5.0 ASSESSMENT OF CONVENTIONAL AND MODIFIED OCEAN DEPLOYED BEACH SEINES

5.1.0 Introduction

At present there are no published data available that quantitatively describes the catch compositions of NSW ocean deployed seines, the spatial and temporal variations in catches (species: target and non–target) or what percentage of these catches are comprised of juvenile fish and subsequently discarded. There are also no published studies available that examine the selectivity of conventional beach seines deployed from oceanic beaches in Australia. There are also limited publications that describe the compositions or selectivities of beach seine catches throughout the world (but see Lamberth et al., 1994; Evans et al., 1995; Tosunoğlu, Z, 2003). There are however as previously discussed, publications that examine conventional and modified estuarine deployed beach seines in NSW (see section 1.7.0 and chapter 4).

5.1.1 Examination of NSW oceanic beach seine gears

During the period November 2004–February 2005, information was gathered from members of the NSW ocean beach seine fishery to determine the fundamental similarities and differences between gears used throughout the state. Utilising NSW commercial catch data statistics provided by DPI–Fisheries, key fishers in each zone were identified, interviewed and surveyed (Survey sheet – Appendix A). Beach seines used throughout NSW, (see section 1.2.1 and Table 3), are regulated by minimum and maximum mesh sizes in specific components of the gear. All beach seines used in NSW ocean waters are regulated under the same legislation and ultimately, are similar in overall construction and configuration (see 1.2.6 and Table 2). The major differences to the gears used by specific crews were generally in the design and construction of the central bunt component and fishing depth of the gear used (number of meshes in the normal–N direction, Fig. 2).

5.1.2 Choosing a location for study

After examining the gears used throughout NSW, a suitable crew located at South West Rocks were identified to assess ocean deployed beach seines for the following reasons:

1) Fisher's use gear typical of NSW beach seine crews.
2) 52 years ocean beach seine experience of the skipper.
3) Other crew members highly experienced (including two others endorsed as skippers) –35 and 20 years experience.
4) Interest shown by crew in reducing capture of juvenile fish.
5) Crew is a full–time ocean seine crew targeting many species of fish throughout the entire year.
6) Region is highly productive and valued in relation to NSW total catches.
7) South West Rocks was a very suitable location (after consulting local commercial seine fishers).

5.2.0 General methodology

Using licenced commercial beach seine fishers in South West Rocks (30°89'S, 153°04'E) during March 2005 and July 2006, data were collected on the sizes of the target and non-target species caught in conventional and modified ocean deployed beach seines.

5.2.1 Research methodology

The following research methodologies were either utilised or considered, which was determined by: temporal and/or spatial variability and availability of catches, sea conditions and/or lack of manpower.

5.2.1.1 Alternate Haul

Initially, it was expected that an alternate haul sampling design could be used to estimate the selectivity properties of ocean deployed beach seines. Three centre bunt and codend configurations were constructed from polyethylene materials with identical twine thickness, to be attached using zippers to the conventional 80–mm anterior wings. The first configuration (termed the 'conventional') was a design that represented the majority of commercial seine net configurations used throughout NSW (general purpose haul net), with mesh sizes in the bunt ranging between 61 and 65–mm and a codend mesh of 51–mm. The second and third configurations (termed the '102' and 'control') were identical in dimensional design to the conventional, varying only in mesh size (bunt and codend 102– and 30–mm, respectively (Fig. 20). The bunts and posterior wings were rigged with zippers (Buraschi S146R, 6m in depth) to facilitate their attachment and removal upon completion of a given deployment. The two gears to be assessed (conventional and 102–mm) were to be compared against the small–meshed (control) codend in independent, alternate haul arrangements. In principle, control gears are non–selective and the size distribution of the catch should therefore be representative of the fish being encountered (Millar, R.B. and Fryer, R.J., 1999).

The order of the gears being tested was to be determined randomly and deployed following normal commercial operations. It was envisaged that two to three replicate comparisons of one of the treatment gears alternating with the control gear would be examined on each sampling day (catch size and weather dependent), with a maximum of 5 replicate deployments per day. However, due to the nature of the fishery, it was later observed that this was not practical, as different sea and wind conditions, tidal influences, moon phase and a number of other factors (see section 2.4.0), strongly influenced the behaviour and presence of travelling fish, and hence the ability to deploy a specific gear type in replication.

Commercial operators working at South West Rocks, utilise a variety of nets, which differ only in their fishing depth and length/ circumference of the codend. The specific net chosen for the haul is generally determined by the primary target species, estimates on abundance, sea conditions, depth of water and substrate consistency. Using a net with less depth allows its use in shallower water and reduces the 'sanding up' or burying of the net and directs the enclosed school of fish toward the codend. Due to the variables described above, it was not possible to utilise the experimental net at all times.

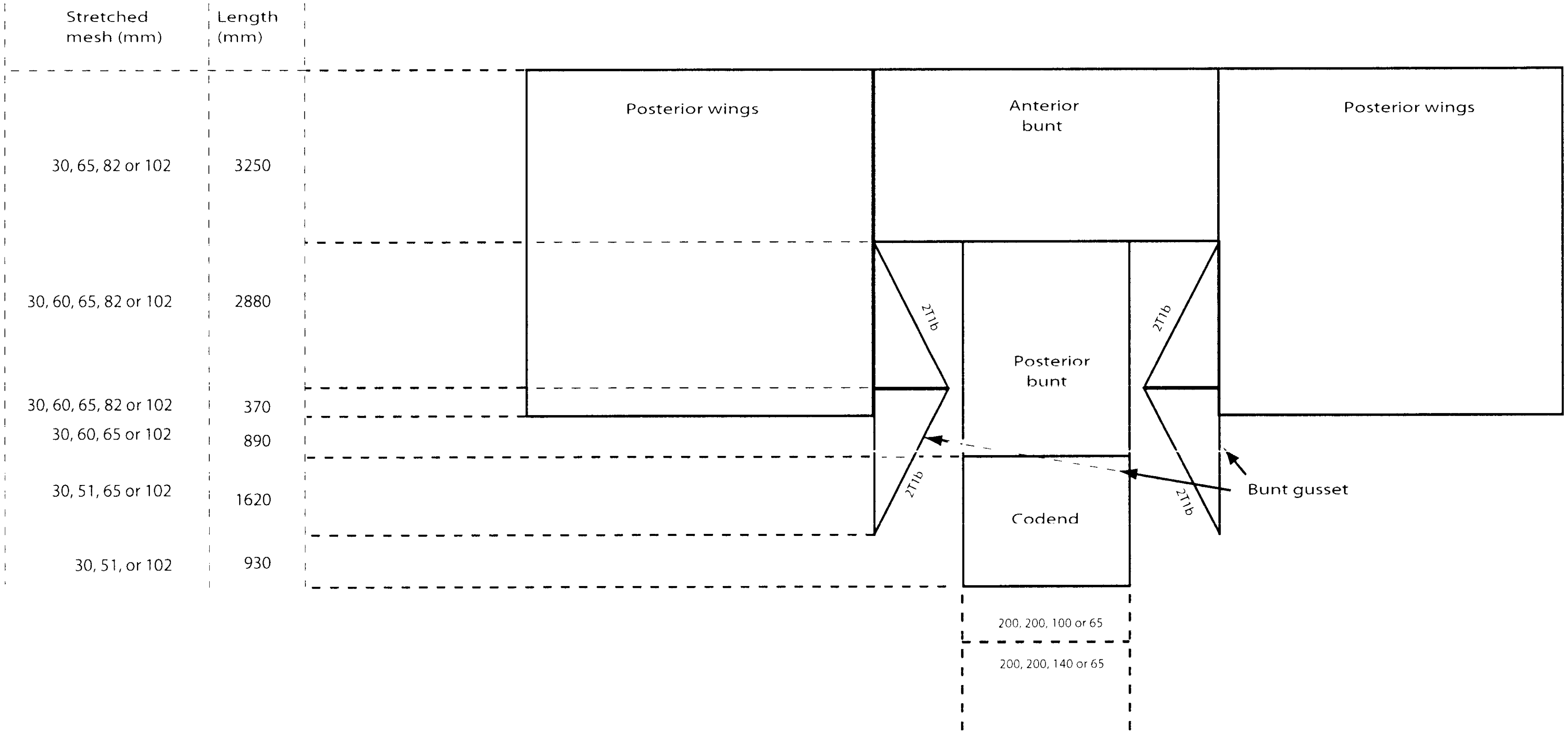

Figure 20 Beach seine net plans used in the ocean deployed selection analyses trials.

