. inside traps were positively related to numbers of these species in the 2-metre area surrounding traps with large mesh and baited with pilchards. A strong negative correlation was registered between these variables in traps baited with pilchards deployed at Pioneer Bay (r^2=0.95) (Tab.3.3).

Target species in the 2-metre areas surrounding traps and the total catch

At Cattle Bay, the number of fish inside different meshed traps and traps baited with pilchards was found to be positively related to the number of *S.doliatus* in the 2-metre area surrounding these traps. The catch in large-meshed traps and baited traps was positively related to the number of *L.carponotatus* outside these traps. In addition to this, the catch in small-meshed traps was positively related to the numbers of *Plectropomus* spp. in the 2-metre area surrounding these traps. Significant relationships between these variables were also found for baited traps deployed at each location being positive at Cattle Bay and negative at Pioneer Bay. In all cases, *L.carponotatus* and *S.doliatus* showed very weak relationships with very low coefficients of determination (Tab.3.3). However, the number of *Plectropomus* spp. outside traps appeared strongly related to the multispecific catch (r^2= 0.95) (Tab.3.3).

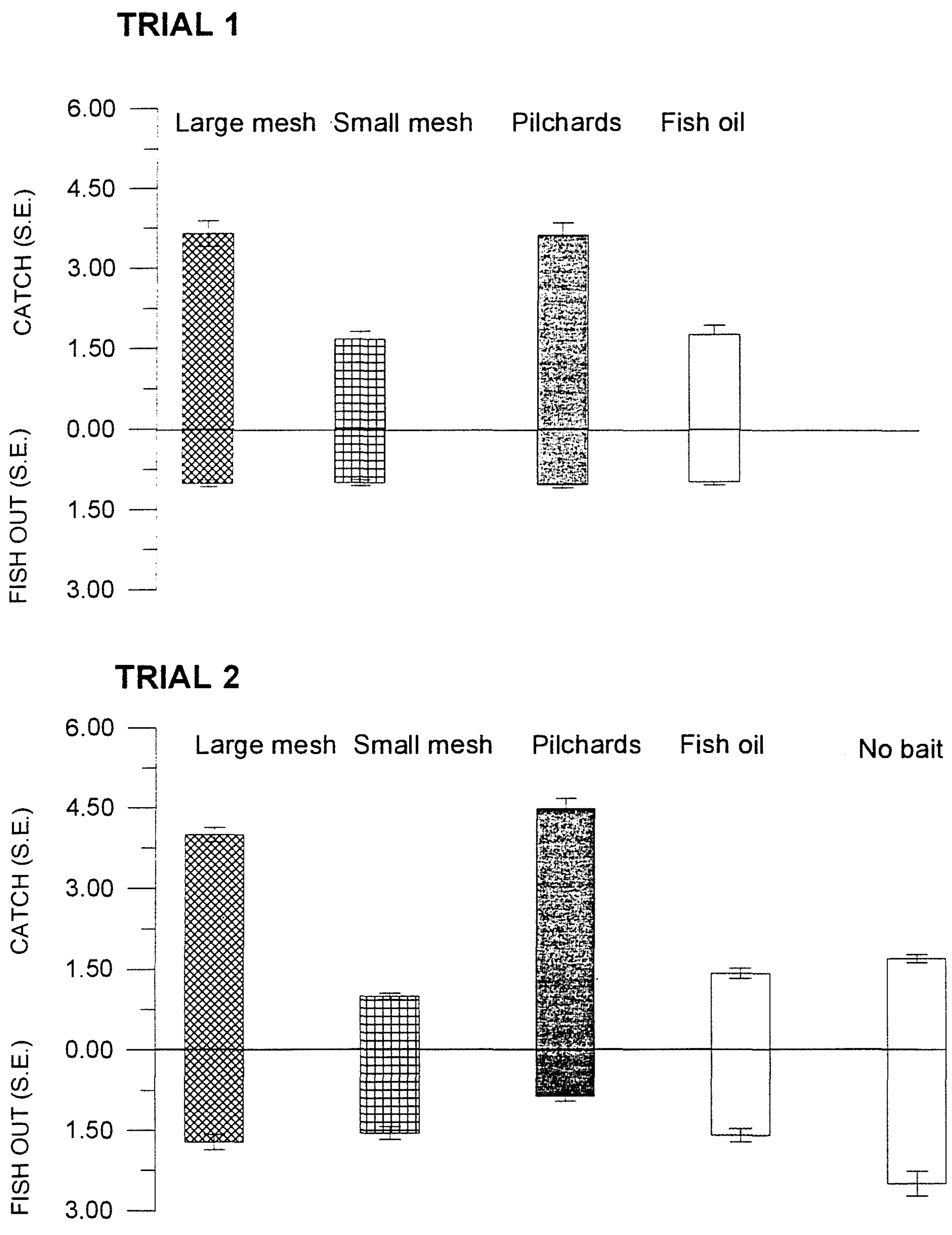


Fig.3.5. Mean number of fish observed within the 2-metre area surrounding traps and mean number of fish trapped at the time of the observation. Both trials are shown (Trial 1: Cattle Bay and Trial 2: Pioneer Bay). (Error bars represent standard errors)

Table.3.3. Summary of the correlations carried out between the number of fish outside the traps and the catch, number of target species outside and inside the traps and number of target species in relation to the multispecific catch. (*) denotes significance at 0.05 probability level. (-) indicates negative relationships between the variables.

	S.doliatus			*Plectropomus spp.*			*L.carponotatus*			Multispecific stock		
Large mesh	r2	n	P	r2	n	P	r2	n	P	r2	n	P
S.doliatus	TRIAL 1 0.034 TRIAL 2	188	<0.05*							TRIAL 1 0.042 TRIAL 2	188	<0.05*
Plectropomus spp.				TRIAL 1 0 TRIAL 2 0.017	188 28	<0.05* >0.05				TRIAL 1 0 TRIAL 2 0.009	188 28	>0.05 >0.05
L.carponotatus							TRIAL 1 0.048 TRIAL 2 0.004	188 28	<0.05* >0.05	TRIAL 1 0.065 TRIAL 2 0.375	188 28	<0.05* >0.05
Multispecific stock										TRIAL 1 0.013 TRIAL 2	188	<0.05*
Small mesh												
S.doliatus	TRIAL 1 0.043 TRIAL 2	188	<0.05*							TRIAL 1 0.004 TRIAL2	188	<0.05*
Plectropomus spp.				TRIAL 1 0.011 TRIAL2 0.083	188 28	>0.05 >0.05				TRIAL 1 0.057 TRIAL2 -0.202	188 28	<0.05* <0.05*
L.carponotatus							TRIAL 1 0.011 TRIAL2 0.004	188 28	>0.05 >0.05	TRIAL 1 0 TRIAL2 0.049	188 28	>0.05 >0.05
Multispecific stock										TRIAL 1 0.003 TRIAL2	188	<0.05*
Pilchards												
S.doliatus	TRIAL1 0.043 TRIAL2	188	<0.05*							TRIAL1 0.018 TRIAL2	188	<0.05*
Plectropomus spp.				TRIAL1 0.032 TRIAL2 -0.951	188 18	<0.05* <0.05*				TRIAL1 0.006 TRIAL2 -0.951	188 18	<0.05* <0.05*
L.carponotatus							TRIAL1 0.032 TRIAL2 0.056	188 18	<0.05* >0.05	TRIAL1 0.006 TRIAL2 0.002	188 18	<0.05* >0.05
Multispecific stock										TRIAL1 0.018 TRIAL2	188	<0.05*
Fish oil												
S.doliatus	TRIAL 1 0.019	188	>0.05							TRIAL1 0.024	188	>0.05
Plectropomus spp.				TRIAL1 0.019 TRIAL 2 0	188 20	>0.05 >0.05				TRIAL 1 0.022 TRIAL2 0.1316	188 20	<0.05* >0.05
L.carponotatus							TRIAL1 0.019	188	>0.05	TRIAL 1 0.022 TRIAL 2 0.03	188 20	<0.05* >0.05
Multispecific stock										TRIAL1 0.024 TRIAL 2	188	>0.05
Unbaited												
S.doliatus												
Plectropomus spp.				TRIAL 2 0.006	18	>0.05				TRIAL 2 0.006	18	>0.05
L.carponotatus												
Multispecific stock										TRIAL 2 -0.276	18	<0.05*

3.5.3. *INGRESS/ESCAPEMENT EVENTS : MINIMUM ESTIMATES*

Net ingress of the multispecific stock into traps was significantly higher in large-meshed traps during each trial (Fig.3.6.; Tab.3.4.). The bait factor also had a significant effect on net ingress of the individuals into traps by the end of the soak period. During each trial, consistently higher numbers of fish entered traps baited with pilchards than fish oil and no bait (Fig.3.6). *A posteriori* comparison of means indicated that a significantly higher number of fish entered traps baited with pilchards compared to fish oil or no bait in traps deployed at Pioneer Bay (Tab.3.10.).

The consistency of the ingress results at each location was not observed in net escapements from different meshed traps (Fig.3.7.). During the first trial mesh size does not appear to have any effect on the number of fish that escaped from traps, however, bait type had a significant effect on escapement, with a higher number of fish escaping from traps baited with pilchards. In the second trial, fish escapement from large-meshed traps was significantly higher than in small mesh ones, but bait did not significantly affect the final number of escapements (Tab.3.5.).

Net ingress and escapements into/from traps appeared to be species-specific, varying within different treatments. Minimum numbers of *S.doliatus* entering traps differed significantly between large- and small-meshed traps at each location (Tab.3.6.). Higher numbers of *S.doliatus* entered and escaped from large-meshed traps (Fig.3.8). No significant bait effect on numbers escaping was found in any of the trials. (Tab.3.7.). As for *S.doliatus* catches described in the previous chapter, the high variability of this species cannot be attributed to that expected by random sampling, but to a tendency of high numbers of *S.doliatus* to occur together in the same type of trap. This is because of the significant effect of the different mesh sizes on mean numbers of this species (Fig.3.8).

The different baits used had a significant effect on the numbers of *L.carponotatus* that entered the traps at each location (Tab.3.8). At Cattle Bay, significantly higher numbers of this species entered traps baited with pilchards (Fig.3.10.). Also, at Pioneer Bay *a posteriori* multiple comparisons of means showed significantly higher numbers of this species entering traps baited with pilchards (Tab.3.10.). Bait also had a significant effect on numbers of escapements. At Cattle Bay and Pioneer Bay, higher numbers of *L.carponotatus* escaped from traps baited with pilchards (*a posteriori* multiple comparison of means) (Fig.3.10.). At Pioneer Bay, mesh size also had a significant effect on the number of *L.carponotatus* that escaped and was significantly greater in large-meshed traps (Tab.3.9). Mesh sizes and bait types did not significantly affect the final numbers of *Plectropomus* spp. (Tab.3.11. & 12.) that entered and escaped into/from traps at any location (Fig.3.12. & 13.).

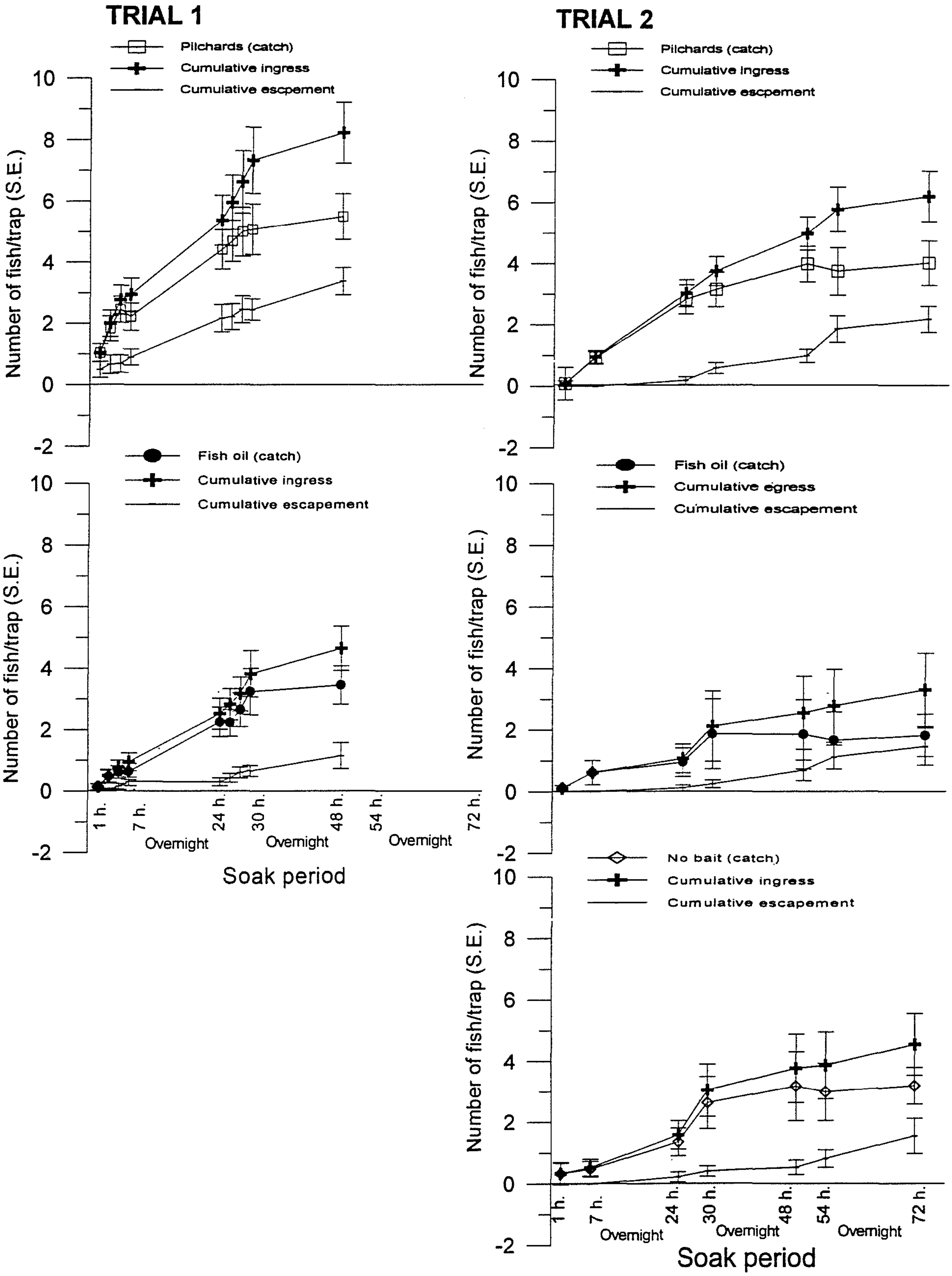


Fig.3.6. Mean catch, ingress and escapement in traps during the two trials. (Error bars represent standard errors)

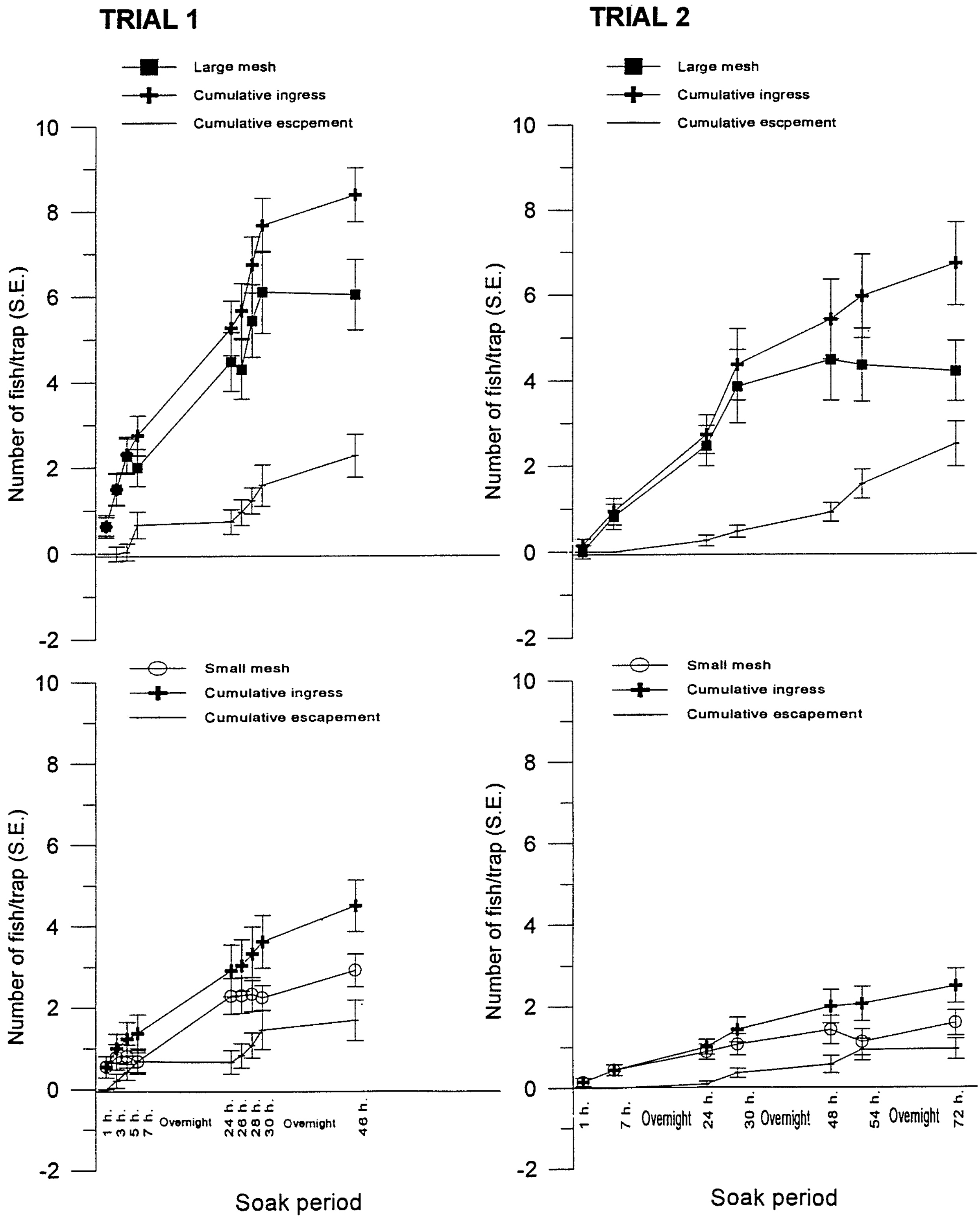


Fig.3.7. Mean catch, cumulative ingress and cumulative escapements in traps during the two trials. (Error bars represent standard errors)