5.2.1.2 Covered codend

The covered codend method is well established and utilised in various selectivity analyses (Lamberth et al., 1995; Gray et al., 2000; Tosunoğlu, 2003; Macbeth et al., 2005a). The cover is usually attached to the gear or codend being tested, however problems encountered with previous studies (Gray et al., 2000), with fish re–entering the codend from the cover and influencing the results and hence was not adopted in this study. In addition, ocean deployed seines are affected by wave and current conditions, and would most probably have been an added issue with this method.

An attempt was made however, very similar to the covered codend method, using both the modified bunt/ codend (102–mm) attached to the conventional seine wing assembly, and a fine meshed bait net (13–mm) acting as a cover, deployed simultaneously using two rowed vessels with only 2–5 m separating the two nets (Fig. 21 and 22). After completion of the deployment, the treatment bunt, e.g. 102–mm bunt, was hauled back toward the beach with the control net's haul stalled, and located behind the modified seine configuration (Fig. 22). Once the 102–mm bunt section was at 25% of total haul time, the control gear was hauled in conjunction with the treatment gear.

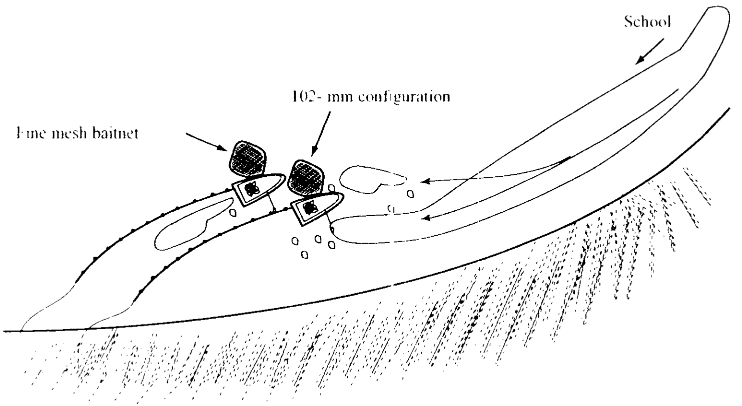

Figure 21 Utilising a fine mesh bait net to capture fish escaping through the codend.

The objective of this type of method was to ensure all fish escaping through the meshes were retained in the control bunt. This method attempted to quantify the sizes of individuals escaping through the meshes of the conventional, treatment and control bunts.

Consequently, whilst attempting a backup deployment with the bait net, we determined the method was not practical, as we lacked personnel and vehicles to complete the operation successfully. It was also noted that fish often avoided the first (treatment) net and sometimes divided, becoming trapped between the two nets and would have effectively biased the results (Fig. 22).

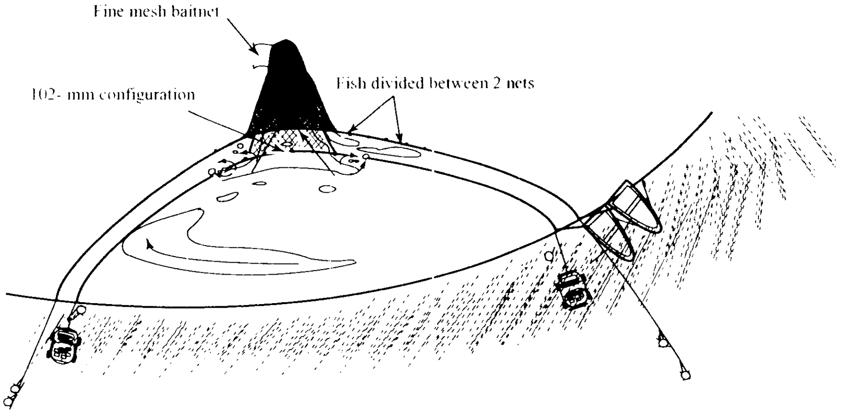

Figure 22 Difficulties whilst utilising a fine mesh bait net as a cover.

These problems are not uncommon. Gray et al., (2000) described the use of a cover net surrounding the bunt of a commercial estuary deployed beach seine and suggested that the cover influenced the effectiveness and 'true' selectivity of the gears examined, with small fish leaving the cover and re-entering the main gear when hauling neared completion. Problems are also encountered with the estimation of selectivity in this method, due to fish leaping the headline and escaping under the leadline of the treatment net, resulting in their capture in the cover net. This makes it difficult to determine which size classes actually escaped through the meshes.

5.2.1.3 Conventional ocean deployed beach seines

Due to the difficulties faced in gathering replicate hauls to assess selection characteristics in ocean deployed seines (i.e., temporal and spatial availability and variability), and due to the high value of the mono-specific catches targeted and landed during travelling season, it was determined that an observer-based survey (length frequency analysis) of conventional hauls with different net configurations would be undertaken during March 2005 –Sept 2006. These hauls were sampled in accordance with that described in section 2.2.0.

5.2.1.4 Modified ocean deployed beach seines

Towards the end of the sea mullet migrations, important benthic target species such as yellowfin bream and luderick usually begin their annual spawning migrations. Initial observations made during the 2005 season suggested the conventional seine used was poorly selective when compared with a 33–mm control bunt and codend. It was concluded that we could compare the conventional bunt and codend configuration with a 102–mm treatment (modified) bunt and codend (see Chapter 3, Table 10) describing appropriate mesh size selection.

Owing to a very brief, yet rapid, migratory season for yellowfin bream in 2004/05 (3 days observed travelling) and limited markets available for luderick, it was determined that night and morning seines (deployed in early morning or evening), in a dark moon and during suitable tidal conditions, could be achieved in replication. These seine deployments are referred to as a 'blind dig', as the quantities and species targeted are often not accurately known. It is common for some seining crews to quickly scan an area using a high–powered light, to briefly assess fish quantities and anticipated success or failure of a deployment. On other occasions, fishers believe fish become spooked and therefore they will not use lighting. Through previous fishing experience in similar conditions (sea, wind, moon phase etc), estimates are made on species compositions and expected catches (Table 5, Table 6).

5.3.0 Field Methodology

All commercial seines deployed were assessed in terms of the species and sizes captured. A maximum of 3 hauls were assessed on each day fish were caught. During the modified gear trials, a maximum of one deployment was possible on each sampling day (morning or evening).

Following each seine deployment and retrieval, catches in the pairs of posterior wings (i.e. fish that were always meshed or entangled) and codend (either meshed, entangled or otherwise) were separated on the beach, and if required, unsaleable individuals were measured, weighed and released (e.g. rays and live juveniles, if any). Upon completion, the next bunt was zippered to the wing ends and loaded onto the fishing vessel ready for deployment. The remainder or all of the catch was then either sub–sampled (if mono–specific) or, if the catch was of mixed species composition, was transported to the local fisherman's co–operative at Jerseyville, South West Rocks. The catch was then sorted into individual species (Fig. 23) and, if required, sorted into retained and discarded components. For each of the two sections of the seine, data were recorded for i) pair of posterior wings and ii) the bunt and codend (Fig. 24). The numbers and weights of the total retained and discarded catches of all species and their sizes (total length –TL to the nearest 0.5 cm for the entire catch or at least 100 randomly taken individuals for all species per seine deployment^{-1}) were collected for all seines.