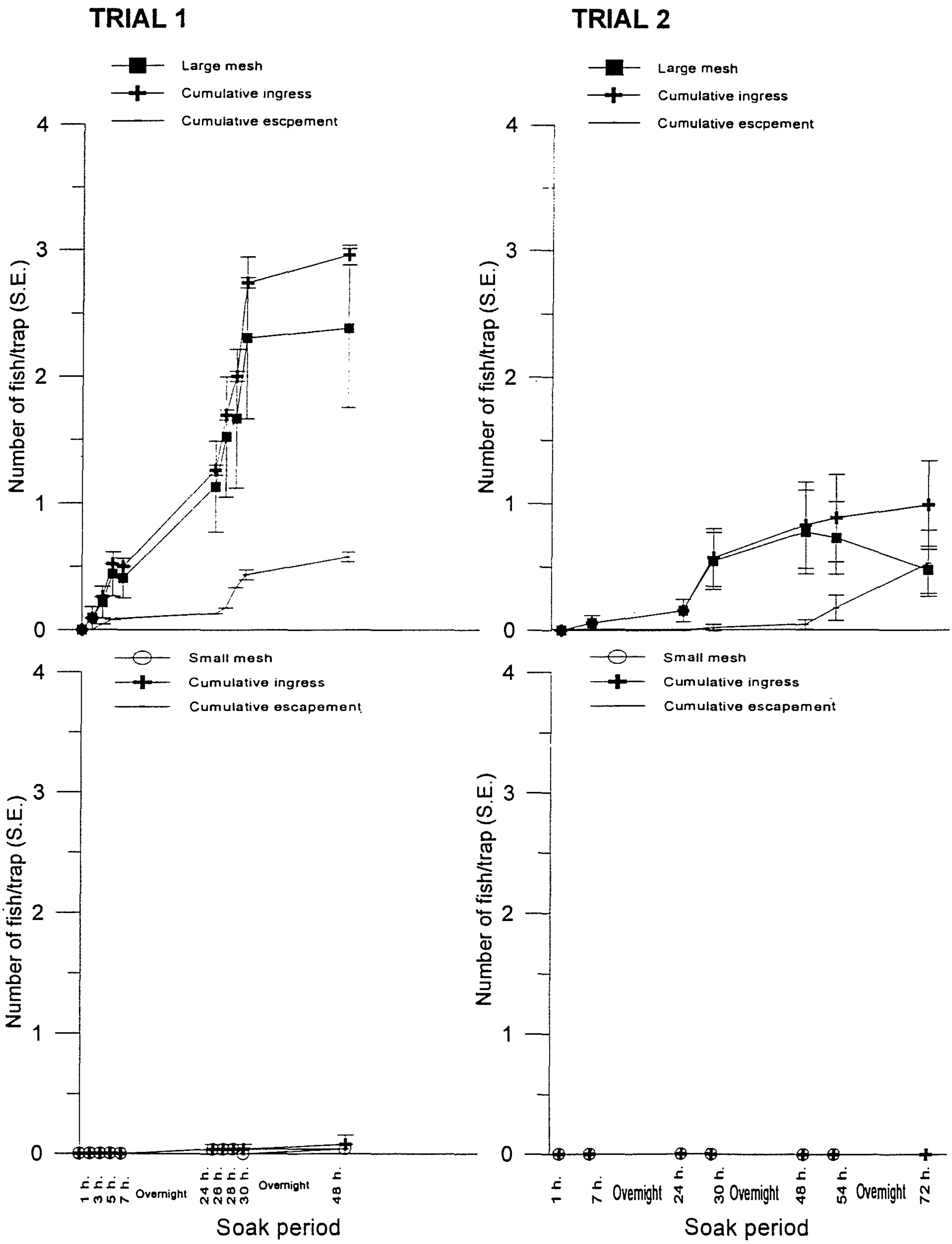


Fig.3.8. Mean catch, cumulative ingress and cumulative escapements in meshed traps for *S.doliatus* during the two trials. (Error bars represent standard errors)

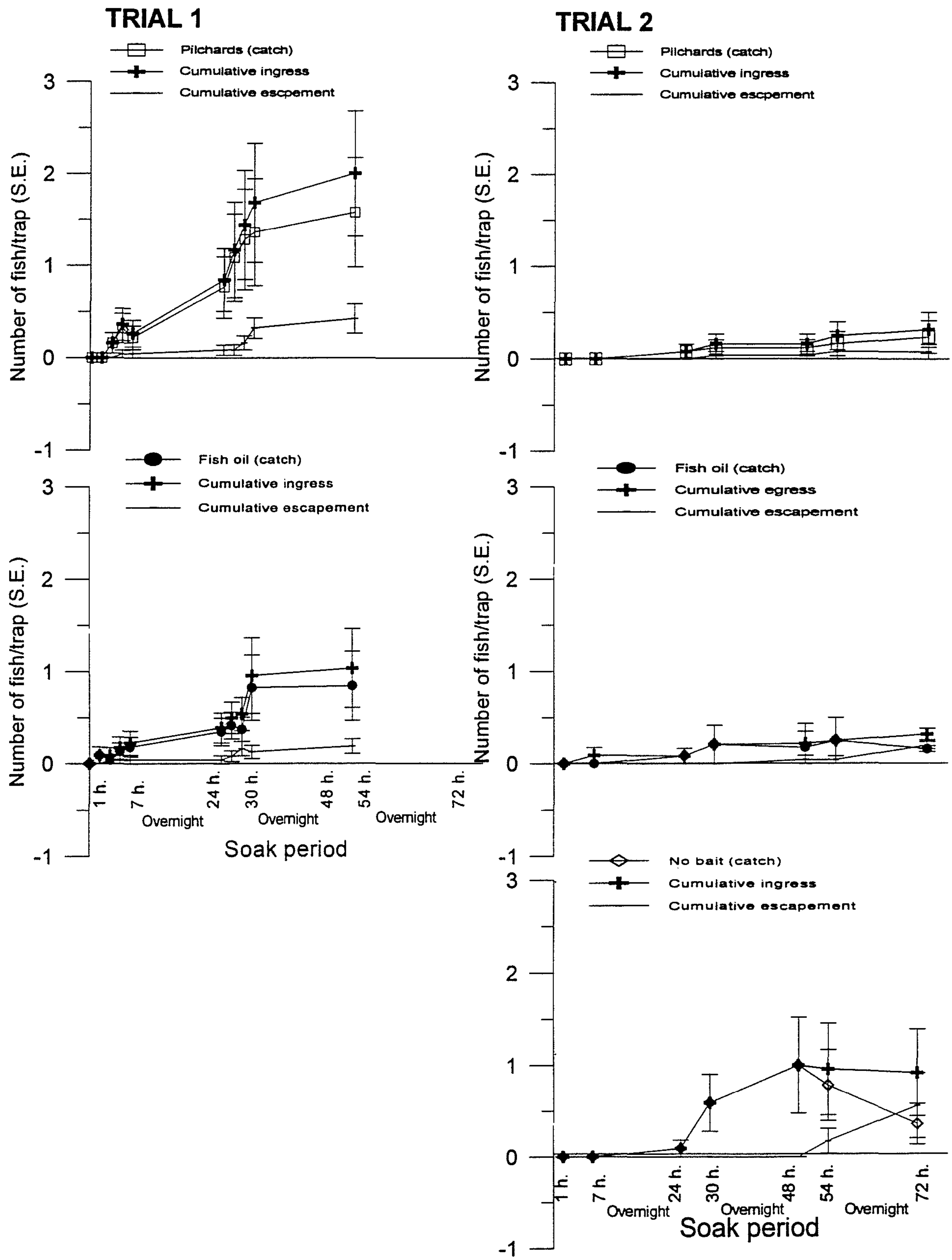


Fig.3.9. Mean catch, ingress and escapement of *S.doliatus* in traps during the two trials for bait factor. (Error bars represent standard errors)

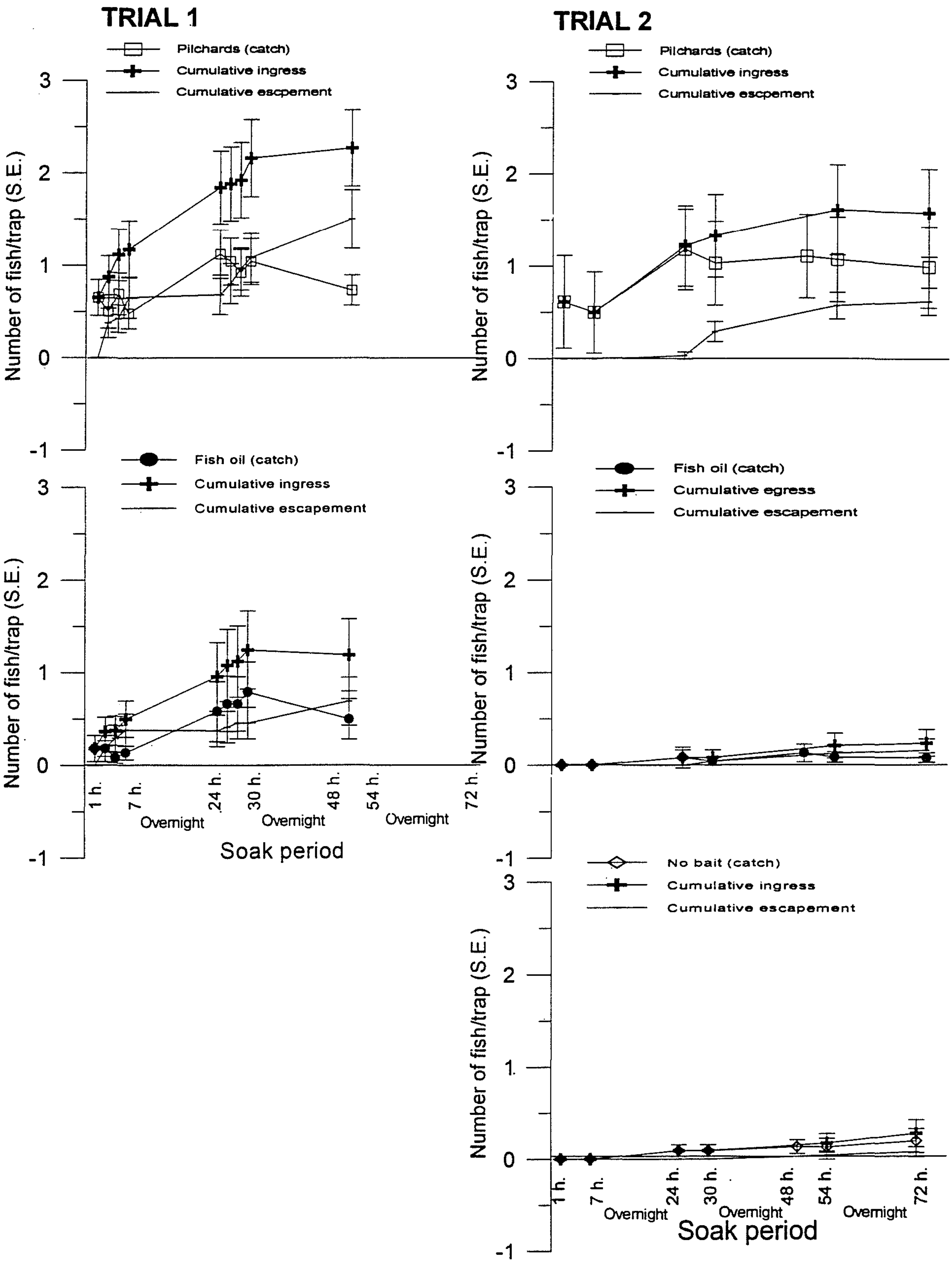


Fig.3.10. Mean catch, ingress and escapement of *L.carponotatus* in traps during the two trials for bait factor. (Error bars represent standard errors)

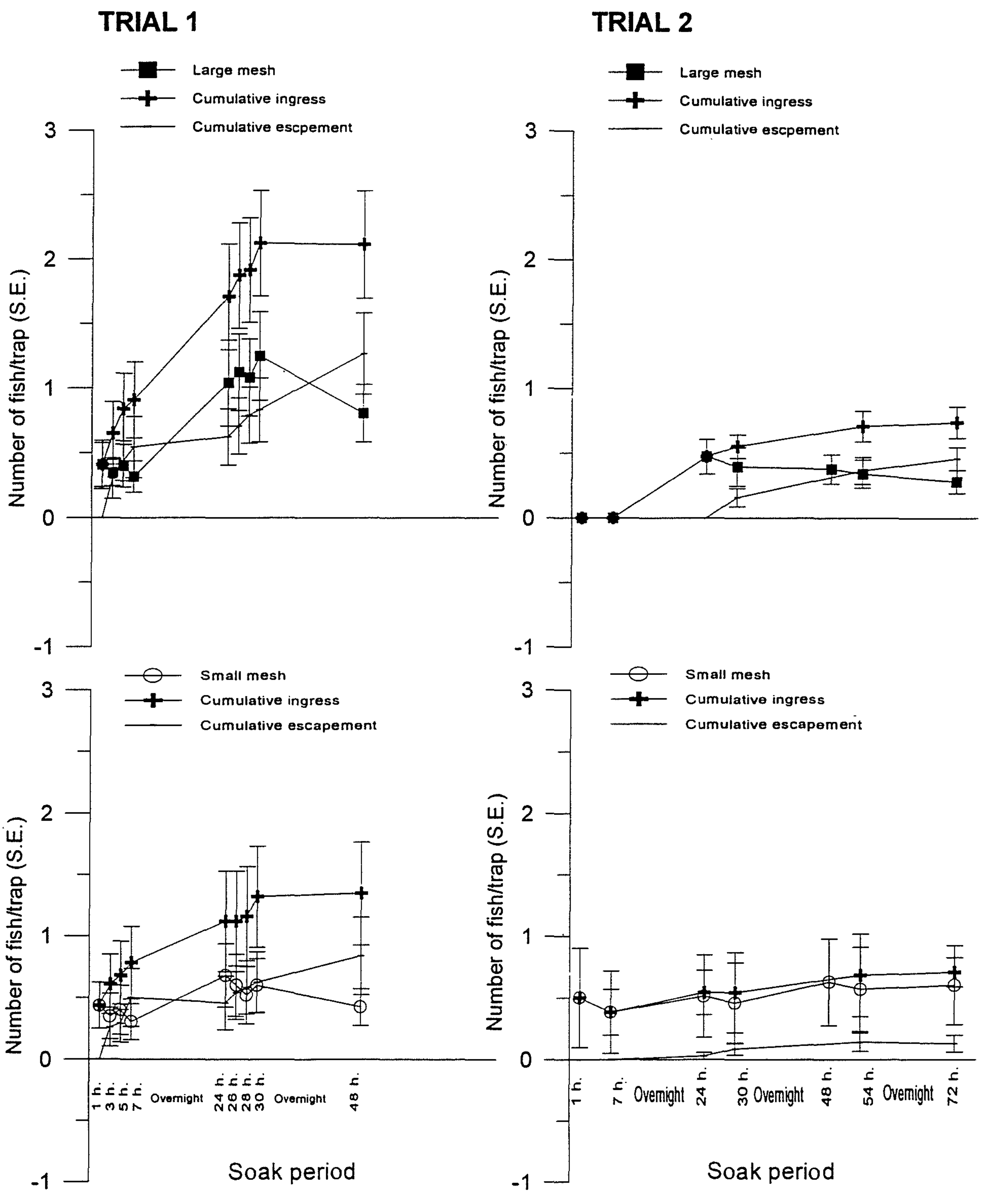


Fig.3.11. Mean catch, cumulative ingress and cumulative escapements in traps for *L.carponotatus* during the two trials. (Error bars represent standard errors)

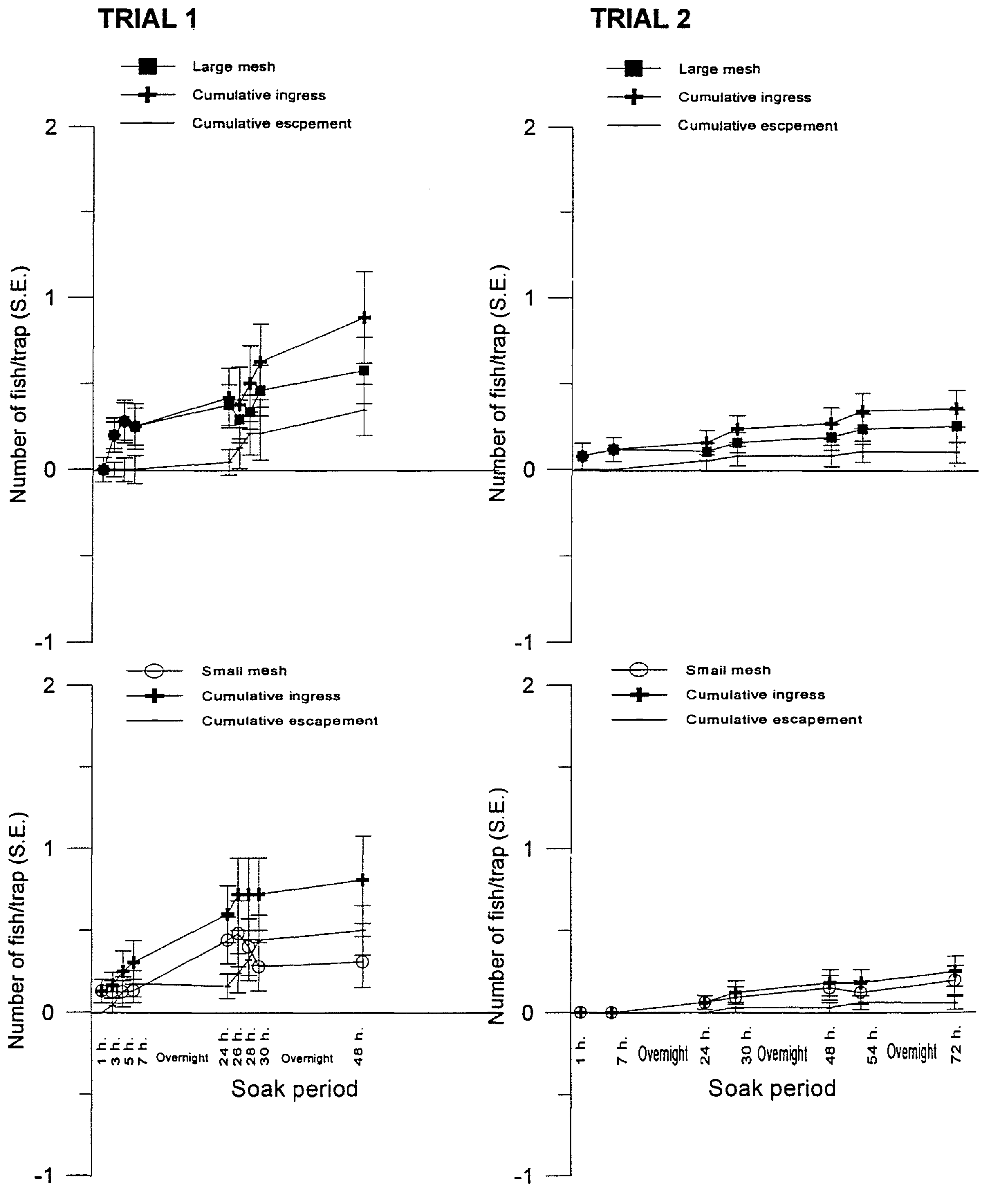


Fig.3.12. Mean catch, cumulative ingress and cumulative escapements in meshed traps for *Plectropomus* spp. during the two trials. (Error bars represent standard errors)

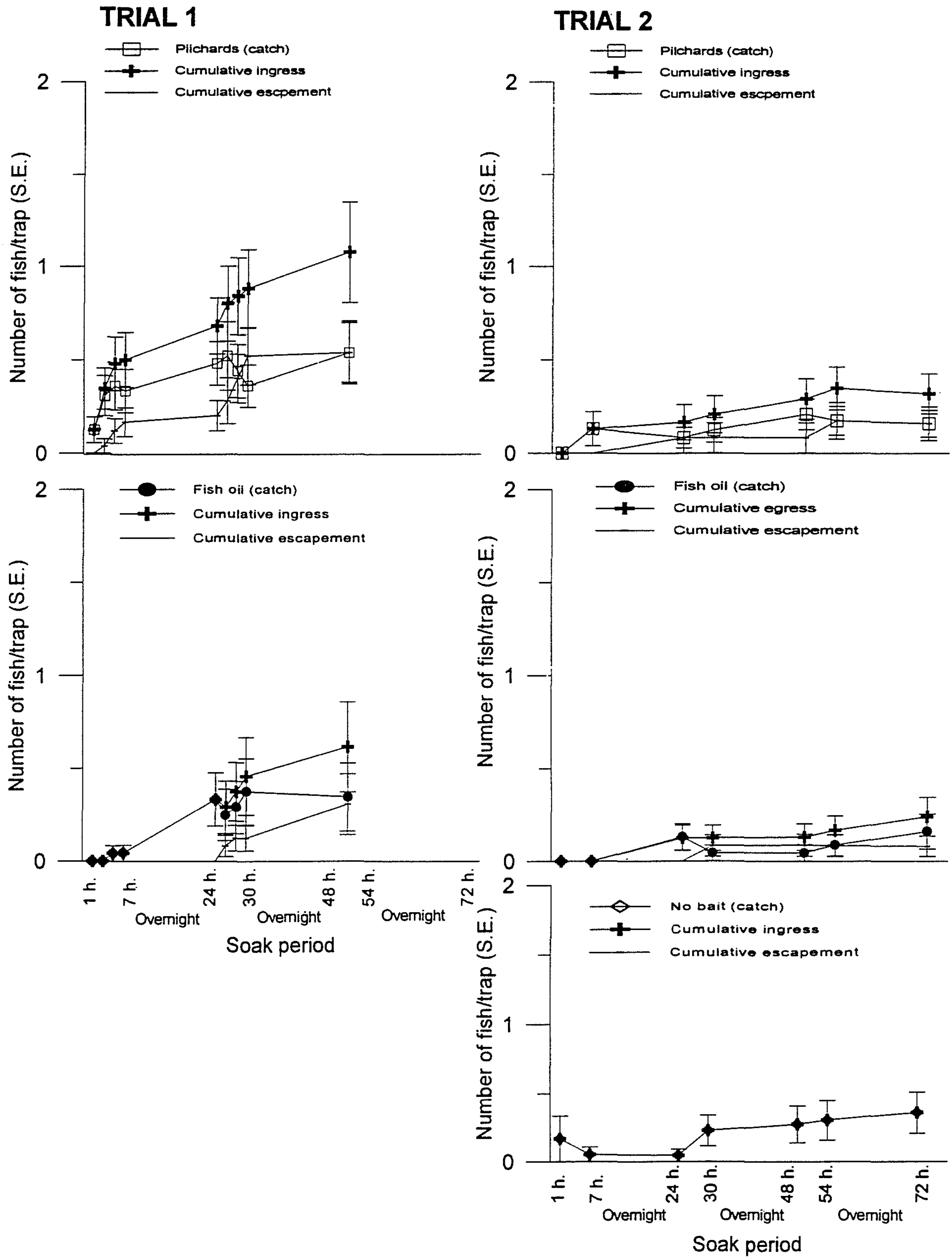


Fig.3.13. Mean catch, ingress and escapement of *Plectropomus* spp. in traps during the two trials for bait factor. (Error bars represent standard errors)

Table.3.4. ANOVA results of the effect of bait and mesh on fish numbers entering traps for each of the trials. Data was log (x+1) transformed. (*) denotes significance at 0.05 probability level.

Source of variation	Trial 1: Cattle Bay d.f.	MSS	F	P	Trial 2 : Pioneer Bay d.f.	MSS	F	P
Mesh (M)	1	0.7217	9.891	0.0028*	1	1.5975	14.176	0.0003*
Bait (B)	1	0.8104	11.11	0.0017*	2	0.8241	7.313	0.0013*
M x B	1	0.0020	0.028	0.8701	2	0.1138	1.009	0.3697
Residuals	48	0.0730			69	0.1127		

Table.3.5. ANOVA results of the effect of bait and mesh on fish numbers escaping from traps for each of the trials. Data was log (x+1) transformed. (*) denotes significance at 0.05 probability level.

Source of variation	Trial 1: Cattle Bay d.f.	MSS	F	P	Trial 2 : Pioneer Bay d.f.	MSS	F	P
Mesh (M)	1	0.0917	0.910	0.3551	1	0.6306	6.589	0.0124*
Bait (B)	1	0.7391	7.331	0.0094*	2	0.2506	2.618	0.0802
M x B	1	0.0726	0.720	0.4094	2	0.0365	0.382	0.6841
Residuals	48	0.1008			69	0.0957		

Table.3.6. Randomised ANOVA results of the effect of bait and mesh on numbers of *S.doliatus* entering traps for each of the trials. Data was log (x+1) transformed. (*) denotes significance. at 5% probability level.

	Trial 1: Cattle Bay				**Trial 2 : Pioneer Bay**			
Source of variation	**d.f.**	**MSS**	**F**	**P%**	**d.f.**	**MSS**	**F**	**P%**
Mesh (M)	1	2.234	27.88	0.02*	1	0.5811	10.88	0.24*
Bait (B)	1	0.1477	1.84	27.96	2	0.0466	0.87	48.22
M x B	1	0.0635	0.79	48.24	2	0.0466	0.87	47.80
Residuals	48	0.0801			60	0.0534		

Variance range as % of error MS=214.04
Sig.level of variance=0.04%

Variance range as % of error MS=323.19
Sig.level of variance=1.38%

Table.3.7. Randomised ANOVA results of the effect of bait and mesh on numbers of *S.doliatus* escaping from traps for each of the trials. Data was log (x+1) transformed. (*) denotes significance at 5% probability level.

	Trial 1: Cattle Bay				**Trial 2 : Pioneer Bay**			
Source of variation	**d.f.**	**MSS**	**F**	**P%**	**d.f.**	**MSS**	**F**	**P%**
Mesh (M)	1	0.2581	12.55	0.08*	1	0.1737	5.29	3.88*
Bait (B)	1	0.0303	1.47	31.96	2	0.0352	1.07	47.98
M x B	1	0.0082	0.40	51.86	2	0.0352	1.07	38.90
Residuals	48	0.0206			60	0.0329		

Variance range as % of error MS=253.07
Sig.level of variance=0.06%

Variance range as % of error MS=369.50
Sig.level of variance=8.66%

Table.3.8. ANOVA results of the effect of bait and mesh on numbers of *L.carponotatus* entering traps for each of the trials. Data was log (x+1) transformed. (*) denotes significance at 0.05 probability level.

Source of variation	Trial 1: Cattle Bay d.f.	MSS	F	P	Trial 2 : Pioneer Bay d.f.	MSS	F	P
Mesh (M)	1	0.2970	3.481	0.0682	1	0.0523	0.649	0.4318
Bait (B)	1	0.5582	6.544	0.0137*	2	1.0120	12.57	0.0000*
M x B	1	0.0014	0.017	0.8995	2	0.0625	0.776	0.4643
Residuals	48	0.0853			69	0.0805		

Table.3.9. ANOVA results of the effect of bait and mesh on numbers of *L.carponotatus* escaping from traps for each of the trials. Data was log (x+1) transformed. (*) denotes significance at 0.05 probability level.

Source of variation	Trial 1: Cattle Bay d.f.	MSS	F	P	Trial 2 : Pioneer Bay d.f.	MSS	F	P
Mesh (M)	1	0.1490	2.361	0.1310	1	0.1070	5.501	0.0219*
Bait (B)	1	0.3058	4.846	0.0326*	2	0.1819	9.348	0.0003*
M x B	1	0.0289	0.459	0.5086	2	0.0054	0.282	0.7554
Residuals	48	0.0631			69	0.0195		

Table.3.10. ***A posteriori*** **comparison of means (Ryan's Q-test) results of significant bait factor on numbers entering and escaping into/from traps during trial 2.**

	Ingress	Escapement
Multispecific stock	Pilchards> No bait Fish oil	
L.carponotatus	Pilchards> No bait Fish oil	Pilchards> No bait Fish oil

Table.3.11. ANOVA results of the effect of bait and mesh on numbers of *Plectropomus* spp. entering traps for each of the trials. Data was log (x+1) transformed. (*) denotes significance at 0.05 probability level.

	Trial 1: Cattle Bay				**Trial 2 : Pioneer Bay**			
Source of variation	**d.f.**	**MSS**	**F**	**P**	**d.f.**	**MSS**	**F**	**P**
Mesh (M)	1	0.0052	0.084	0.7763	1	0.0125	0.476	0.5001
Bait (B)	1	0.1550	2.478	0.1220	2	0.0035	0.133	0.8753
M x B	1	0.0388	0.621	0.4431	2	0.0079	0.302	0.7406
Residuals	48	0.0626			69	0.0263		

Table.3.12. ANOVA results of the effect of bait and mesh on numbers of *Plectropomus* spp. escaping from traps for each of the trials. Data was log (x+1) transformed. (*) denotes significance at 0.05 probability level.

	Trial 1: Cattle Bay				**Trial 2 : Pioneer Bay**			
Source of variation	**d.f.**	**MSS**	**F**	**P**	**d.f.**	**MSS**	**F**	**P**
Mesh (M)	1	0.0342	1.004	0.3214	1	0.0018	0.248	0.6255
Bait (B)	1	0.0547	1.603	0.2115	2	0.0108	1.417	0.2493
M x B	1	0.0449	1.316	0.2569	2	0.0015	0.202	0.8173
Residuals	48	0.0342			69	0.0075		

3.5.4. *OBSERVED INGRESS/ESCAPEMENT EVENTS*

During observations carried out at Cattle Bay, 29 ingress and escapement events were registered. Underwater video-recordings deployed at Pioneer Bay registered 21 ingress and escapement events.

Positive relationships between observed ingress and fish numbers inside traps were obtained in small-meshed traps and baited traps deployed during the first trial (Tab.3.13.). However, no significant relationships of this type were found in any of the traps deployed at Pioneer Bay (Fig.3.14.). At Cattle Bay, the number of ingress events observed in large-meshed traps and baited traps were negatively correlated to number of fish in the 2-metre area surrounding these traps (Fig.3.15). However, at Pioneer Bay negative relationships were registered between ingress to traps and fish numbers in the area surrounding all traps.

There was no apparent relationship between number of escapements from traps and number of trapped fish in any of the treatments and locations (Tab.3.13.). However, at Cattle Bay and Pioneer Bay, the number of escapement events observed in traps baited with pilchards and different meshed traps, respectively, was negatively related to the number of fish in the 2-metre area surrounding these traps.

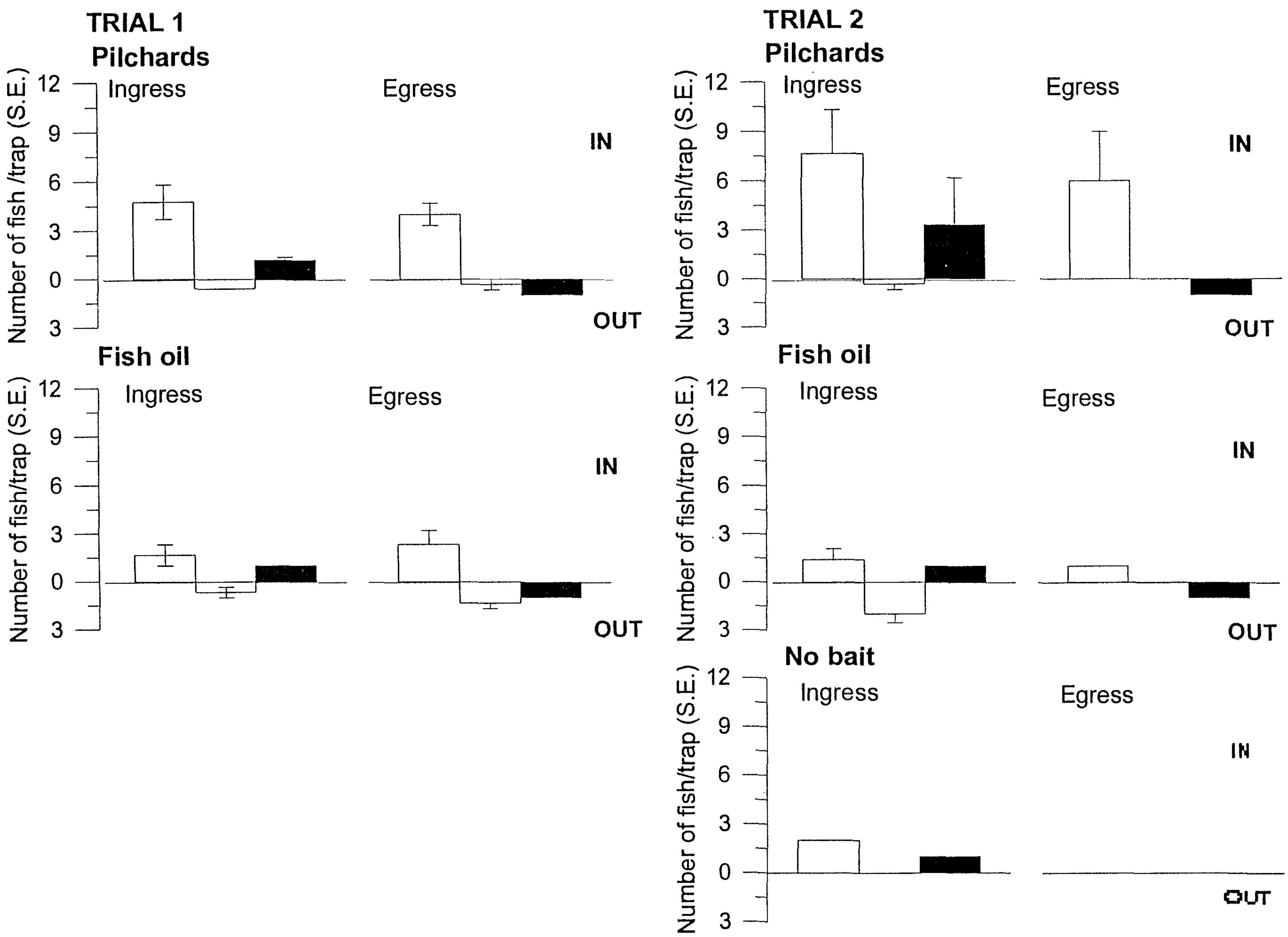


Fig.3.14. Number of entries and escapements (dark pattern) in relation to the catch and the number of fish in the 2 metre area surrounding the traps during observations for different baits at each location (Trial 1:Cattle Bay and Trial 2:Pioneer Bay).

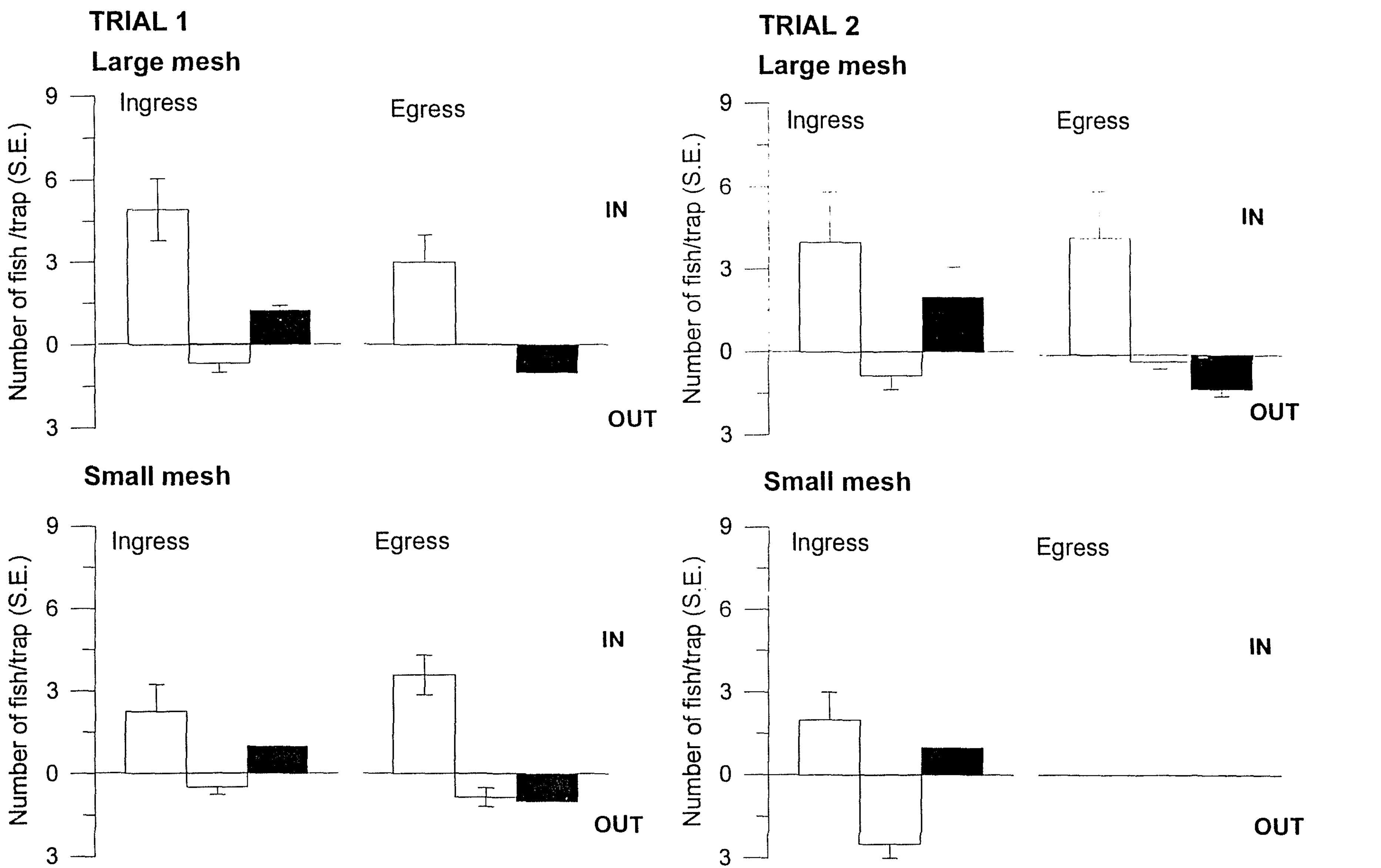


Fig.3.15. Number of entries and escapements (dark pattern) in relation to the catch and the number of fish in the 2 metre area surrounding traps during observations for both mesh sizes at each location (Trial 1:Cattle Bay and Trial 2: Pioneer Bay).