Figure 23 Sorted 'blind dig' catch landed at Laggers Point, SWR, during July of 2005.

Figure 24 Sampling the catch and collecting length frequency data.

5.4.0 Results

For the key species captured in each of the gears, size frequency distributions in the (i) bunt and codend and (ii) total gear, were combined across all deployments (Figs. 25, 26, 28–30). Using the commercially used seine net configured with the 51–mm bunt and codend as a control, logistic selection curves were successfully fitted for yellowfin bream captured in the seine configured with the 102–mm bunt and codend (Fig. 27) using the estimated–split SELECT model for alternate hauls and via maximum likelihood (Millar and Walsh, 1992). Converged models were corrected for over dispersion arising from between haul variation using the replicate estimate of dispersion (Millar et al., 2004).

A total of 69 962 fish weighing 50 473 kg were caught from 53 deployments during the two year study to quantitatively assess commercial and modified ocean deployed beach seine catch characteristics, including 4 deployments utilising the 30–mm mesh bunt and codend configuration, termed 'control'. A total of 5 gears types were assessed in the study, consisting of: 3 variations of commercial seine nets, termed 'commercial, middle and long shallow'; a modified 102–mm mesh seine and a control net. An attempt was made utilising a baitnet (12 –mm diamond mesh) to completely surround the modified seine; however problems with this method resulted in its exclusion from the overall catch data (Figs. 21 and 22). Of the fish captured a total of 1 130 individuals (248.6 kg or 1.6% by number and 0.49% by weight of the total catch), were discarded because they were less than the required MLTL or MCTL, inclusive of the 'control' seine deployments.

A total of 35 species were caught during the two–year study, although more than 95 and 96% of the total catch (by number) for years 1 and 2, respectively consisted of 6 species: sea mullet (39.73 and 71.19%), luderick (15.60 and 16.20%), flat–tail mullet (23.56 and 0.57%), swallowtail dart (5.87 and 2.94%), yellowfin bream (3.69 and 5.13%) and tailor (7.49 and 0.18%). The catch rates of these 6 species were within the ranges experienced during normal commercial operations.

Irrespective of the gear and codend utilised, less than 1% of all fish were meshed or entangled in the (110m) anterior wings. Typically, the majority of the landed total catch was retained in the bunt and codend (greater than 92 and 94%) for years 1 and 2 respectively. Hence, these data were used in the analyses of differences in length distributions for individual species amongst gear types. Between 7 and 5% of fish were meshed or entangled in the (20 m) posterior wings for years 1 and 2, although the quantities of individual species of fish caught in this section varied considerably (from 0 to 65%). Each individual haul, in response to varying target species, water depth, tidal, benthic topography, and sea and current conditions, often meant that total numbers and species varied considerably also.

Greater than 98% of sea mullet captured (38, 719 of 39, 223) from all gear types were landed in the bunt and codend. This is indicative of the behavioural characteristics of travelling sea mullet and their herding behaviour away from the gear. At times however, it was visually noted and filmed, that some large schools of mullet actively attempted escape through the posterior wings. Due to their size in relation to the small meshes available for escape, a solid congregation of fish may, in their attempt to escape, force the headline under the surface and lift the leadline from the sea floor. This can lead to large proportions of the targeted school escaping from the gear in which they were enclosed. Sea mullet were visually observed to enter and attempt escape through the codend, often circling and returning to the bunt. Nearing completion of the haul, especially at times where large seas and surf were present, sea mullet were observed to utilise the wave action to leap the bunt and escape.

All catch data collected were tested with the null hypothesis of no association between gear type and size frequency distributions. This was achieved using the Minitab software package. Chi–square analysis detected significant differences in the size frequency distributions for all of the species examined in the gear types in which they were retained. Table 14 and 15 describe the gear types used and summarises chi–square analyses to determine the association between gear type and size frequency distributions amongst species, in the codend and total seine catch, respectively.

Table 14 Results of chi square analyses to determine the association between gear type and size frequency distributions for the 10 key species captured in the codend of ocean deployed beach seines. $P << 0.001 = ***^{sd}$, $P < 0.01$ $**^{sd}$, $P < 0.5$ $*^{sd}$ (^{sd} = significant difference). ✓ = gears included in analyses, NA = insufficient data to complete analyses.

Species	Chi square	Probability	Commercial	Middle	Long shallow	102- mm	Control
Sea mullet	$\chi^2_{16} = 1986.0$	$P << 0.001^{***sd}$	✓	✓	✓	✓	✓
Yellowfin bream	$\chi^2_{12} = 273.7$	$P << 0.001^{***sd}$	✓	NA	✓	✓	✓
Luderick	$\chi^2_{12} = 944.4$	$P << 0.001^{***sd}$	✓	NA	✓	✓	✓
Tarwhine	$\chi^2_{4} = 61.8$	$P << 0.001^{***sd}$	✓	NA	NA	✓	NA
Tailor	$\chi^2_{4} = 91.8$	$P << 0.001^{***sd}$	✓	NA	NA	✓	NA
Flat-tail mullet	$\chi^2_{4} = 52.0$	$P << 0.001^{***sd}$	✓	NA	NA	✓	NA
Sand whiting	$\chi^2_{4} = 17.3$	$P < 0.002$ $**_{sd}$	✓	NA	NA	✓	NA
Bigeye trevally	$\chi^2_{4} = 12.4$	$P = 0.015$ $*_{sd}$	✓	NA	NA	✓	NA
Silver trevally	$\chi^2_{4} = 23.4$	$P << 0.001^{***sd}$	✓	NA	NA	✓	NA
Swallowtail dart	$\chi^2_{4} = 204.2$	$P << 0.001^{***sd}$	✓	NA	NA	✓	NA

Table 15 Results of chi square analyses to determine the association between gear type and size frequency distributions for the 10 key species captured in the total seine of ocean deployed beach seines. $P \ll 0.001 = {***}^{sd}$, $P < 0.01$ ${**}^{sd}$, $P < 0.5$ ${*}^{sd}$, (^{sd} = significant difference). ✓ = gears included in analyses, NA = insufficient data to complete analyses.

Species	Chi square	Probability	Commercial	Middle	Long shallow	102- mm	Control
Sea mullet	$\chi^2_{16} = 3922.9$	$P \ll 0.001^{***sd}$	✓	✓	✓	✓	✓
Yellowfin bream	$\chi^2_{12} = 256.9$	$P \ll 0.001^{***sd}$	✓	NA	✓	✓	✓
Luderick	$\chi^2_{12} = 1002.4$	$P \ll 0.001^{***sd}$	✓	NA	✓	✓	✓
Tarwhine	$\chi^2_{4} = 34.9$	$P \ll 0.001^{***sd}$	✓	NA	NA	✓	NA
Tailor	$\chi^2_{4} = 45.1$	$P \ll 0.001^{***sd}$	✓	NA	NA	✓	NA
Flat-tail mullet	$\chi^2_{4} = 51.9$	$P \ll 0.001^{***sd}$	✓	NA	NA	✓	NA
Sand whiting	$\chi^2_{4} = 29.6$	$P \ll 0.001\ {***}_{sd}$	✓	NA	NA	✓	NA
Bigeye trevally	$\chi^2_{4} = 9.5$	$P = 0.05\ {*}_{sd}$	✓	NA	NA	✓	NA
Silver trevally	$\chi^2_{4} = 34.6$	$P \ll 0.001^{***sd}$	✓	NA	NA	✓	NA
Swallowtail dart	$\chi^2_{4} = 234.5$	$P \ll 0.001^{***sd}$	✓	NA	NA	✓	NA

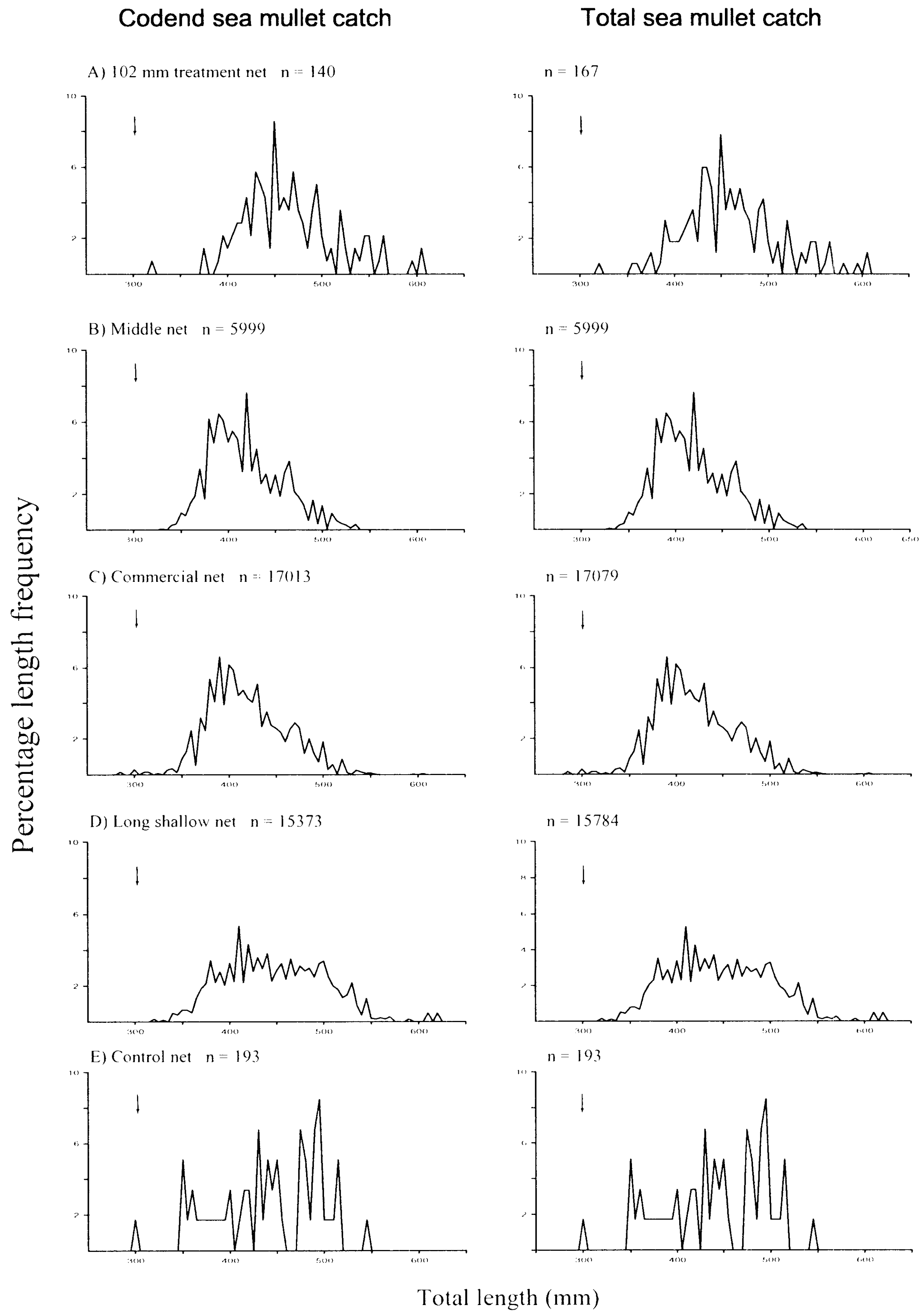

Figure 25 Percentage length frequency of sea mullet (*Mugil cephalus*) captured in the codend and total catch in A) treatment, B) middle, C) commercial, D) long shallow and E) control nets. Arrow indicates legal size of sea mullet (300 mm).

Sea mullet were tested with the null hypothesis of no association between 5 different gear types: 102–mm, middle, commercial, long shallow and the control (Table 14 and 15, Fig. 25) and respective length frequency distributions for both the codend and total seine catches. The null hypotheses was rejected, X^2_{16} = 1986.0, 3922.9, respectively (Table 14 and 15), illustrating significant differences amongst gear type and length frequencies, $P<<0.001$. In total, 36 721 or 94% (by number) of all sea mullet were captured in the bunt and codend from all deployed seines for years 1 and 2. A total of 461 fish or < 1.15% by number caught in all gear types were less than 350 mm TL.

Of all gears utilised, a total of 25 or < 0.1% of sea mullet by number were less than 300 mm, the MLTL for this species. Of the 3 conventional configurations, which caught a total of 36 363 sea mullet, > 91% captured ranged between 350 and 500 mm TL. This is comparable with the distributions found throughout all gears.

The 102–mm modified bunt and codend were utilised on 13 separate hauls, with 7 hauls containing sea mullet. Data were pooled for all hauls using the 102–mm configuration. A total of 167 sea mullet were caught in the 102–mm configuration, with 84% captured in the bunt and codend. Of the sea mullet caught in the 102–mm bunt and codend, 88% had TL's ranging between 350 and 500 mm, with the majority 62.9% greater than 450 mm TL.