Table.3.13. Relationship between ingress and escapement into/from traps of fish in the 2 metre area surrounding the traps and catch. (*) denotes significance at 0.05 probability level. (-) denotes negative relationships between the parameters.

	Fish inside traps			Fish in trap surrounds		
LARGE MESH	**r2**	**n**	**P**	**r2**	**n**	**P**
	TRIAL 1			**TRIAL 1**		
Ingress	0.0189	188	>0.05	-0.0254	188	**<0.05***
	TRIAL 2			**TRIAL 2**		
	0	28	>0.05	-0.1861	28	**<0.05***
	TRIAL 1			**TRIAL 1**		
Escapement	0.001	188	>0.05	0.0003	188	>0.05
	TRIAL 2			**TRIAL 2**		
	-0.015	28	**<0.05***	-0.1598	28	**<0.05***
SMALL MESH						
	TRIAL 1			**TRIAL 1**		
Ingress	0.0363	188	**<0.05***	-0.0109	188	>0.05
	TRIAL 2			**TRIAL 2**		
	0.0659	28	>0.05	-0.2250	28	**<0.05***
	TRIAL 1			**TRIAL 1**		
Escapement	0.0002	188	>0.05	0.0011	188	>0.05
	TRIAL2			**TRIAL2**		
	0.1257	28	>0.05	-0.3038	28	**<0.05***
PILCHARDS						
	TRIAL1			**TRIAL1**		
Ingress	-0.2161	188	**<0.05***	-0.1141	188	**<0.05***
	TRIAL2			**TRIAL2**		
	0.0307	18	>0.05	-0.3199	18	**<0.05***
	TRIAL1			**TRIAL1**		
Escapement	0.0002	188	>0.05	-0.0765	188	**<0.05***
	TRIAL2			**TRIAL2**		
	-	-	-	-	-	-
FISH OIL						
	TRIAL 1			**TRIAL 1**		
Ingress	0.286	188	**<0.05***	-0.1945	188	**<0.05***
	TRIAL2			**TRIAL2**		
	0.0004	20	>0.05	0.4801	20	>0.05
	TRIAL 1			**TRIAL1**		
Escapement	0.005	188	>0.05	0.0039	188	>0.05
	TRIAL2			**TRIAL 2**		
	0.0841	20	>0.05	0.1437	20	>0.05
NO BAIT						
Ingress	**TRIAL2**			**TRIAL2**		
	0.0009	18	>0.05	0.1403	20	>0.05
Escapement	**TRIAL2**			**TRIAL 2**		
	-	-	-	-	-	-

3.5.5. *CONSPECIFIC ATTRACTION IN S.doliatus*

Experimental traps were fished for 120 trap-days giving a total catch of 185 fish from 38 species and 19 families. A mean number of 4.6 fish/trap (s.e.=±0.8) were captured in these traps over the study period. This is a mean number of 1.5 fish/trap/day (s.e.=±0.28). The most numerous species were *S.doliatus* making up 40% of the catch, *Siganus puellus* accounting for 6.5% and *Scolopsis margaritifer* constituted 5.9 % of the total catch. Family Siganidae with 86 individuals was the most numerically abundant caught in experimental traps.

Catch rates of the total number of individuals

A combination of large-meshed traps with *S.doliatus* present were comparatively more effective in catching fish, although mesh size and the presence or absence of *S.doliatus* did not appear to have any significant effect on the final number of fish and species numbers captured in these traps (Fig.3.16; Tab.3.14.). The rate of catch build-up in large-meshed traps with *S.doliatus* was almost twice that of small-meshed traps with this species present. Catches in large-meshed traps steadily increased after the first soak day and were consistently higher than in small-meshed traps. All traps followed an increasing trend over the soak period with catches in small-meshed traps, with *S.doliatus* present, only increasing at the beginning and the end of the soak period (Fig.3.16.). There was a great variation in mean catches throughout the soak period.

Catch rates of the family Siganidae and S.doliatus.

Mesh size and the presence or absence of *S.doliatus* had a significant effect on the final catch of siganids (Fig.3.17). The number of siganids was significantly greater in traps with large mesh and in those with *S.doliatus*, a combination of large mesh and *S.doliatus* provided the largest catches. The interaction between mesh size and *S.doliatus* was not significant (Tab.3.15). It was notable that small-meshed traps primed with *S.doliatus* caught siganids, whereas these traps on their own seldom catch fish.

The catch build-up of the family Siganidae, as for the multispecific catch, steadily increased over the soak period in large-meshed traps with or without *S.doliatus*. While catches in small-meshed traps with *S.doliatus* followed a slightly decreasing trend after the first 24 hours soak reaching its maximum value during the afternoons of the first and third day soak period. The absence of these species in small-meshed traps without *S.doliatus* was consistent over the second and third day of the soak period (Fig.3.17). Only 3 siganids were caught in these traps during the afternoon of the first day soak and 2 siganids constituted the final catch of these traps. Mean catch in traps with *S.doliatus* increased almost three times faster than in empty traps with the same mesh.

Large-meshed traps and traps with *S.doliatus* captured a significantly higher number of *S.doliatus* which was also the most numerically abundant species trapped from the family Siganidae (Fig.3.18.; Tab.3.15). There was no significant interaction between these two factors indicating that their effects were directly additive (Tab.3.15.) Catch rates of *S.doliatus* were significantly greater in large-meshed traps ($t=2.010$; $d.f.=38$; $P<<0.05$) and in traps primed with conspecifics ($t=2.508$; $d.f.=38$; $P<<0.05$). They followed a very similar trend to the catch rates of the family Siganidae, that is, as explained above: increasing in large-meshed traps with or without *S.doliatus* present through all the soak period. Catches decreased slightly in small-mesh traps with *S.doliatus* after the first day soak although maximum catches were reached during the afternoon of the first and third day soak period. *S.doliatus* were absent in small-meshed traps without conspecifics over the second and third day of the soak period (Fig.3.18).

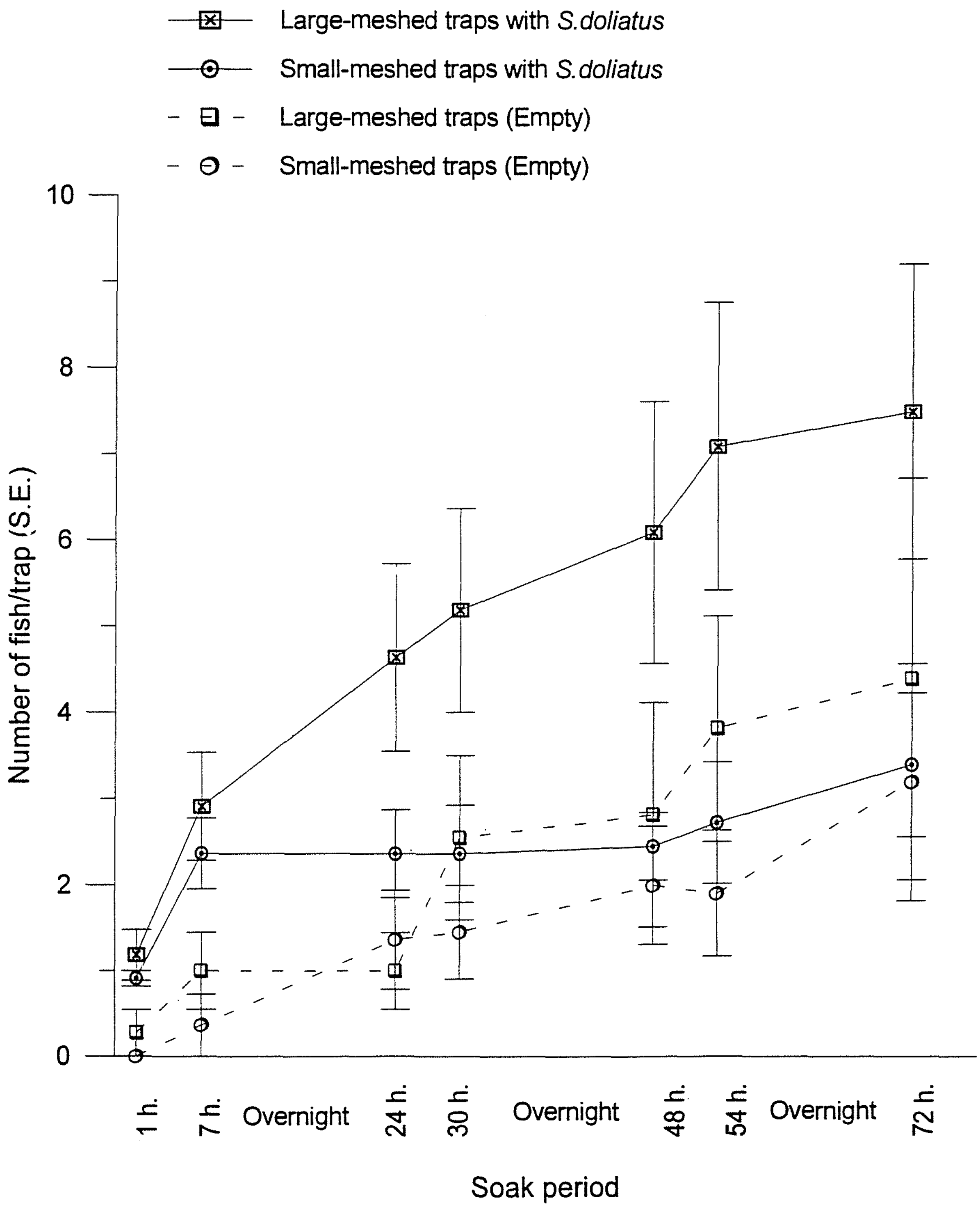


Fig.3.16. Mean number of individuals (S.E.) caught in experimental traps at Pioneer Bay. Each treatment combination is indicated.

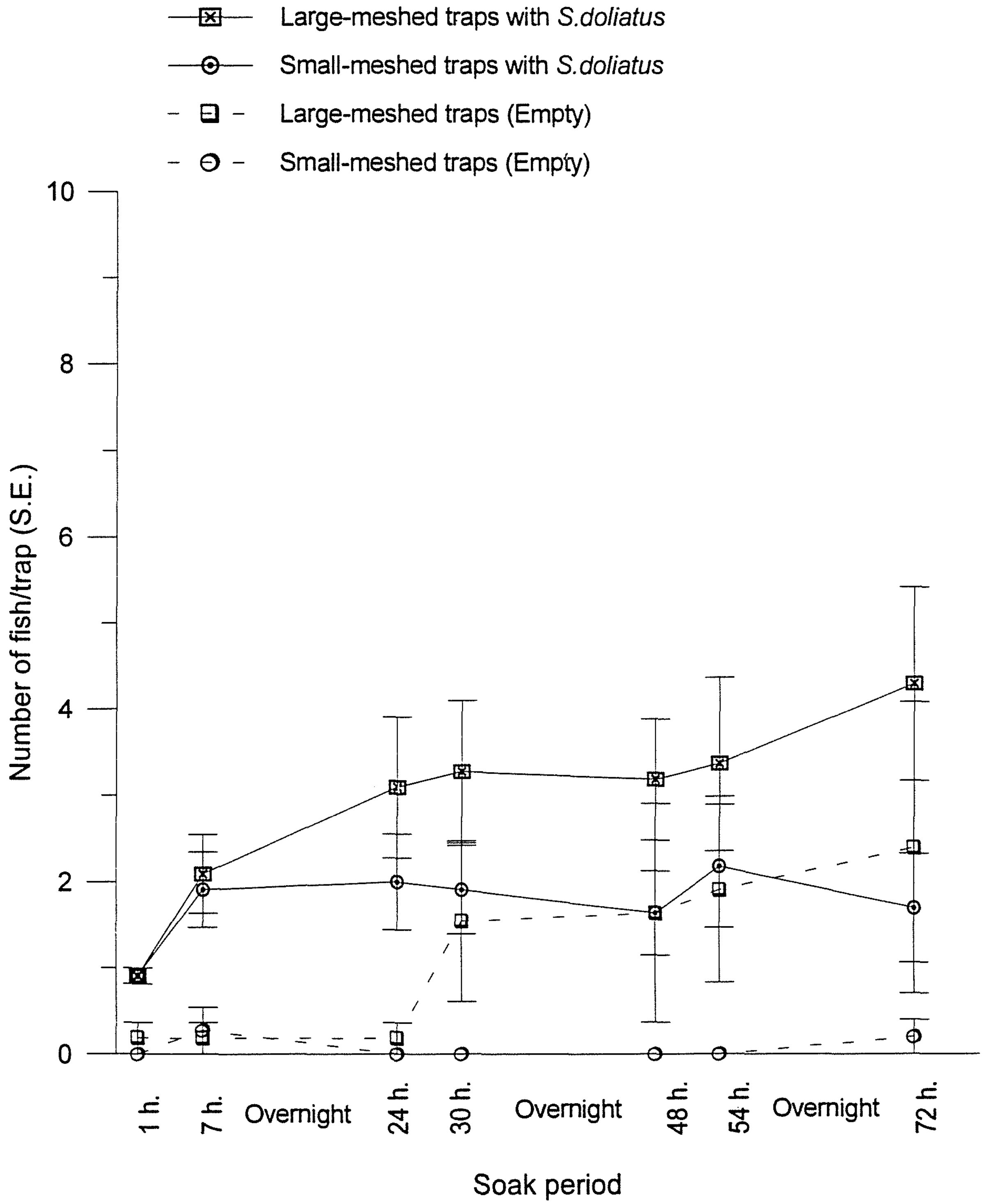


Fig.3.17. Mean number of siganids (S.E.) (Family Siganidae) caught in experimental traps at Pioneer Bay. Each treatment combination is indicated.

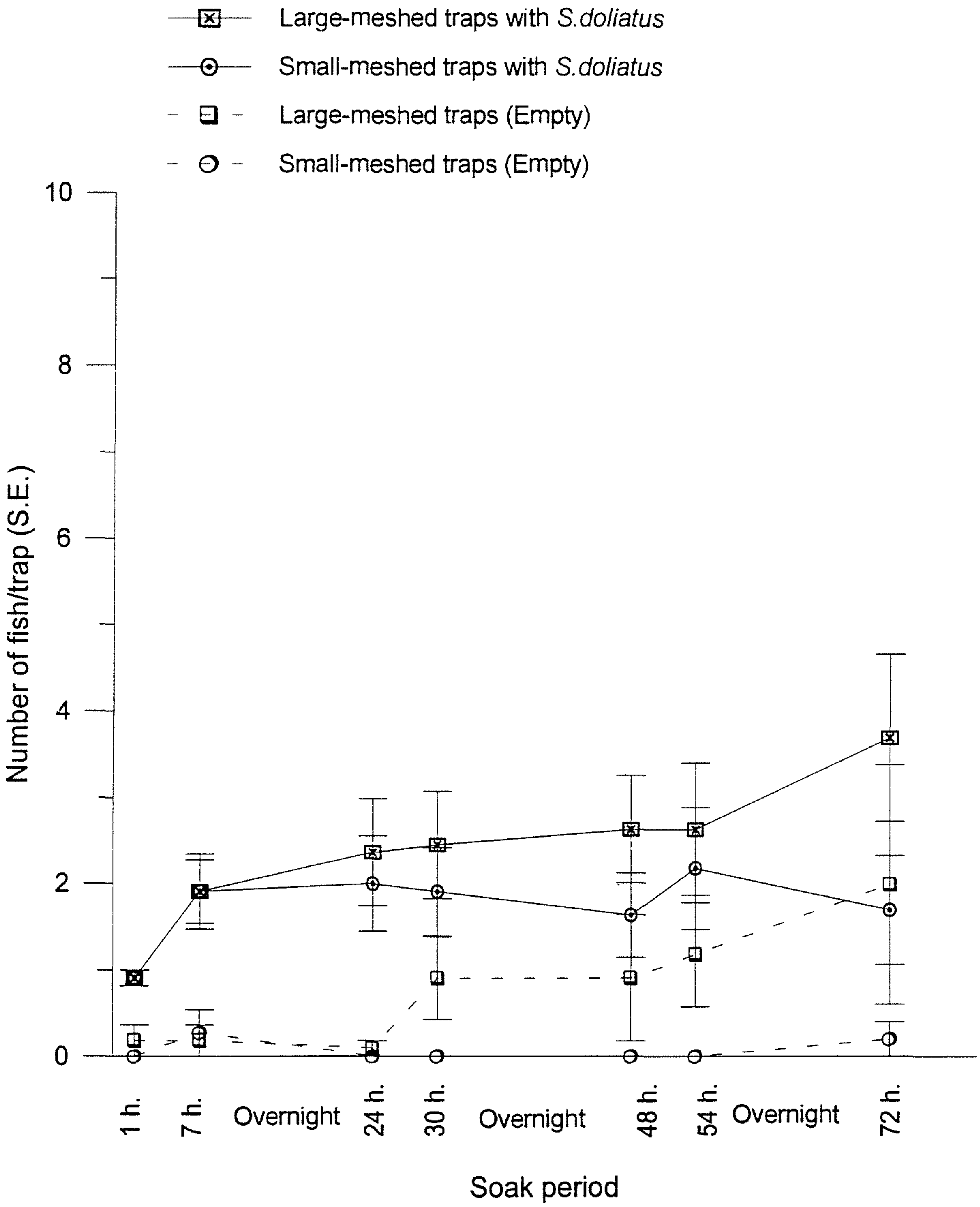


Fig.3.18. Mean number of *S.doliatus* (S.E.) caught in experimental traps at Pioneer Bay. Each treatment combination is indicated.

Table.3.14. Results of two-factor ANOVA for number of individuals and numbers of species of fish caught in manipulated experimental fish traps. (*) indicates significance at the 0.05 probability level.