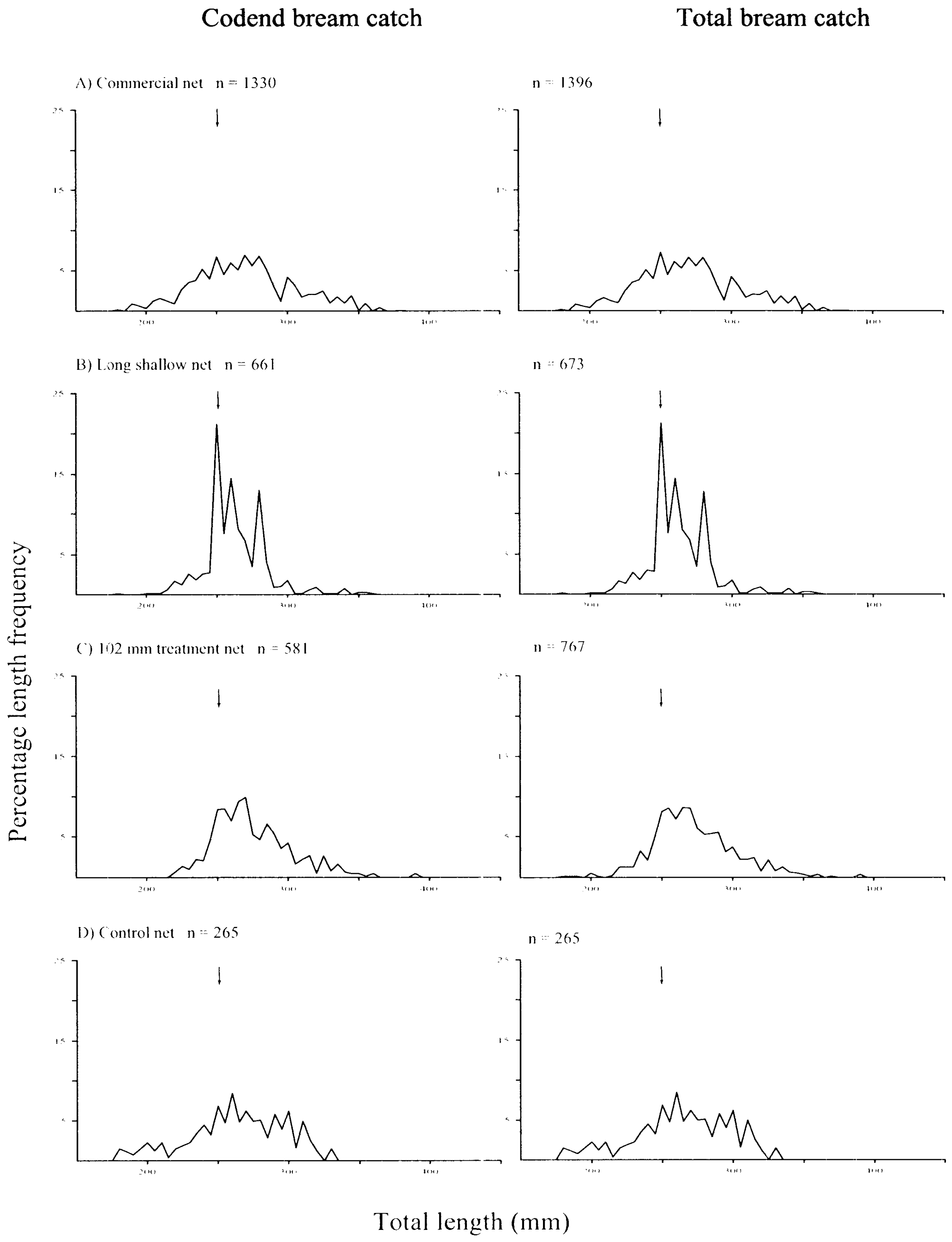

Figure 26 Percentage length frequency of yellowfin bream (*Acanthopagrus australis*) captured in the codend and total catch in A) commercial, B) long shallow, C) treatment and D) control nets. Arrow indicates legal size of yellowfin bream (250 mm).

Yellowfin bream were tested with the null hypothesis of no association between 4 different gear types: 102–mm, commercial, long shallow and the control (Table 14 and 15; Fig. 26) and length frequency distribution for both the codend and total seine catches. The null hypotheses were rejected, X^2_{12} = 273.7, 256.9, respectively (Table 14 and 15), P<<0.001, indicating the gear utilised affected the size frequency distributions of retained yellowfin bream.

In total, 2 837 or 93 % of total retained yellowfin bream, were caught in the bunt and codend, from all observed hauls for both years. Of the yellowfin bream retained in the commercial codend, 23.6% were less than the 250–mm MLTL. In comparison, a reduction of almost half, 12.0% in the modified 102–mm bunt and codend were below the MLTL. Data were pooled for all seine configurations that captured yellowfin bream, with a total of 580 fish or 19.9% (by number) less than the MLTL were captured in the bunt and codend, in all gear types. The two commercial bunt and codend configurations used throughout both years accounted for 75% of the undersize yellowfin bream catches.

The 102–mm modified bunt and codend configuration were used on 13 separate hauls, with 8 hauls containing yellowfin bream. Data were pooled for all deployments using the modified seine. A total of 767 bream were captured, with 76% captured in the bunt and codend. Eighty eight percent had TLs greater than the MLTL. The majority of the undersize bream retained in the bunt and codend were within sizes ranging 225–245 mm TL. These were also observed to be at times were the posterior wings convoluted and entangled fish.

During the spawning migrations of yellowfin bream, (3 days observed in 2005), the majority of these schools were observed to be either mono–specific, or were intermingled with luderick and sea mullet. It is important to note that during these periods, bycatches were minimal or non–existent. Due to the short, yet rapid, migration of yellowfin bream, limited personnel available to complete alternated hauls, and with the presence of competing commercial crews, only a small number of deployments were achievable utilising the 102–mm modified seine configuration.

Using the 51-mm commercial seine as a control, attempts were made to converge logistic selection curves to model the selection in the modified 102–mm seine (Fig. 27).

The L_{50} = 23.31 (0.28) corresponded closely to the predicted girth for the mesh size (Fig. 19). The selection ranges (SR's) were quite narrow, 1.65 (0.41).

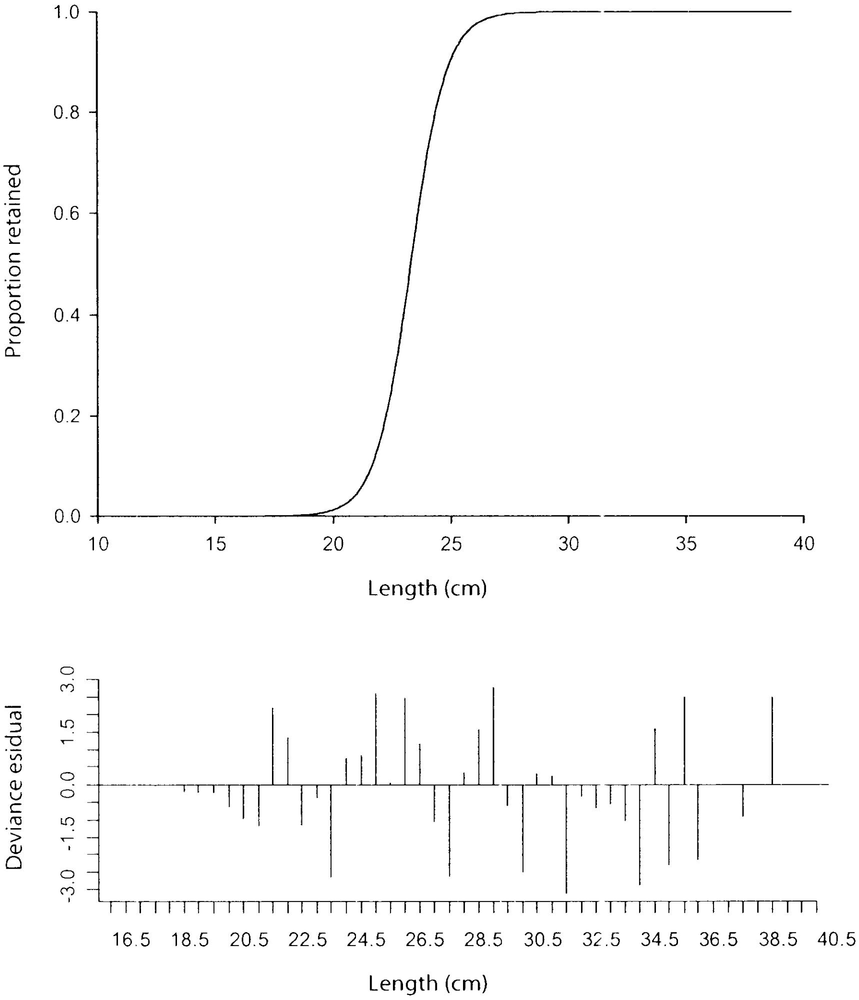

Figure 27 Converged logistic selection curve generated for yellowfin bream captured in the modified (102–mm) bunt and codend using the commercial (51–mm) bunt and codend as a control.

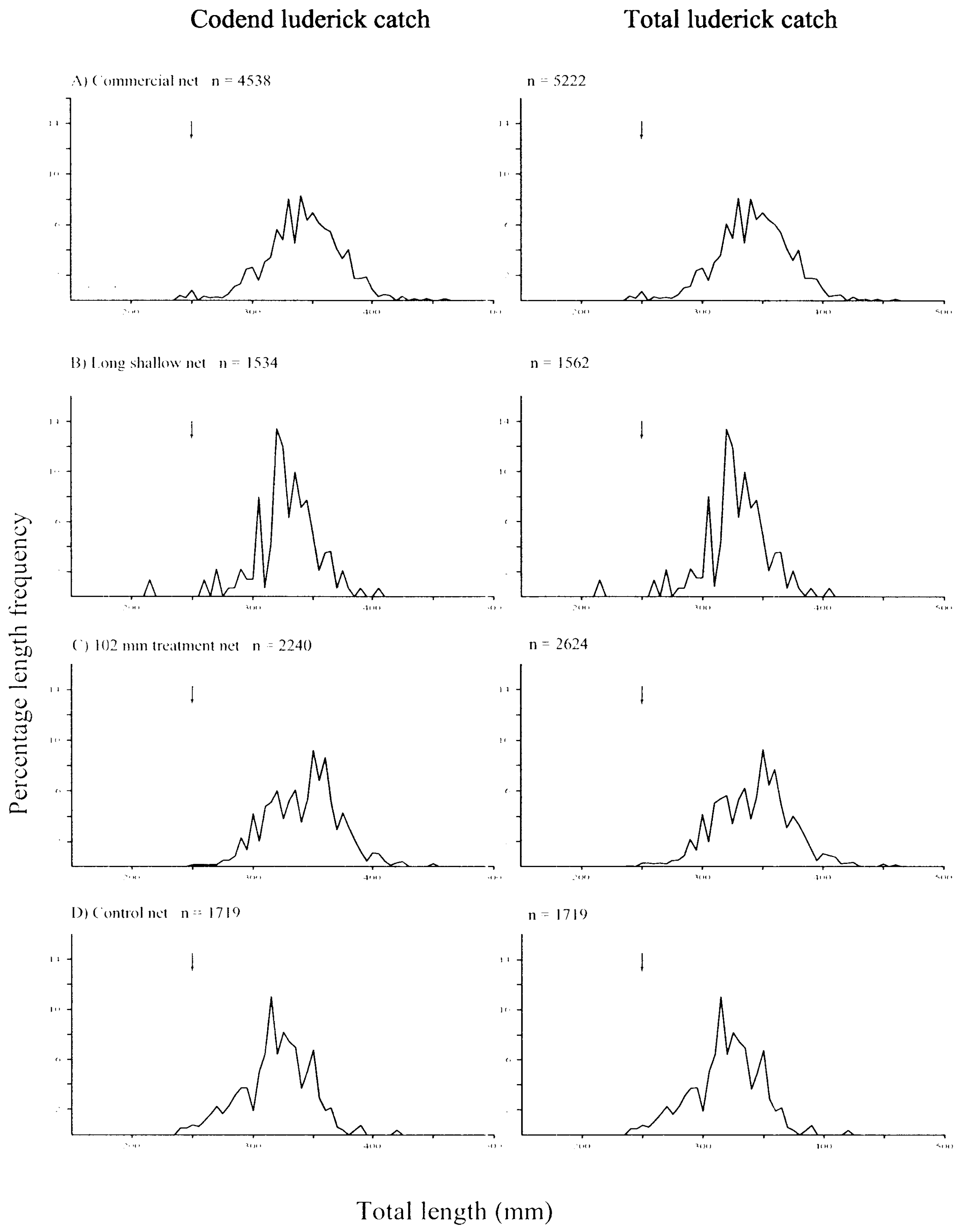

Figure 28 Percentage length frequency of luderick (*Girella tricuspidata*) captured in the codend and total catch in A) commercial, B) long shallow, C) treatment and D) control nets. Arrow indicates legal size of luderick (250 mm).

Luderick were tested with the null hypothesis of no association between 4 different gear types: 102–mm, commercial, long shallow and the control (Tables 14 and 15, Fig. 28) and length frequency distribution, for both the codend and total seine catches. The null hypotheses were rejected, X^2_{12} = 944.4, 1002.4, P<< 0.001, indicating the gear utilised affected the size–frequency distributions of retained luderick. In total, 11 132 luderick were captured in the bunt and codend from all observed hauls for years 1 and 2. A total of 67 fish or 0.6% by number captured in the bunt and codend in all gear types were less than the 250 mm MLTL.

The two commercial bunt and codend configurations, commercial and long shallow, used throughout both years accounted for 72% of these minor contributions by undersize luderick.

Of the 13 separate hauls where the modified bunt and codend were utilised, 10 hauls contained luderick. Data were pooled for all deployments using the 102–mm configuration. A total of 2 625 luderick were captured in the 102–mm configuration, with 85% captured in the bunt and codend. All luderick captured in the 102–mm bunt and codend had TL's greater than the MLTL.

During the observed spawning migrations of luderick, the majority of these schools were mono–specific. It is important to note that during these periods, bycatches were minimal or non–existent. On the rare occasion, luderick were intermingled with yellowfin bream and/or sea mullet and flattail mullet. Due to the specific demands and markets available for large quantities of luderick, only a limited number of deployments were performed. During, late June and July of 2006, numerous mono–specific schools of luderick were observed to be travelling past the designated hauling grounds off SWR, however deployments were only completed when those specific demands needed meeting.

Data were unsuccessful in generating selectivity curves for luderick captured in the seines rigged with the 102–mm bunt. This is most probably due to the absence of quantities of juveniles amongst all gears.