Source of variation	d.f.	Number of fish MS	F	P	Number of species MS	F	P
Mesh (M)	1	0.1481	0.893	0.3609	0.0209	0.269	0.612
Fish (F)	1	0.5764	3.476	0.0704	0.2955	3.810	0.059
M x B	1	0.1513	0.913	0.3559	0.0353	0.455	0.511
Residual	36	0.1658			0.0775		

Table.3.15 . Results of Two-factor ANOVA for total numbers of *S.doliatus* and individuals of the family Siganidae caught in experimental manipulated traps. (*) indicates significance at 0.05 probability level

Source of variation	d.f.	Number of *S.doliatus* MS	F	P	Number of siganids MS	F	P
Mesh (M)	1	0.4526	4.251	0.046*	0.5737	4.845	0.034*
Fish (F)	1	0.9003	8.456	0.006*	0.0956	8.076	0.007*
M x B	1	0.0050	0.047	0.831	0.0099	0.084	0.776
Residual	36	0.1064			0.1184		

Family and species composition of the catch

Large-meshed traps yielded 119 fish (64.32%) from 26 species and 14 families. Small-meshed traps captured 66 fish from 19 species and 11 families. Of the total number of 185 fish from 38 species captured during the experimental study, 19 fish species were captured exclusively in large-meshed traps, 12 species in small-meshed traps and 7 species were caught in both small- and large-meshed traps: *L.carponotatus*, *Plectropomus* spp., *Epinephelus ongus*, *Epinephelus quoyanus*, *Cromileptes altivelis*, *S.doliatus* and *Amlyglyphidodon curacao*.

Traps with *S.doliatus* yielded a total number of 109 fish (58.9%) fish from 26 species and 15 families. Empty traps caught a total number of 76 fish from 20 species and 11 families. Four of these species were common in both trap types: *L.carponotatus*, *Plectropomus* spp., *S.doliatus* and *Cromileptes altivelis*. One of the species caught in traps with *S.doliatus* was not recorded in empty traps: *Amlyglyphidodon curacao* and one species was exclusively caught in empty traps: *Epinephelus ongus*.

The families Siganidae (36.21%) and Serranidae (14.59%) dominated the catch of large-meshed traps. Fish families such as Nemipteridae (5.94%), Holocentridae (4.86%) and Pomacanthidae (4.86%) accounted for the higher proportion of the catch in both meshed traps. Family Siganidae (55%) and Serranidae (14.67%) dominated the final catch in traps where *S.doliatus* were set and in empty traps (34.2% and 14.47%, respectively). One species from the family Nemipteridae captured in traps with no *S.doliatus* accounted for 14.47% of the catch followed by family Holocentridae contributing 9.2% to the catch (Tab.3.16) .

The most numerically abundant species captured in experimental traps was *S.doliatus*: 46.22% and 28.79% of the catch in large- and small-meshed traps, respectively; and 28.1% and 11.9% in traps with and without *S.doliatus*, respectively (Fig.3.19). The second most abundant species was *S.puellus* captured in large-meshed traps and in traps where *S.doliatus* were placed (6.49% and 4.3%, respectively). While in small-meshed traps and in empty traps, the second most abundant species were *Scolopsis margaritifer* (5.94%) and *Myripistis murdjan* (3.8%), respectively. An important proportion of the catch in large-meshed traps was constituted by *Plectropomus* spp. (4.86%) and *Pomacanthus sexstriatus* (3.78%). In traps with *S.doliatus*, *Plectropomus* spp. made up 3.8% of the total catch.

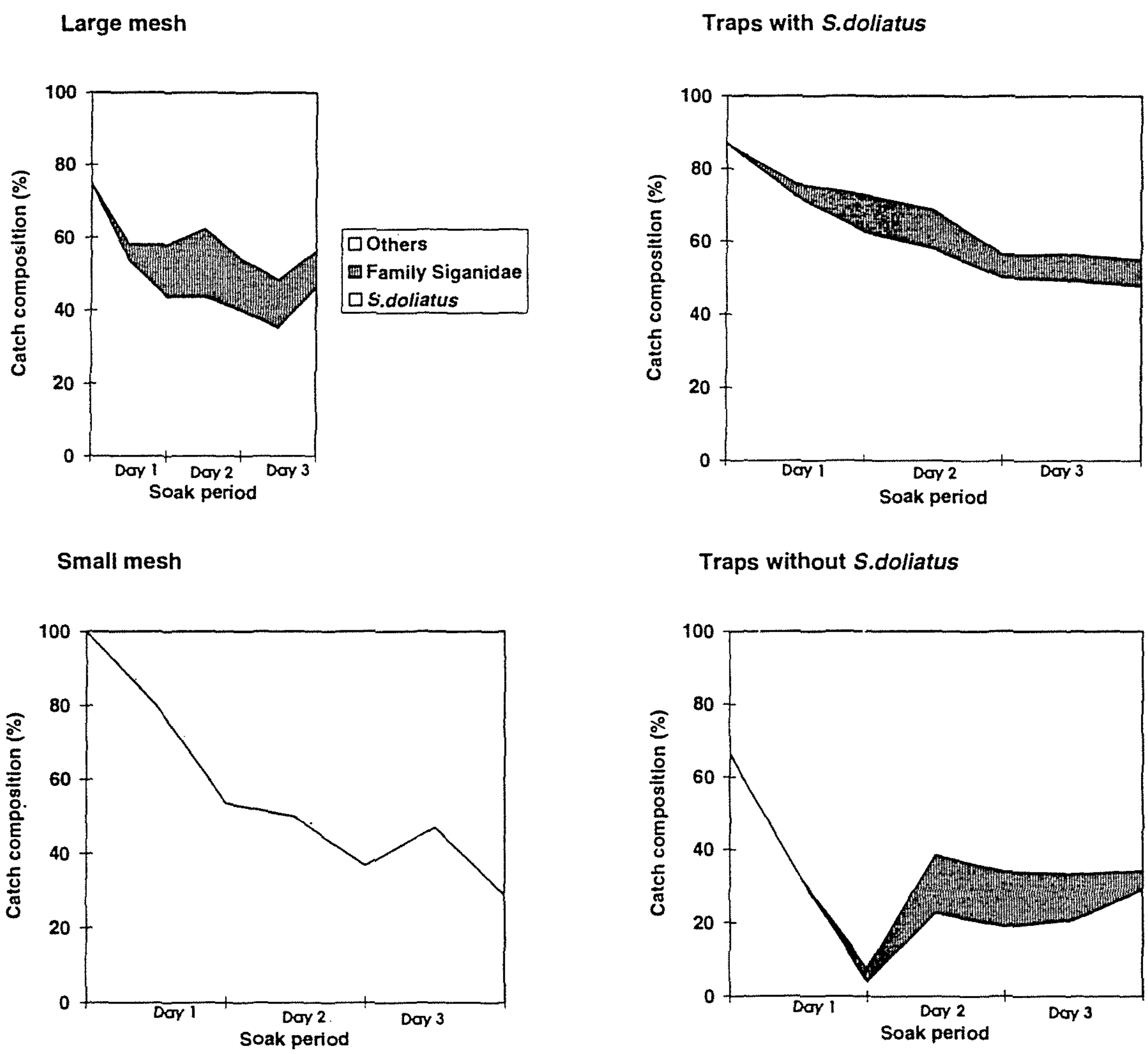


Fig.3.19. Contribution of *S.doliatus* and Family Siganidae to the catch in manipulated experimental traps over the 3 day soak period. Under Family Siganidae are included all siganids caught in the experimental traps except *S. doliatus*.

Table.3.16. Family and species composition of the catch in manipulated experimental traps deployed at Pioneer Bay.

	Mesh size				Presence /absence of S.doliatus			
	Large mesh numbers	%Total catch	Small mesh numbers	%Total catch	S.doliatus present numbers	% Total catch	S.doliatus absent numbers	% Total catch
Lutjanidae	6	3.24	2	1.08	2	1.08	6	3.24
Lutjanus carponotatus	5	2.70	2	1.08	2	1.08	5	2.70
Lutjanus seboe	1	0.54	-	-	-	-	1	0.54
Serranidae	14	7.57	13	7.03	16	8.65	11	5.95
Plectropomus spp	9	4.86	1	0.54	7	3.78	3	1.62
Cephalopholis cyanostigma	-	-	3	1.62	2	1.08	1	0.54
Anyperodon leucogrammicus	1	0.54	-	-	-	-	1	0.54
Epinephelus ongus	1	0.54	5	2.70	6	3.24	-	-
Epinephelus malabaricus	1	0.54	-	-	-	-	1	0.54
Epinephelus quoyanus	1	0.54	2	1.08	-	-	3	1.62
Cromileptes altivelis	1	0.54	2	1.08	1	0.54	2	1.08
Siganidae	67	36.22	19	10.27	60	32.43	26	14.05
Siganus doliatus	55	29.73	19	10.27	52	28.11	22	11.89
Siganus puellus	12	6.49	-	-	8	4.32	4	2.16
Labridae	3	1.62	-	-	3	1.62	-	-
Cheilinus fasciatus	1	0.54	-	-	1	0.54	-	-
Epibulus insidiator	2	1.08	-	-	2	1.08	-	-
Squirrel fish	1	0.54	8	4.32	2	1.08	7	3.78
Myripistis murdjan	-	-	8	4.32	1	0.54	7	3.78
Sargocentron cornutum	1	0.54	-	-	1	0.54	-	-
Pomacanthidae	9	4.86	-	-	4	2.16	5	2.70
Pomacanthus sexstriatus	7	3.78	-	-	2	1.08	5	2.70
Pomacanthus semicirculatus	1	0.54	-	-	1	0.54	-	-
Chaetodontoplus duboulayi	1	0.54	-	-	1	0.54	-	-
Chaetodontidae	1	0.54	3	1.62	1	0.54	3	1.62
Chaetodon aureofasciatus	0	0.00	3	1.62	-	-	3	1.62
Chaetodon rainfordi	1	0.54	-	-	1	0.54	-	-
Scaridae	2	1.08	-	-	-	-	2	1.08
Scarus spp.	1	0.54	-	-	-	-	1	0.54
Scarus microrhinos	1	0.54	-	-	-	-	1	0.54
Nemipteridae								
Scolopsis margaritifer	-	-	11	5.95	-	-	11	5.95
Pomacentridae	3	1.62	4	2.16	7	3.78	-	-
Neoglyphidodon melas	2	1.08	-	-	2	1.08	-	-
Pomacentrus adelus	-	-	1	0.54	1	0.54	-	-
Amlyglyphidodon curacao	1	0.54	1	0.54	2	1.08	-	-
Pomacentrus brachialis	-	-	-	-	-	-	-	-
Acanthochromis polyacanthus	-	-	1	0.54	1	0.54	-	-
Chrysiptera rex	-	-	1	0.54	1	0.54	-	-
Acanthuridae								
Acanthurus grammoptilus	2	1.08	-	-	2	1.08	-	-
Apogonidae	-	-	2	1.08	2	1.08	-	-
Apogon fuscus	-	-	1	0.54	1	0.54	-	-
Cheilodipterus artus	-	-	1	0.54	1	0.54	-	-
Caesidae								
Caesio cuning	6	3.24	-	-	6	3.24	-	-
Centropomidae								
Psammoperca waigiensis	-	-	2	1.08	1	0.54	1	0.54
Muraenidae								
Gymnothorax spp.	1	0.54	-	-	1	0.54	-	-
Hemigaleidae								
Triaenodon obesus	3	1.62	-	-	1	0.54	2	1.08
Carcharhinidae								
Carcharhinus melanopterus	1	0.54	-	-	-	-	1	0.54
Dasyatidae								
Dasyatis kuhlii	-	-	1	0.54	1	0.54	-	-
Platycephalidae								
Plaltycephalus spp.	-	-	1	0.54	-	-	1	0.54
TOTALS	119	64.32	66	35.68	109	58.92	76	41.08

Length frequency distribution of the catch

The influence of aperture size of mesh on the selectivity of fish size classes was examined in relation to the number of the most abundant species caught in the two different mesh sizes. Two-tailed Fisher's exact tests were carried out to examine size classes of *L.carponotatus* and *Plectropomus* spp. and the χ^2-homogeneity test with Yate's correction was used for *S.doliatus* lengths. No statistical test was carried out for *Scolopsis margaritifer* and *S.puellus* because of their nil capture in large- and small-meshed traps, respectively. Size classes for *L.carponotatus* were 0-<30 cm and ≥30 cm, for *Plectropomus* spp.: 0-<30 cm and ≥30 cm (Fig.3.20) and *S.doliatus* 0-<20 cm and ≥20 cm (Fig.3.20b.).

No significant differences were found in the size distribution of *L.carponotatus* in traps of either mesh size. The total length frequency of *Plectropomus* spp. was significantly different for both mesh sizes ($n=9$, $m_1=1$, $m_2=1$, $f_{12}=0$, f_{crit} = -,-; f_{12}> -). The size frequency distribution of *S.doliatus* was significantly different for large- and small-meshed traps ($\chi^2=55.02$, d.f.=1, $P<0.05$). A tukey-type test for multiple comparison of proportions was carried out for the size classes of *Plectropomus* spp. and *S.doliatus* caught in different meshed traps (Tab.3.17.). Comparable numbers of large and small *S.doliatus* were caught in large-meshed traps. These traps caught significantly more *S.doliatus* than small-meshed traps. Within 12.5 mm square mesh traps, large-sized *S.doliatus* were caught in higher numbers than the small-sized ones. In experimental traps meshed with either large or small mesh, large-sized *Plectropomus* spp. were more frequently caught than small-sized ones.

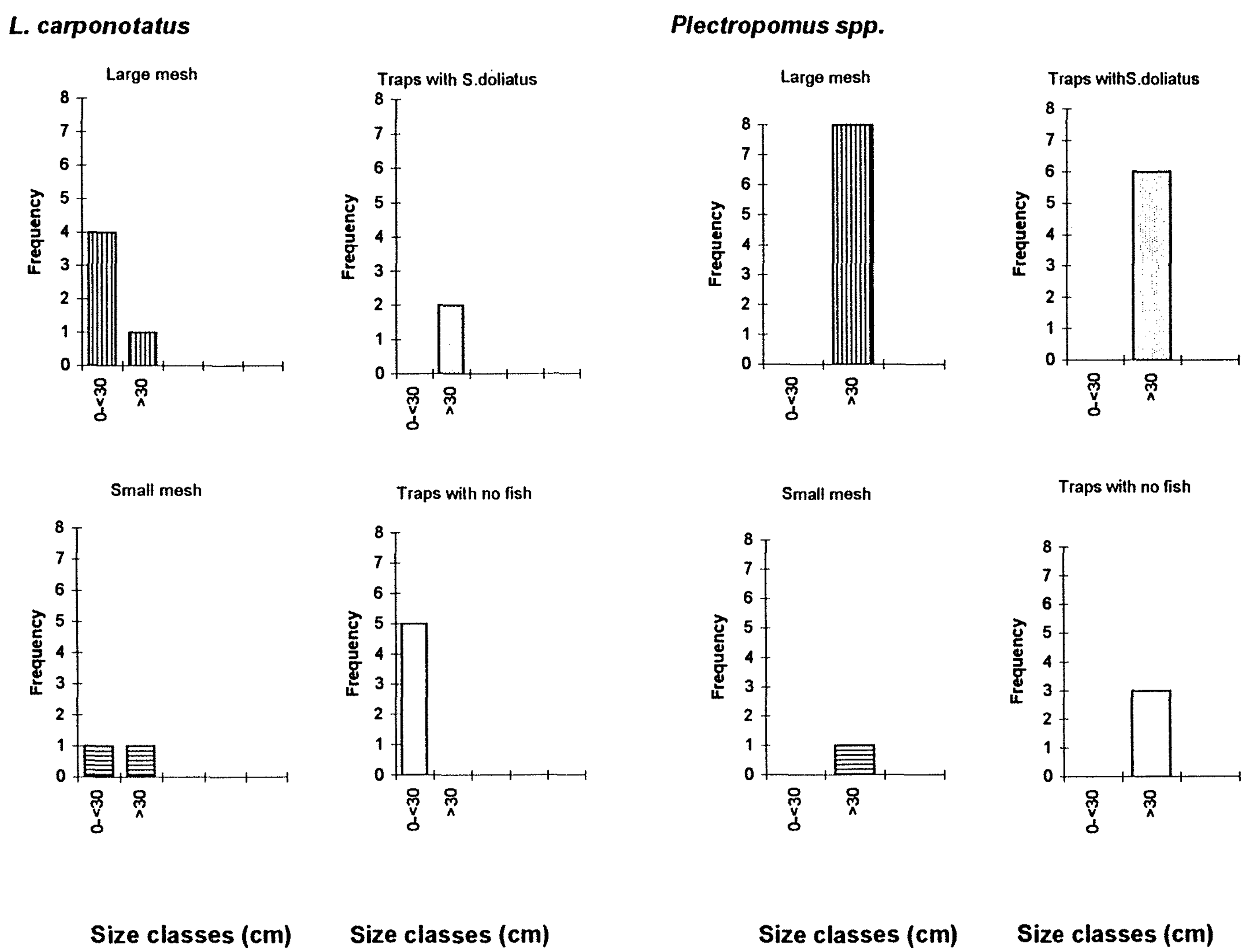


Fig.3.20a. Length frequency of *L.carponotatus* and *Plectropomus spp*. caught in manipulated experimental traps deployed deployed at Pioneer Bay. Only size classes used in the statistical analysis are shown.

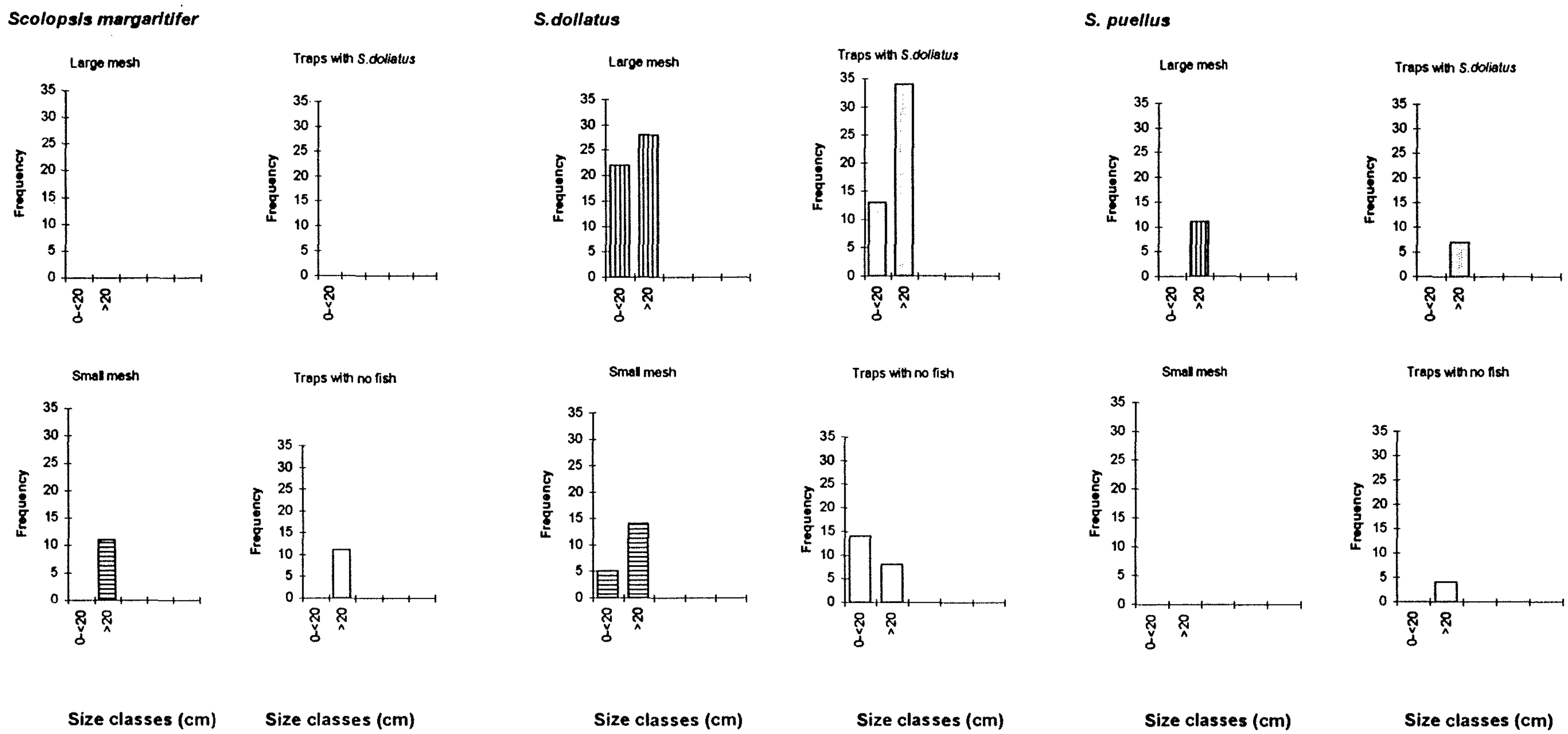


Fig.3.20b. Length frequency of *S.doliatus* and most abundant species (cm) caught in manipulated experimental traps deployed at Pioneer Bay. Only size classes used in the statistical analysis are shown.

Table.3.17. Results of Tukey-type test for multiple comparison of proportions of frequency of *S.doliatus and Plectropomus* spp. of different size classes for each mesh size. Underlined size class proportions were not significant.

Size classes	*Siganus doliatus*	Size classes	*Plectropomus* spp.
0-<20 cm	Large>Small	**0-<40 cm**	Large Small
≥ 20 cm	Large>Small	**≥40 cm**	Large Small
L(≥ 20) L(0-<20) > S(≥ 20) S(0-20)		L(≥40) S(≥40) > L(0-<40) S(0-<40)	

(S= Small= 13mm square mesh, L= Large= 42 mm hexagonal mesh)

3.6. DISCUSSION

A number of generalisations and species-specific patterns emerged when examining the effect of different trapping protocols on attraction of fish to traps, ingress and escapement.

Trap attractiveness

Traps of different mesh size and bait type from two locations attracted a comparable total number of fish in their proximity, suggesting that differences in catch rates were not determined by differences in the number of fish attracted. If fish were responding to olfactory signals in the bait plume, a different number of fish attracted to traps with different baits would be expected (Campbell *et al.*, 1987). The fact that treatments with no bait attracted similar numbers of fish suggests that bait does not play a major role in determining fish aggregation at traps at this location. Also, the different sized mesh on the traps might have been expected to attract different numbers if certain meshes are perceived more easily than others (Munro *et al.*, 1971; Luckhurst & Ward, 1987). As no differences in numbers were found, fish arrivals to traps deployed in shallow water are likely to be related to random fish movements or curiosity during foraging (High & Beardsley, 1970). The total number of arrivals to traps would depend on the stock density of the area rather than trap or bait characteristics (Campbell *et al.*, 1987).

In general, numbers of fish aggregating around traps decreased towards the end of the second day of soak at each location, suggesting curiosity wanes after a few days. At the end of the soak period, a decrease in arrivals was also expected due to some degree of depletion of the more vulnerable stock as fish were being caught by the traps (Campbell *et al.*, 1987). However, because of the increasing number of fish at Pioneer Bay, it appears that this is more related to specific relationships between the catch and the fish in the immediate area.

Particular species were attracted in different numbers around traps, but again these numbers did not generally differ between traps with different mesh sizes or bait types. Some differences in fish numbers were found during each observation time at each location. At Cattle Bay, more *S.doliatus* appeared to be gathered around large-meshed traps and stayed longer in their proximity at the beginning of the soak period. After the first overnight soak period more *Plectropomus* spp. were observed at small-meshed traps spending longer time in their vicinity. This may have been caused by increasing numbers of fish caught in these traps (High & Beardsley, 1970; Hartsuijker & Nicholson, 1981; Parrish, 1982). In these cases, the selectivity of the mesh sizes in terms of the species composition of the catch could have affected fish arrivals rather than the visual effect of these traps underwater (Luckhurst & Ward, 1987).

Mesh sizes had an effect of attracting some fish species in different numbers during some instances of the soak period. Herbivorous fish such as *S.doliatus* are known to enter traps during the first stages of the soak period (Dalzell & Aini; 1987; Davies, 1989) and so they could have attracted more conspecifics around these traps. Also the importance of overnight periods in increasing trap catches (Wolf & Chislett, 1974) resulted in predators (i.e. *Plectropomus* spp.) being attracted to them. However, the two different sampling methods involved and the different abundance of fish suspected between locations (pers.obs.) require cautious interpretations of these processes.

Relationship between fish aggregation around traps and catch

In general, there was a poor relationship between the numbers of fish aggregating around traps and number of fish already caught, when comparing different bait types and mesh sizes. Hence, catches were based on the likelihood of ingress once a fish is in the vicinity of the trap, rather than the number of fish coming to the trap. These relationships appeared to vary depending on the location. At Cattle Bay, high catches were related to large numbers of fish gathered in the trap proximity, probably because of mechanisms of conspecific attraction and predator-prey relationships. However, at Pioneer Bay, nil or negative relationships between fish inside and outside traps were found. It seems likely that the larger number of positive relationships found at Cattle Bay was a result of a positive response of the most abundant fish species observed in the trap vicinity (*L.carponotatus*, *Lutjanus sebae* and *Diagramma pictum*) to the diver's presence (pers.obs.) rather than different attracting mechanisms of the traps. The negative relationships found at Pioneer Bay may have been caused by a stabilisation and even decrease in catches at the end of the three day soak period while the number of fish outside the traps increased due to inter-intraspecific relationships.

Plectropomus spp. abundance outside traps appeared to be highly correlated to conspecifics trapped and multispecific catches in a positive and negative relationship depending on the location. The higher catch rates of traps baited with pilchards resulted in the highly significant relationships detected at these particular traps. Differences between locations were mainly due to the ability to observe specific behaviour displays of undisturbed *Plectropomus* spp. using the video-camera at Pioneer Bay in comparison to their "shy behaviour" displayed in the presence of divers at Cattle Bay. At Cattle Bay, high numbers of these species were related to high catches probably due to:. (1) the presence of small fish in traps (Munro *et al.*,1971; Craig, 1976; Stevenson & Stuart-Sharkey, 1980), (2) the presence of the trap in their home range (Hartsuijker & Nicholson, 1981) and (3) conspecific attraction. However, at Pioneer Bay high numbers of *Plectropomus* spp. outside traps baited with pilchards were strongly related to low numbers of conspecifics trapped. This was probably caused by predation inside traps and subsequent escapement from them. Because of the different sampling techniques and soak time periods used at the two different locations, it appears that these positive and negative relationships could be part of the early and late stages of the same attracting processes rather than different mechanisms affecting this species.

Patterns of ingress and escapement

The better performance of large-meshed traps and traps baited with pilchards in terms of ingress was consistent at both locations, resulting in higher catch rates (see Chapter II). In general, pilchards acted as a highly effective bait to attract fish into the traps and large mesh allowed, supposedly, higher intra or interspecific attraction between individuals inside and outside traps. These traps caught fish at higher rates at the beginning of the soak period, and so the chance of new ingresses was increased when fish outside traps were positively associated to fish already trapped (i.e. conspecific attraction and predator-prey relationships) (Munro *et al.*, 1971). First entries into the traps may have increased the chances of some fish species entering traps in two ways: (1) By creating a bait plume as a result of some fish eating the bait (Whitelaw *et al.*, 1987) (2) Once the bait was depleted and in the case of unbaited traps, by attracting large predators and conspecifics into traps (High & Ellis, 1973; Luckhurst & Ward, 1987; Davies, 1989).

The number of escapements from traps were affected differently by mesh size and bait type depending on the location, suggesting an effect of the different soak periods. In shorter soak periods bait depletion (i.e. pilchards or small "bait" fish) may have enhanced the number of escapements from traps (Munro, 1974; Whitelaw *et al.*, 1991) while during longer soak periods, mesh would have a greater effect on escapements of fish that entered the traps during the late stages of the soak period. Also, the highly variable trap catches (Williams *et al.*, 1992) may have affected the calculation of the minimum estimates of escapements reducing their accuracy when two observations per day were carried out (Pioneer Bay) instead of four observations a day (Cattle Bay). In general, escapements were higher in large-meshed traps and traps baited with pilchards although they are believed to be higher in small-meshed ones because of the clearer funnel opening (Luckhurst & Ward, 1987; Newman, 1990). Subsequently, higher final catches of large-meshed traps appeared to be more related to the initial high number of fish entering these traps rather than the low number of escapements.

Each target species showed different patterns of ingress/escapement in relation to different traps that were consistent between locations. Ingress and escapement of herbivorous fish (i.e. *S.doliatus*) were not affected by different baits used in traps (Luckhurst & Ward, 1987; Davies 1989). The fact that there is a greater perception of conspecifics in large-meshed traps (Newman, 1990) may have enhanced ingress of this species to traps. Pilchard bait proved to be a very effective attractant driving *L.carponotatus* into traps (Campbell *et al.*, 1987; Moran & Jenke, 1989). Fish that easily enter the trap, easily escape from them (Luckhurst & Ward, 1987; Campbell *et al.*, 1987) and so when the bait was depleted, traps using pilchards registered the highest escapements of *L.carponotatus* (Munro *et al.*, 1971). The presence of small prey fish in traps appeared to be a major factor determining ingress and escapement events of *Plectropomus* spp. regardless of mesh sizes and bait types of the traps. Interspecific relationships (predator-prey) were the reason why large fish were trapped when small prey fish were present in the traps (Sutherland & Harper, 1983) escaping from traps after preying on them, without major problem (Parrish, 1982; Campbell *et al.*, 1987).

In general, there was a consistent trend of low numbers of ingresses and escapements with high number of fish outside traps at both locations. Furthermore, from the underwater observations, ingress to traps occurred when solitary individuals approached traps with relatively high catches, confirming Campbell *et al.'s* (1987) observations in north-western Australia. These workers suggested that while the number of arrivals to traps is related to the local density of fish, ingress to traps and subsequently catches would depend on trap characteristics and on intra-interspecific interactions of fish outside traps and the catch. It appeared that relatively large numbers of frantic fish in traps could have frightened other fish from the area and hence from entering the traps ("saturation effect") (High & Beardsley, 1970) and also escaping from them (Campbell *et al.*, 1987). The highly variable time spent by individual fish around traps before being trapped can be explained by different abilities between individual fish in finding the trap entrance (Campbell *et al.*, 1987). The majority of early ingress and escapement events would be from those fish that easily found the trap funnels while slower fish remained in the area surrounding traps (Luckhurst & Ward, 1987; Campbell *et al.*, 1987). Catches were stabilised by the increasing numbers of escapements through straight funnels (Luckhurst & Ward, 1987) while ingress rates kept increasing and, for some species (*S.doliatus*, *L.carponotatus*, *Plectropomus* spp.), levelled off (Munro, 1974).

Effect of conspecific attraction on catches of S.doliatus

Higher catches of *S.doliatus* in traps where they were present is likely due to conspecific attraction. When *S.doliatus* were added to traps, catches of *S.doliatus* were significantly higher than the controls, indicating that interactions between individuals do affect catch rates. The high variances observed in catches of *S.doliatus* throughout this study were unlikely to come from a random distribution of individuals but rather from a tendency of large numbers of fish to occur together. Munro *et al.*, (1971) suggested that intraspecific patterns of fish behaviour, such as schooling, has a major effect in catch composition. He explained high variability of trap catches as a consequence of conspecific interaction displayed by some fish species. Invariably, the total catches of individuals of each species are not randomly distributed among traps. The presence of *S.doliatus* trapped increased the probabilities of new ingresses of individuals of the same species (High & Ellis, 1973; Parrish, 1982; Luckhurst & Ward, 1987; Davies, 1989; Newman, 1990). That *S.doliatus* were observed swimming along the outside of traps following trapped conspecifics supports the above.

Differences in catches of *S.doliatus* in traps of different mesh sizes may have been due to the different effect of the traps when submerged. As Newman (1990) suggested, the strong visual outline of small-meshed traps underwater may have decreased the amount of conspecific attraction. The silhouette created by small-meshed traps underwater does not appear attractive to *S.doliatus*. Lower catches were registered in small-meshed traps but conspecific interaction still had an effect when conspecifics were present.

The families and species-composition of the catches in these experimental traps were dominated by siganids because of 1) conspecific attraction and 2) their great abundances in shallow zones of the coral reefs (Bouchon-Navarro, 1981; Harmelin-Vivien, 1981; Russ, 1984b) establishing a general trend of species composition in trap catches with herbivorous fish dominating them (Munro, 1974; Stevenson & Stuart-Sharkey, 1980; Dalzell & Aini, 1987; Davies, 1989). All marked *S.doliatus* set in the traps died after the first day soak, probably due to internal injuries when taken down to the traps to be placed in them. This could have enhanced the number of large-sized *Plectropomus* spp. ingressing these traps.

Conclusions

Direct observations, either directly by using divers or indirectly using video cameras, have enabled the different effects of traps on fish aggregation, ingress and escapement to be separated. It appears that catches relate more to ingress than fish attraction but these can be modified by fish escapement. Patterns of ingress are influenced by interactions between fish species and trap characteristics and are species-specific. They are also influenced by the presence of fish in the trap. The combined knowledge of these processes could be used to maximise catches. For example, the greatest catch of *S.doliatus* would occur in large-meshed traps with conspecifics added. Catches of *L.carponotatus* would be maximised in traps with highly attractive baits such as pilchards and also when traps are designed to decrease the number of escapements after bait depletion (i.e. using horse-neck funnels). Greater numbers of *Plectropomus* spp. would be caught in traps with high catch rates of small fishes at the beginning of the soak periods and after long soak periods. Because of the catching selectivity of traps of different characteristics (mesh size and bait types) on some fish species, trap catches do not always reflect accurately the relative abundances of fish species. Further studies on fish behavioural patterns of species of interest in responses to different traps is needed to maximise ingress, minimise escapement and determine optimum soak time.

CHAPTER IV

GENERAL DISCUSSION AND CONCLUSIONS

The increasing use of fish traps as non-destructive sampling techniques in fish stock assessment on the Great Barrier Reef requires information on factors affecting catch size and selectivity, and factors affecting variability in catch rates. The distribution, abundance and dispersion of fish in the habitat is only one component of this, as fish that are present do not necessarily enter traps. The objective of this study was to determine the species-specific behaviour patterns that affect trap catches of target species when traps of different characteristics (mesh size and bait type) are deployed in shallow inshore fringing reef waters. It represents the first use of underwater video cameras to monitor fish behaviour in traps on the Great Barrier Reef. The results of this study indicate that traps must be designed and deployed to maximise catch and minimise variance in catches for particular species. This has to be considered when catches of traps of given characteristics are used as estimates of local fish densities and assemblages. The experimental approach taken here indicates how knowledge of species-specific behavioural patterns can be used to maximise catch rates, either by increasing attraction and ingress, or by minimising escapement.

The higher performance of traps with large mesh and traps baited with pilchards in catching target and most abundant species (*S.doliatus*, *L.carponotatus* and *Plectropomus spp.*) and in general, the multispecific stock (total number of individuals) in the area, was due to the different fish behavioural responses to the traps. The number of *L.carponotatus* present in traps may have progressively declined because of an increasing number of escapements and less ingress due to bait depletion (Campbell *et al.*, 1987). When they are caught in traps with a constant supply of bait, this only maintained the catch during the overnight periods probably reducing escapement. *S.doliatus* and *Plectropomus spp.* registered a steady increase in catch rates until the end of the soak period. The accumulation of trap catches differed due to: conspecific attraction processes (Munro, 1974; Luckhurst & Ward, 1987; Davies, 1989) and predator-prey relationships (High & Ellis, 1973; Campbell *et al.*, 1987), respectively, involved in trapping these species. Catch rates of the target species in this study can not be compared to those in previous studies (Davies, 1989; Newman, 1990) because traps of different trap characteristics (funnel shape and trap volume) were used and because of the supposed differences in fish abundances at different locations.

Final catches were the result of the ingress and escapement events of the target species in different traps, rather than differences in the number of fish attracted to traps. Large-meshed traps resulted in higher catches of *S.doliatus* because of the higher conspecific attraction registered in these traps (Newman, 1990) and traps baited with pilchards were highly effective in catching *L.carponotatus,* because of the attractiveness of the bait (Campbell *et al.*, 1987; Moran & Jenke, 1989). The possibility of obtaining higher final catches of *Plectropomus spp.* was enhanced in traps with relatively higher multispecific catch rates at the beginning of the soak period (i.e. large mesh and traps baited with pilchards) (Sutherland & Harper, 1983).

In general, in large mesh traps and traps baited with fish oil or no bait, the family and species composition was dominated by herbivorous grazing families (Siganidae, Pomacanthidae) followed by a larger predatory fish family (Serranidae) which was distributed across all trap types. This probably reflects the high abundances of herbivorous fish in shallow areas of the coral reefs (Bouchon-Navarro, 1981; Harmelin-Vivien, 1981; Russ, 1984b) and their dominance in trap catches is fairly general (Munro, 1974; Stevenson & Stuart-Sharkey, 1980; Koslow *et al.*, 1988; Dalzell & Aini, 1987; Davies, 1989; Newman, 1990). Also, high catches of herbivorous fish may be related to shelter seeking behaviour (High & Ellis, 1973).