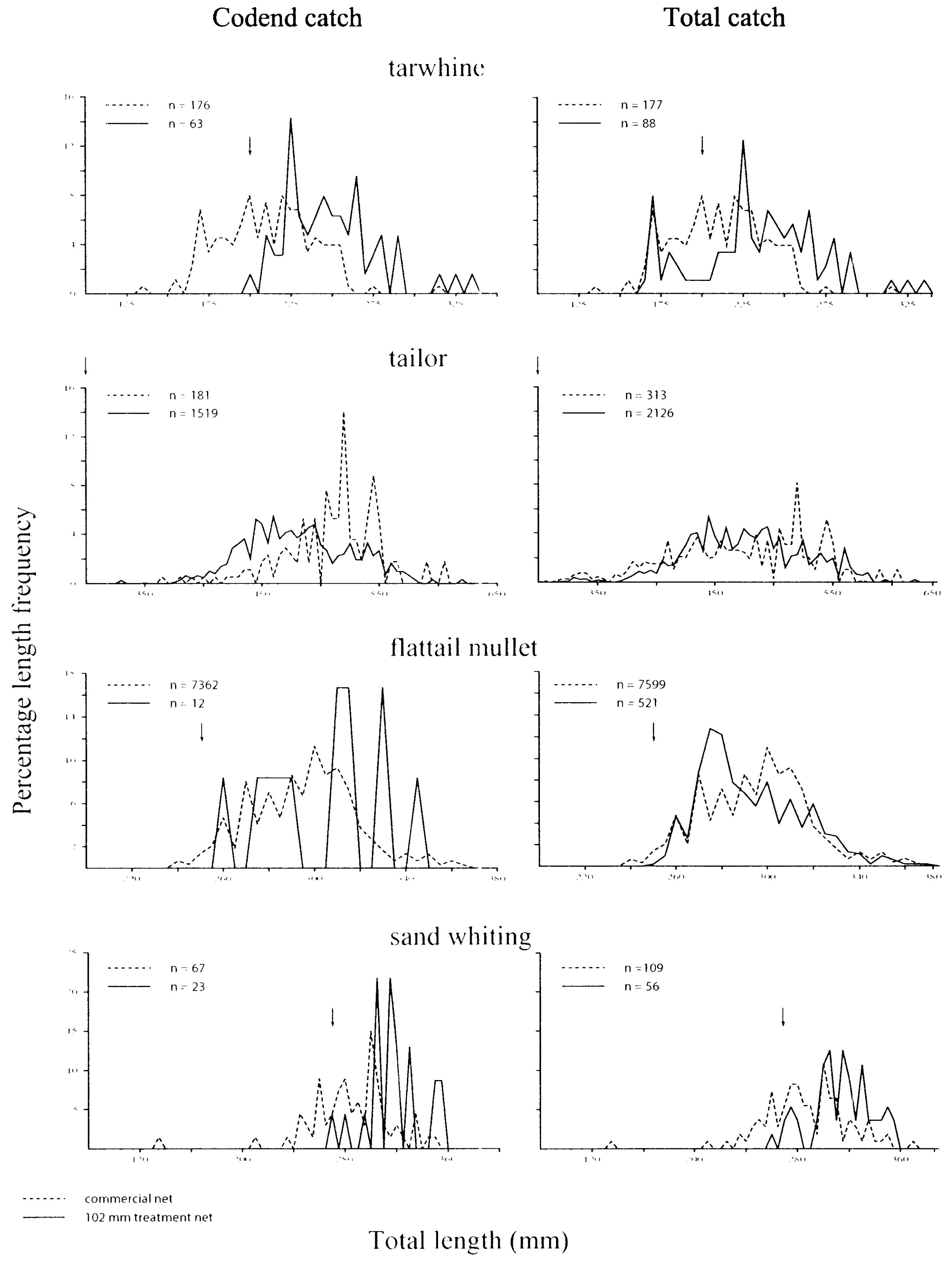

Figure 29 Percentage length frequency of tarwhine (*Rhabdosargus sarba*), tailor (*Pomatomus saltatix*), flattail mullet (*Liza argentea*) and sand whiting (*Sillago ciliata*) captured in the codend and total catch in the modified 102-mm treatment and commercial seine configurations. Arrows indicate legal sizes of species.

The following species were also investigated with the null hypothesis of no interaction between gear type and the length frequency distribution of retained individuals: tarwhine, tailor, flattail mullet, sand whiting, bigeye trevally, silver trevally and swallowtail dart. These species were assessed in terms of their catches from 2 gear configurations, the commercial and the modified 102–mm bunt and codend and total catch. Chi square analyses of these species demonstrated significant differences in their respective length frequencies between the two gear configurations (Tables 14 and 15), codend catch and total catch for all species.

Figures 29 and 30 illustrate the percentage length frequencies between the 2 gears configurations examined for both the codend and total catch for the remainder of the species captured with adequate numbers. These data were not sufficient to enable attempts at modelling selectivity for these species. It is quite evident however, the modified 102–mm bunt/ codend was more efficient in allowing juveniles of a number of these species to be discarded at greater proportions than through the currently legislated commercial net. This also applies to species such as flattail mullet, bigeye trevally, silver trevally and swallowtail dart (which possess no MLTL), and in the case of flattail mullet, with limited market potentials.

Figures 29A–D; 30A–C illustrate the significant variation in percentage length frequency distributions between the 102–mm and the commercial configuration. The relative shift in distribution for tarwhine is quite substantial in the codend, illustrating the reduction in catches of juveniles for these species through the codend (Fig. 29A). However, the posterior wings play a key role in the retention of juveniles for this species, hence influencing the total catch distribution.

Figure 29B and C illustrate the length frequency distribution for tailor and flattail mullet. Both are species which reveal a broad influence on their capture by the posterior wings. The majority of tailor caught were captured in the modified 102–mm configuration, but this was attributable to one 'blind dig' seine deployment in July of 2005. Fifty seven and 71% of tailor (by number) were captured in the codend during pooled commercial and modified seine deployments. This contrasts substantially with flattail mullet which were caught in the commercial and modified bunt and codend at 97 and 2% respectively. The substantial decrease in retained flattail mullet caught in the modified seine configuration is attributable to the species morphology and the size of the available mesh openings in the bunt and codend. Large quantities of flattail mullet were observed to escape successfully. Flattail mullet are species for which there are limited market demands and this species, during periods of no market availability, are often discarded.

Even with limited catches of sand whiting in both the commercial and modified gears, n= 109 and 56, significant differences in length frequencies were revealed. Sixty one and 41% of total sand whiting catches were retained in the bunt and codend of the commercial and modified gears, respectively. Figure 29D illustrates the significant reduction in juvenile sand whiting captured in the modified seine. It is quite probable that legal-size individuals also escaped through this gear. One observed haul during April of 2005, the only deployment over the 2 years that targeted a sand whiting school, utilised the modified seine. This school once encircled was estimated at ~ 200kg. Sand whiting were visually observed to enter the bunt and escape through the tail of the codend. Only large fish (22 individuals weighing 5.45 kg) were retained in the codend. Only 1 whiting was caught in the modified bunt and codend for the remainder of observed seine deployments. Of the 109 sand whiting captured in the commercial and modified seine configurations, 75 and 98% were greater than the MLTL.

There was a significant interaction between gear configuration and length-frequency distributions in both codend and total catches, for bigeye and silver trevally and swallowtail dart (Table 15).