It appears that when predatory species occurred in high numbers at the beginning of the soak periods, herbivorous fish did not enter the traps until numbers of the former fish groups decreased and vice versa, high number of *S.doliatus* in traps at the beginning of the soak periods would progressively decline when large predators (*Plectropomus spp.*) start entering traps in the latter stages of the soak period. Piscivorous fish (Lutjanidae) occurred more often in traps baited with pilchards and in small mesh traps, especially at the beginning of the soak periods because of the presence of fresh bait (Campbell *et* *al.*, 1987; Moran & Jenke, 1989), and they seem to coexist in lower abundances with herbivorous fish in traps. The species composition of trap catches will be determined by the initial fish ingresses and so the decline in numbers of some species would favour the increment of other species negatively associated with them in traps.

In general, attraction of fish to traps set on shallow coral reefs would depend on the local abundance of fish in the area while ingress and escapement events into and from traps, respectively would depend on individual fish displays in response to the trap and their contents (Campbell *et al.*, 1987). Ingress to traps results from individual fish seeking to enter the trap because of its contents rather than random movements around the traps resulting in accidental entries. This would result in different catches of the same fish species in traps of different characteristics. The same trap type might be used to compare abundances of the same species at different places and times, but not to compare the relative abundance of species.

Speculation about the reduction of conspecific attraction between *S.doliatus* inside and outside small-meshed traps have been made in this study based on Newman's (1990) suggestion. However, why *S.doliatus* do not enter small mesh traps when no conspecifics are present is still to be clarified. The very strong silhouette of the small-mesh traps underwater may have caused this. From previous studies, it appears that, depending on the fish species, small-meshed traps would have opposite effects such as driving some herbivorous fish species into them as a response of shelter seeking behaviour but stopping other species from entering.

The ability to observe individual fish behaviour, without interfering it, is clearly an advantage in determining the mechanisms involved with trap success. Underwater video systems do not appear to affect fish behaviour, as do the divers' presence in relation to some fish species (Rutecki *et al.*, 1983). Divers can also account for other problems such as interpretation biases showed by the observers. Underwater video cameras can be deployed longer and under different light levels providing permanent records that can be reviewed as many times as needed. The use of video cameras consistently improve the accuracy of the information obtained from traps deployed at Pioneer Bay and the understanding of the trapping processes.

Since fish are caught in traps swimming voluntarily into them, there is a need for further examination of fish behaviour in relation to traps to enhance the effectiveness of such traps catching different fish species. The great flexibility of traps in terms of deployment at different depths, habitats (Newman, 1990) and the possibility of targeting different species by using different mesh sizes and bait types make traps very appropriate tools for obtaining large numbers of live, healthy fish for mark and recapture studies (Davies, 1989). This has a direct application in obtaining information about growth, recruitment, movement and mortality of reef fish and, thus distribution and abundance data on reef fishes for population studies purposes. If traps are to be used as sampling tools for estimating relative and total densities of reef fishes, their marked selectivity in terms of species captured and optimum soak periods have to be considered when assessing these parameters.

The use of traps of the same characteristics in different areas of the Great Barrier Reef would result in different final catches and catch rates as a result of different fish assemblages and fish behavioural patterns. Further research is needed to identify fish responses to traps in other locations, depths and habitats. Under standard conditions of soak period, lunar phase, depth and habitat, further studies should be directed to the role of rebaiting traps on catch rates in both shallow and deep waters. Experiments of conspecific attraction could be carried out setting decoy fish, instead of live ones, in the traps to assess to what point just visual attraction is important in traps with different mesh sizes. Video camera recordings of these experiments would expand the discernment of these processes. Extending the recording hours to different times of the day (i.e.during late morning and early afternoon of the soak periods) would clarify ingress and escapement events displayed in traps by herbivorous species.

CONCLUSIONS

It would be impossible to identify all the reasons why every individual fish enters and is retained in different traps. However, this study shows that the design of the trap and method of deployment can easily be modified to increase the mean and reduce the variance in catches of certain species. This enhances their utility both as fishing devices and sampling tools. General conclusions from a particular study on some fish species at a given location cannot be extended to other species and places. However, some patterns of fish behaviour were consistently observed: (1) The number of fish in the area surrounding traps deployed in shallow water would depend on the density of fish at that area rather than bait type or mesh sizes of traps used (2) Fish ingress and escapement into and from different traps, respectively, will not result from large fish numbers and random movements around different traps but rather from an individual fish response to the trap contents (3) Different fish species will enter traps because of their contents: conspecifics (*S.doliatus*), bait (*L.carponotatus*) and small prey fish (*Plectropomus spp.*) (4) The presence of conspecifics in traps is the most important factor affecting *S.doliatus* catches in both small and large mesh traps (5) The stronger underwater silhouette of small-meshed traps deters *S.doliatus* from entering these traps when no conspecifics were present (6) The combination of all factors mentioned above resulted in larger multispecific catches in traps with large mesh and traps baited with pilchards. Such factors must be taken into account when designing future trapping programs.

Appendix I. Family and species composition for different meshed traps at the end of each trial. Trial 1=Cattle Bay and Trial 2= Pioneer Bay.

	TRIAL 1				TRIAL 2			
	Large mesh numbers	% of catch	Small mesh numbers	% of catch	Large mesh numbers	% of catch	Small mesh numbers	% of catch
Lutjanidae	30	13.04	12	5.22	23	10.36	20	9.01
Lutjanus carponotatus	**21**	**9.13**	**11**	**4.78**	**11**	**4.95**	**8**	**3.60**
Lutjanus sebae	6	2.61	-	-	8	3.60	12	5.41
Lutjanus russelli	3	1.30	1	0.43	3	1.35	-	-
Symphorus nematophorus	-	-	-	-	1	0.45	-	-
Serranidae	26	11.30	13	5.65	18	8.11	14	6.31
Plectropomus spp	**15**	**6.52**	**9**	**3.91**	**10**	**4.50**	**7**	**3.15**
Cephalopholis cyanostigma	3	1.30	-	-	1	0.45	-	-
Anyperodon leucogrammicus	-	-	-	-	2	0.90	-	-
Epinephelus ongus	-	-	4	1.74	3	1.35	6	2.70
Epinephelus malabaricus	-	-	-	-	-	-	1	0.45
Epinephelus quoyanus	7	3.04	-	-	-	-	-	-
Cromileptes altivelis	1	0.43	-	-	2	0.90	-	-
Siganidae	67	29.13	1	0.43	27	12.16	-	-
Siganus doliatus	**62**	**26.96**	**1**	**0.43**	**19**	**8.56**	-	-
Siganus puellus	3	1.30	-	-	5	2.25	-	-
Siganus punctatus	1	0.43	-	-	3	1.35	-	-
Siganus argenteus	1	0.43	-	-	-	-	-	-
Labridae	3	1.30	5	2.17	5	2.25	2	0.90
Chaerodon fasciatus	-	-	-	-	-	-	-	-
Choerodon schoenleinii	-	-	-	-	2	0.90	-	-
Cheilinus fasciatus	-	-	-	-	1	0.45	-	-
Thalassoma spp.	-	-	-	-	-	-	1	0.45
Thalassoma lunare	-	-	1	0.43	-	-	1	0.45
Choerodon anchorago	3	1.30	4	1.74	2	0.90	-	-
Holocentridae	3	1.30	15	6.52	5	2.25	4	1.80
Myripistis murdjan	-	-	7	3.04	5	2.25	4	1.80
Sargocentron cornutum	3	1.30	8	3.48	-	-	-	-
Pomacanthidae	7	3.04	1	0.43	29	13.06	1	0.45
Pomacanthus sexstriatus	7	3.04	1	0.43	27	12.16	-	-
Chaetodontoplus meredithi	-	-	-	-	1	0.45	1	0.45
Pomacanthus semicirculatus	-	-	-	-	1	0.45	-	-
Chaetodontidae	2	0.87	-	-	11	4.95	-	-
Chaetodon aureofasciatus	-	-	-	-	7	3.15	-	-
Chelmon rostratus	1	0.43	-	-	-	-	-	-
Chaetodon melannotus	-	-	-	-	4	1.80	-	-
Chaetodon rainfordi	1	0.43	-	-	-	-	-	-
Scaridae								
Scarus spp.	-	-	-	-	5	2.25	-	-
Nemipteridae	4	1.74	4	1.74	14	6.31	-	-
Scolopsis monogramma	-	-	-	-	8	3.60	-	-
Scolopsis margaritifer	3	1.30	3	1.30	6	2.70	-	-
Scolopsis bilineatus	1	0.43	1	0.43	-	-	-	-

Appendix I (continue) Family and species composition for different meshed traps at the end of each trial. Trial 1=Cattle Bay and Trial 2=Pioneer Bay.

	TRIAL 1				TRIAL 2			
	Large mesh numbers	% of catch	Small mesh numbers	% of catch	Large mesh numbers	% of catch	Small mesh numbers	% of catch
Lethrinidae	5	2.17	1	0.43	8	3.60	2	0.90
Lethrinus obsoletus	-	-	-	-	6	2.70	-	-
Lethrinus nebulosus	5	2.17	1	0.43	1	0.45	2	0.90
Lethrinus xanthochilus	-	-	-	-	1	0.45	-	-
Pomacentridae	2	0.87	3	1.30	-	-	2	0.90
Neoglyphidodon melas	1	0.43	-	-	-	-	1	0.45
Chromis nitida	-	-	-	-	-	-	1	0.45
Amlyglyphidodon curacao	1	0.43	-	-	-	-	-	-
Dischistodus prosopotaenia	-	-	3	1.30	-	-	-	-
Haemulidae								
Diagramma pictum	1	0.43	-	-	2	0.90	2	0.90
Acanthuridae								
Acanthurus grammoptilus	-	-	-	-	9	4.05	-	-
Apogonidae	-	-	8	3.48	-	-	4	2.29
Apogon fuscus	-	-	-	-	-	-	3	1.35
Apogon compressus	-	-	8	3.48	-	-	1	0.57
Apogon moluccensis	-	-	-	-	-	-	-	-
Caesionidae								
Caesio cuning	-	-	-	-	1	0.45	1	0.57
Tetraodontidae	1	0.43	-	-	-	-		
Canthigaster valentini	-	-	-	-	-	-	1	0.45
Arothron hispidus	1	0.43	-	-	-	-		
Balistidae								
Abalistes stellatus	6	2.61	8	3.48	5	2.25	2	0.90
Centropomidae								
Psammoperca waigiensis	1	0.43	1	0.43	1	0.45	-	-
Muraenidae								
Gymnothorax spp.	-	-	-	-	-	-	2	0.90
Hemigaleidae								
Triaenodon obesus	-	-	-	-	1	0.45	-	-
Orectolobidae								
Orectolobus ornatus	-	-	-	-	1	0.45	-	-
TOTALS	**158**	**68.70**	**72**	**31.30**	**165**	**74.32**	**57**	**25.68**

Appendix II. Family and species composition for different meshed traps at the end of each trial. Trial 1=Cattle Bay and Trial 2=Pioneer Bay.

	TRIAL 1				TRIAL 2			
	Large mesh numbers	**% of catch**	**Small mesh numbers**	**% of catch**	**Large mesh numbers**	**% of catch**	**Small mesh numbers**	**% of catch**
Lethrinidae	5	2.17	1	0.43	8	3.60	2	0.90
Lethrinus obsoletus	-	-	-	-	6	2.70	-	-
Lethrinus nebulosus	5	2.17	1	0.43	1	0.45	2	0.90
Lethrinus xanthochilus	-	-	-	-	1	0.45	-	-
Pomacentridae	2	0.87	3	1.30	-	-	2	0.90
Neoglyphidodon melas	1	0.43	-	-	-	-	1	0.45
Chromis nitida	-	-	-	-	-	-	1	0.45
Amlyglyphidodon curacao	1	0.43	-	-	-	-	-	-
Dischistodus prosopotaenia	-	-	3	1.30	-	-	-	-
Haemulidae								
Diagramma pictum	1	0.43	-	-	2	0.90	2	0.90
Acanthuridae								
Acanthurus grammoptilus	-	-	-	-	9	4.05	-	-
Apogonidae	-	-	8	3.48	-	-	4	2.29
Apogon fuscus	-	-	-	-	-	-	3	1.35
Apogon compressus	-	-	8	3.48	-	-	1	0.57
Apogon moluccensis	-	-	-	-	-	-	-	-
Caesionidae								
Caesio cuning	-	-	-	-	1	0.45	1	0.57
Tetraodontidae	1	0.43	-	-	-	-		
Canthigaster valentini	-	-	-	-	-	-	1	0.45
Arothron hispidus	1	0.43	-	-	-	-		
Balistidae								
Abalistes stellatus	6	2.61	8	3.48	5	2.25	2	0.90
Centropomidae								
Psammoperca waigiensis	1	0.43	1	0.43	1	0.45	-	-
Muraenidae								
Gymnothorax spp.	-	-	-	-	-	-	2	0.90
Hemigaleidae								
Triaenodon obesus	-	-	-	-	1	0.45	-	-
Orectolobidae								
Orectolobus ornatus	-	-	-	-	1	0.45	-	-
TOTALS	**158**	**68.70**	**72**	**31.30**	**165**	**74.32**	**57**	**25.68**

Appendix III. Family and species composition of the catch at end of the soak period for traps using different bait type and for unbaited traps deployed at Cattle Bay (Trial 1) and Pioneer Bay (Trial 2)

	TRIAL 1				TRIAL 2					
	Pilchards number	% of catch	Fish oil number	% of catch	Pilchards number	% of catch	Fish oil number	% of catch	No bait number	% of catch
Lutjanidae	28	12.17	14	6.09	35	15.77	3	1.35	5	2.25
Lutjanus carponotatus	**19**	**8.26**	**13**	**5.65**	**12**	**5.41**	**2**	**0.90**	**5**	**2.25**
Lutjanus sebae	6	2.61	-	0.00	19	8.56	1	0.45	-	-
Lutjanus russelli	3	1.30	1	0.43	3	1.35	-	-	-	-
Symphorus nematophorus	-	-	-	-	1	0.45	-	-	-	-
Serranidae	26	11.30	13	5.65	12	5.41	6	2.70	14	6.31
Plectropomus spp	**15**	**6.52**	**9**	**3.91**	**4**	**1.80**	**4**	**1.80**	**9**	**4.05**
Cephalopholis cyanostigma	3	1.30	-	-	1	0.45	-	-	-	-
Anyperodon leucogrammicus	-	-	-	-	2	0.90	-	-	-	-
Epinephelus ongus	1	0.43	3	1.30	3	1.35	1	0.45	5	2.25
Epinephelus malabaricus	-	-	-	-	-	-	1	0.45	-	-
Epinephelus quoyanus	6	2.61	1	0.43	-	-	-	-	-	-
Cromileptes altivelis	1	0.43	-	-	2	0.90	-	-	-	-
Siganidae	44	19.13	24	10.43	8	3.60	5	2.25	14	6.31
Siganus doliatus	**41**	**17.83**	**22**	**9.57**	**6**	**2.70**	**4**	**1.80**	**9**	**4.05**
Siganus puellus	1	0.43	2	0.87	2	0.90	-	-	3	1.35
Siganus punctuatus	1	0.43	-	-	-	-	1	0.45	2	0.90
Siganus argenteus	1	0.43	-	-	-	-	-	-	-	-
Labridae	5	2.17	3	1.30	5	2.25	1	0.45	1	0.45
Choerodon schoenleinii	-	-	-	-	1	0.45	-	-	1	0.45
Cheilinus fasciatus	-	-	-	-	-	-	1	0.45	-	-
Thalassoma spp.	-	-	-	-	1	0.45	-	-	-	-
Thalassoma lunare	-	-	1	0.43	1	0.45	-	-	-	-
Choerodon anchorago	5	2.17	2	0.87	2	0.90	-	-	-	-
Holocentridae	8	3.48	10	4.35	-	-	5	2.25	4	1.80
Myripistis murdjan	2	0.87	5	2.17	-	-	5	2.25	4	1.80
Sargocentron cornutum	6	2.61	5	2.17	-	-	-	-	-	-
Pomacanthidae	1	0.43	7	3.04	4	1.80	7	3.15	19	8.56
Pomacanthus sexstriatus	1	0.43	7	3.04	3	1.35	6	2.70	18	8.11
Chaetodontoplus meredithi	-	-	-	-	-	-	1	0.45	1	0.45
Pomacanthus semicirculatus	-	-	-	-	1	0.45	-	-	-	-
Chaetodontidae	1	0.43	1	0.43	-	-	8	3.60	-	-
Chaetodon aureofasciatus	-	-	-	-	-	-	4	1.80	3	1.35
Chelmon rostratus	1	0.43	-	-	-	-	-	-	-	-
Chaetodon melannotus	-	-	-	-	-	-	4	1.80	-	-
Chaetodon rainfordi	-	-	1	0.43	-	-	-	-	-	-
Scaridae										
Scarus spp.	-	-	-	-	1	0.45	-	-	4	1.80
Nemipteridae	5	2.17	3	1.30	6	2.70	4	1.80	4	1.80
Scolopsis monogramma	-	-	-	-	3	1.35	3	1.35	2	0.90
Scolopsis margaritifer	5	2.17	1	0.43	3	1.35	1	0.45	2	0.90
Scolopsis bilineatus	-	-	2	0.87	-	-	-	-	-	-

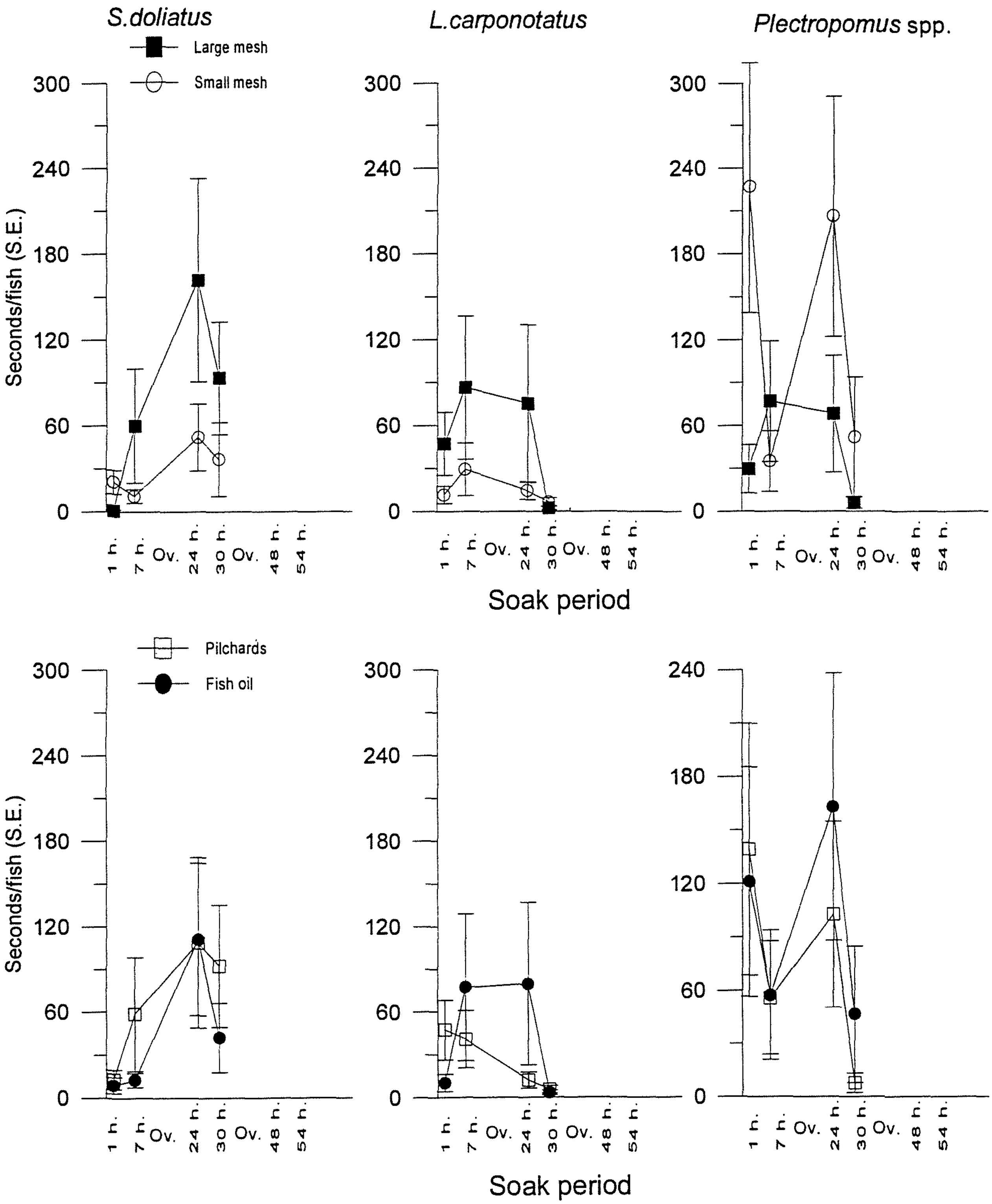
Appendix IV. Family and species composition of the catch at end of the soak period for traps using different bait type and for unbaited traps deployed at Cattle Bay (Trial 1) and Pioneer Bay (Trial 2).

	TRIAL 1				TRIAL 2					
	Pilchards number	% of catch	Fish oil number	% of catch	Pilchards number	% of catch	Fish oil number	% of catch	No bait number	% of catch
Lethrinidae	3	1.30	3	1.30	8	3.60	-	-	2	0.90
Lethrinus obsoletus	-	-	-	-	5	2.25	-	-	1	0.45
Lethrinus nebulosus	3	1.30	3	1.30	2	0.90	-	-	1	0.45
Lrthrinus xanthochilus	-	-	-	-	1	0.45	-	-	-	-
Pomacentridae	2	0.87	3	1.30	1	0.45	-	-	1	0.45
Neoglyphidodon melas	1	0.43	-	-	-	-	-	-	1	0.45
Chromis nitida	-	-	-	-	1	0.45	-	-	-	-
Amlyglyphidodon curacao	-	-	1	0.43	-	-	-	-	-	-
Dischistodus prosopotaenia	1	0.43	2	0.87	-	-	-	-	-	-
Haemulidae										
Diagramma pictum	1	0.43	-	-	3	1.35	-	-	1	0.45
Acanthuridae										
Acanthurus grammoptilus	-	-	-	-	8	3.60	-	-	1	0.45
Apogonidae	4	1.74	4	1.74	-	-	3	1.35	1	0.45
Apogon spp.	-	-	-	-	-	-	-	-	-	-
Apogon fuscus	-	-	-	-	-	-	2	0.90	1	0.45
Apogon compressus	4	1.74	4	1.74	-	-	1	0.45	-	-
Caesidae										
Caesio cuning	-	-	-	-	1	0.45	1	0.45	-	-
Tetraodontidae	1	0.43	-	-	-	-	-	-	1	0.45
Canthigaster valentini	-	-	-	-	-	-	-	-	1	0.45
Arothron hispidus	1	0.43	-	-	-	-	-	-	-	-
Balistidae										
Abalistes stellatus	10	4.35	4	1.74	5	2.25	2	0.90	-	-
Centropomidae										
Psammoperca waigiensis	1	0.43	1	0.43	1	0.45	-	-	-	-
Muraenidae										
Gymnothorax spp.	-	-	-	-	2	0.90	-	-	-	-
Hemigaleidae										
Triaenodon obesus	-	-	-	-	1	0.45	-	-	-	-
Orectolobidae										
Orectolobus ornatus	-	-	-	-	-	-	1	0.45	-	-
TOTALS	**140**	**60.87**	**90**	**39.13**	**101**	**45.50**	**46**	**20.72**	**75**	**33.78**

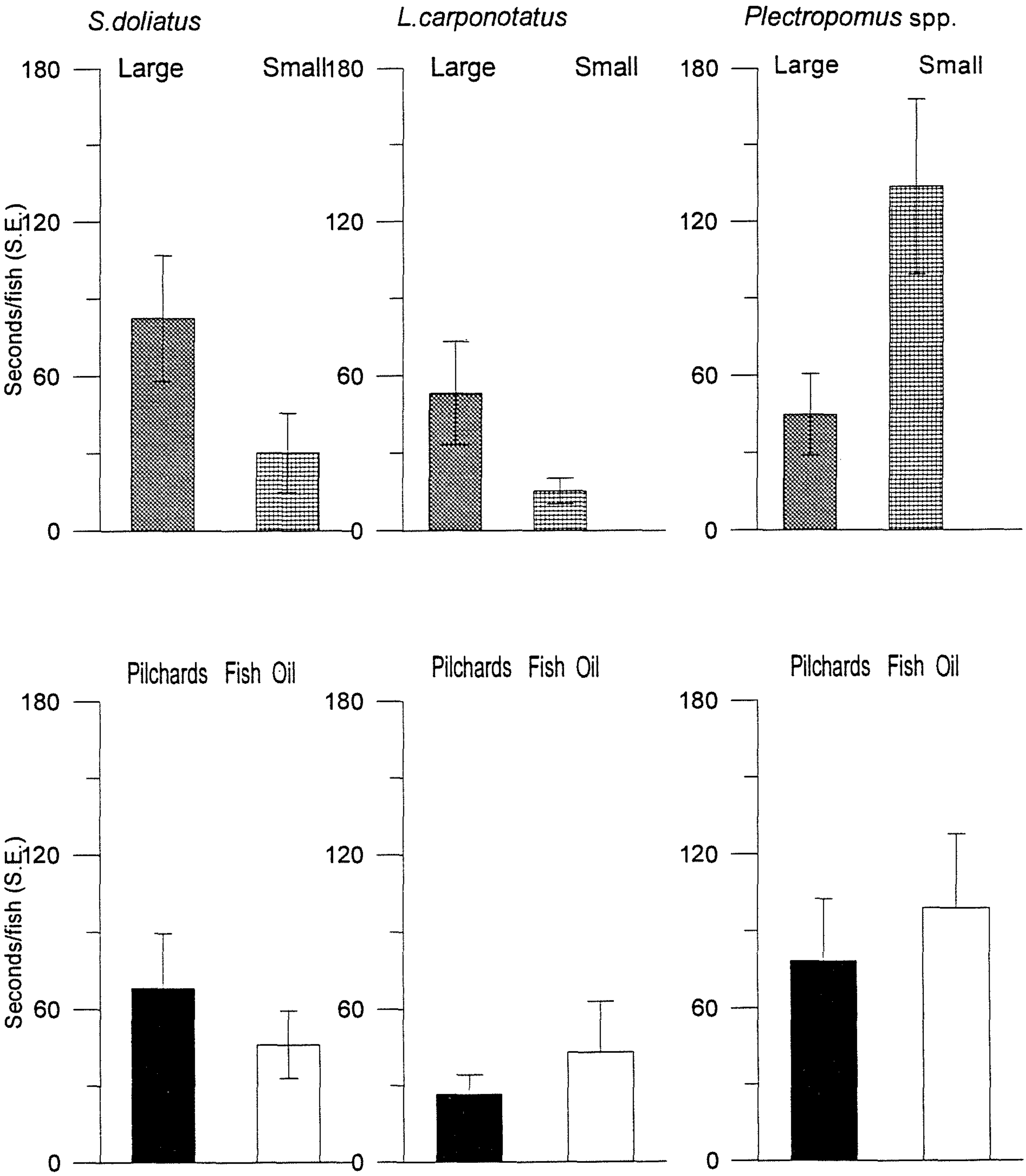
Appendix V. Summary of mean lengths and length range (cm) of the most abundant fish Families (>1%) caugl meshed traps deployed at Cattle Bay (Trial 1) and Pioneer Bay (Trial 2). Underlined values: possibly mesh selctivity within fish families (assuming that they content the same fish species)

	TRIAL 1				TRIAL 2			
	Large mesh numbers		Small mesh numbers		Large mesh numbers		Small mesh numbers	
	Mean (cm)	Range (cm)	Mean (cm)	Range (cm)	Mean (cm)	Range (cm)	Mean (cm)	Range (cm)
Lutjanidae	28.3	20.5-41.0	28.8	24.2-43.0	27.8	18.0-41.5	27.3	13.0-34.5
Serranidae	40.5	22.5-75.0	40.1	26.0-63.0	39.8	26.0-67.0	45.7	23.5-72.0
Siganidae	20.7	13.0-30.0	-	-	22.6	12.0-29.0		
Labridae	27.3	27.0-28.0	22.3	15.0-27.5	35.5	16.0-49.0	43.5	39.0-48.0
Holocentridae	16.5	16.0-28.0	13.3	8.0-16.0	15.5	14.5-16.5	14.7	13.0-16.5
Pomacanthidae	23.9	18.5-30.5	-	-	27.1	17.5-36.0	20.1	15.5-24.0
Chaetodontidae	-	-	-	-	9.4	7.0-11.5	-	-
Scaridae	-	-	-	-	26.7	25.1-30.0	-	-
Nemipteridae	19.9	16.0-22.5	13.8	11.0-19.5	28.6	20.0-36.0	-	-
Lethrinidae	30.5	24.5-35.5	-	-	30.9	24.0-40.0	40	36.0-44.0
Pomacentridae	12.2	12.0-12.5	13.8	11.0-15.5	-	-	7.2	6.5-8.0
Acanthuridae	-	-	-	-	27.8	25.0-31.0	-	-
Apogonidae	-	-	8.3	5.2-11.0	-	-	7.2	5.0-11.0
Balistidae	33.3	32.0-35.0	33.8	30.0-37.5	29.9	23.0-38.0	27.5	25.0-30.0

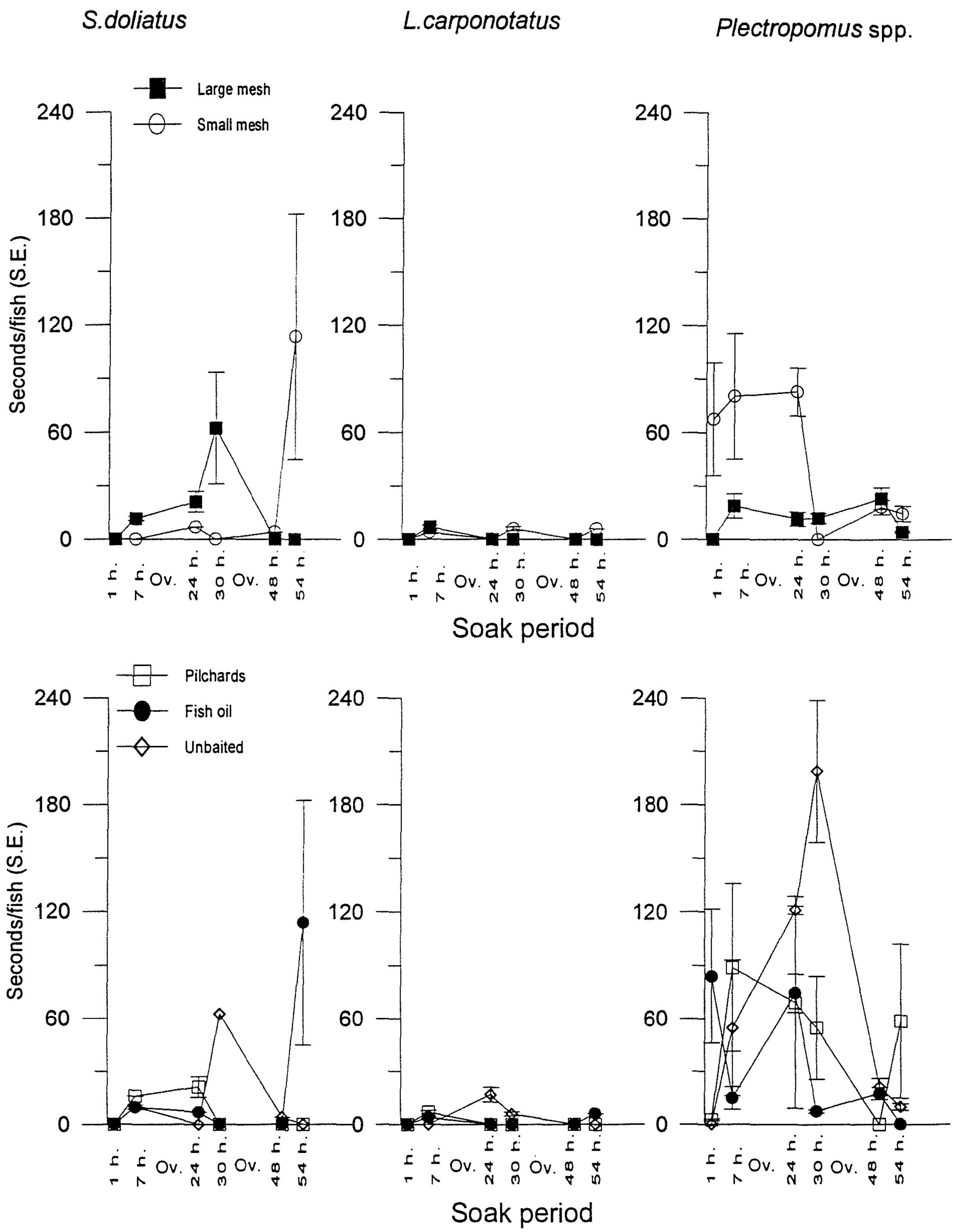
Appendix.VI. Mean time (sec) spent by target species in the 2 metres area surrounding traps deployed at Cattle Bay (TRIAL 1) over the 2 days soak period. (Error bars represent standard errors)



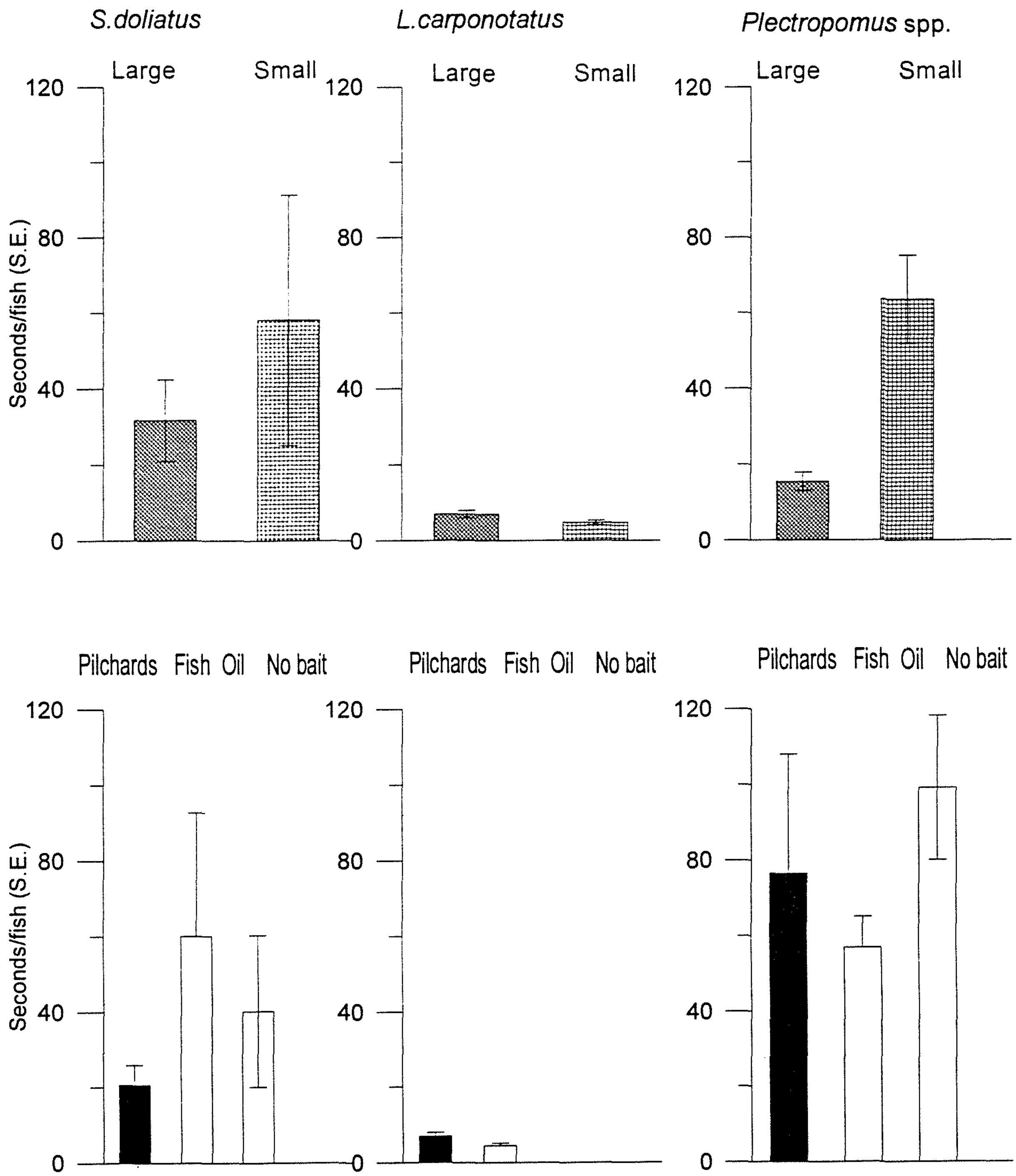
Appendix.VII. Mean time (sec) spent by the target species in the 2 metres area surrounding traps deployed at Cattle Bay (TRIAL 1).(Error bars represent standard errors)



Appendix.VIII. Mean time (sec) spent by target species in the 2 metres area surrounding traps deployed at Pioneer Bay (TRIAL 2) over the 3 days soak period. (Error bars represent standard errors)



Appendix.IX. Mean time (sec) spent by the target species in the 2 metres area surrounding traps deployed at Pioneer Bay (TRIAL 2) (Error bars represent standard errors)



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