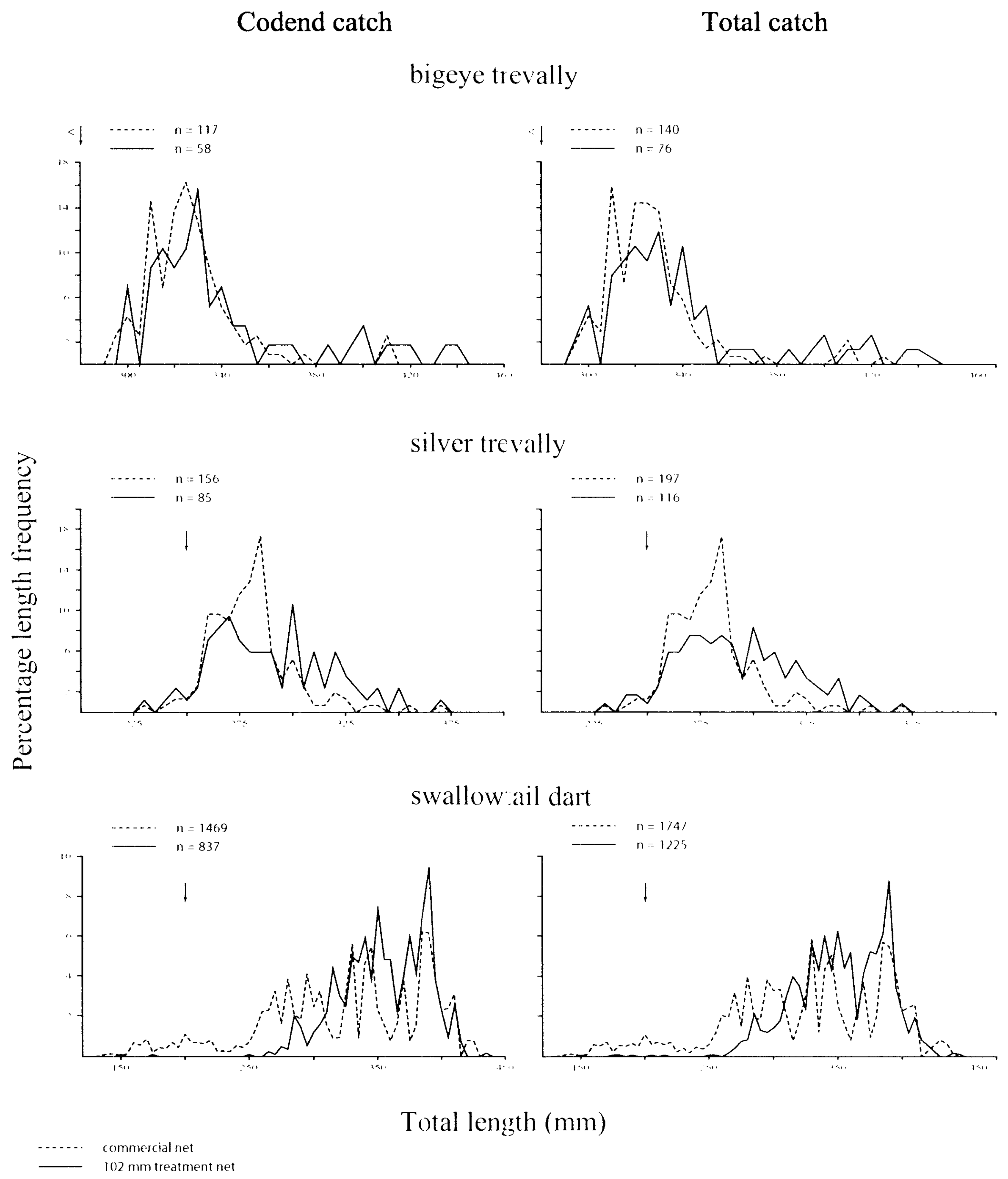

Figure 30 Percentage length frequency of bigeye trevally (*Caranx sexfasciatus*), silver trevally (*Psuedocaranx dentex*) and swallowtail dart (*Trachinotus coppingeri*) captured in the codend and total catch in the modified 102-mm treatment and commercial seine configurations. Arrows indicate minimum commercial sizes for the species.

5.5.0 Discussion

The examination of larger mesh sizes in the bunt and codend in this study showed that the current configurations of NSW beach seines are inappropriate for maximizing size selectivity for nearly all of the retained species. The data presented here correspond with previous studies which indicate a broad, species–specific influence of the posterior sections on the overall selection of the gear. This was most apparent in blind–digs; however, during the majority of hauls which targeted mono–specific schools of travelling fish, up to 100% of the catch was landed in the bunt and codend. Broadhurst et al. (2006a) suggests the morphology and behaviour of some of the main targets can be used as a first step in predicting appropriate mesh sizes and areas suitable to maximise selection.

Visual observations indicate that migratory species were unaware of the gear until the seine had completely surrounded and entrapped the school. This is attributable to the behavioural characteristics of actively travelling fish which swim parallel with the shoreline. For example, it was observed that the normal migratory travelling behaviour of sea mullet, bream and luderick, meant that the school was directed toward the anterior wing that was first deployed. The fish reacted with the anterior wing as if it were a natural barrier and were calmly directed toward the posterior wing and eventually into the codend. Catches in the posterior wings were quite low, less than 5 and 7% for years 1 and 2 respectively, and were most prevalent at times where the meshes convoluted and collapsed. This occurred because i) the bunt and codend was thrown from central alignment due to turbulent swell activity and/or through strong rips and currents, and/or ii) whilst being hauled over large areas with reduced water depth, iii) nearing completion of the haul in shallow waters. Deploying a seine net with a reduced mesh size without reducing twine diameter, directly increases the net's total surface area, and consequently increases drag and resistance. Ultimately, this makes a net more susceptible to surf, tide and current influences, and may disrupt the ability of the net to consistently maintain a parabolic shape and contact with the substrate during the haul. During the final processes of net retrieval, and when the above occurred, the net convoluted and acted like an entanglement net. This reduced the chances of fish locating the entrance to the codend, where the majority of the catch usually attempts escape, furthermore hindering selection by reducing the number of available meshes open.

5.5.1 Increasing the mesh size from 51–mm (commercial) to 102–mm (modified) bunt and codend

10 key species were examined with the null hypothesis of no association between gear type and length frequencies. All species were assessed using chi square analyses, and all displayed significant differences (Table 14 and 15). The three key species most prevalent by weight, (sea mullet, yellowfin bream and luderick), were assessed in all gears in which they were captured in reasonable numbers. The following species were also captured in reasonable numbers in the 102–mm modified and commercial nets: tarwhine, tailor, flattail mullet, sand whiting, bigeye trevally, silver trevally and swallowtail dart, allowing analyses.

Regardless of the gear utilised to catch sea mullet during their annual spawning migrations, less than 1% were below the MLTL. In addition, the majority of observed hauls targeting sea mullet were mono–specific. It is important to note that during these periods, bycatches were minimal or non–existent. This typically suggests that currently enforced gears for these periods are satisfactory. However, towards the end of the sea mullet spawning migrations, the yellowfin bream migration begins and often overlaps with that of sea mullet. It was observed that during these periods, mono–specific schools of both species were present. On the rare occasion during this period, schools of fish may have mixed–species combinations, and include the three key species, bream, luderick and sea mullet. During these periods, fishers are not currently permitted to utilise a seine with increased mesh sizes.

Sea mullet catches landed in the modified 102–mm bunt and codend, illustrate dominant size–frequency distributions ranging between 450 and 500 mm. The modified seine however, can be utilised in environments usually not conducive to successful results; (i.e., the reduced surface area of the larger meshes allows its use in bigger seas due to a decrease in the effects of drag). It appears that sea mullet less than 400–mm were able to escape at a greater proportion through the modified configuration. However this may be indicative of the seasonal changes in sea mullet size structures late in the travelling season as, nearing the end of the sea mullet spawning migrations, larger individuals with greater percentages of females were captured, regardless of the gear deployed.

Deployments sampled during the mono–specific 'hardgut' migrations of yellowfin bream, indicate these schools may comprise large quantities of juvenile conspecifics. From the selection curves plotted for yellowfin bream captured in the 102–mm modified codend, demonstrating an L50% value of 23.3, simple modifications, such as increasing mesh size throughout the bunt/ codend of existing beach seines, are indicated as an appropriate strategy that can significantly improve the size selection of some species and reduce unwanted bycatch. As suggested in Chapters 3 and 4 and Broadhurst et al., (2006c) the minimum mesh size in estuarine beach seines used in NSW could be doubled without significantly reducing the total retained catch of key target species. This also seems applicable in regards to ocean deployed seines, specifically at times where targeted fish are mono–specific in nature (i.e. yellowfin bream and luderick). Therefore, it appears reasonable to allow commercial beach seine operators a range of mesh sizes that they deem suitable to reduce the capture of unwanted juvenile conspecifics.

With 99.4 % of luderick captured throughout all gears greater or equal to the minimum legal total lengths, and with the majority of catches mono–specific or with minimal interactions with other species (mixing), indications are that these species are harvested in a manner which results in the capture of only targeted individuals. Schools of luderick were observed to travel within metres of the shoreline, providing accurate estimations on their abundance. This attribute allows commercial seine operators to capture fish as the market deems necessary, or when no markets are available there is no fishing and no impact on their migratory behaviour. Anecdotal information provided by fishers, indicate juveniles of the species are irregularly encountered, however during these times, increasing the mesh size may be appropriate in reducing the capture of these individuals.

A total of 2439 tailor were captured during the two years of study, and of these individuals 100 % were larger than the MLTL. Increasing the mesh size to 102-mm reduced the capture of individuals ranging between 350 –450 mm with the majority of tailor ranging between 450 and 600 mm. The only disadvantage was that a large proportion of individuals were meshed in the 102–mm bunt and codend. However, regardless of the mesh size, these individuals would most probably have been captured due to their morphology. The use of a smaller mesh in these instances may have decreased the meshing of the fish, and with the drawstring removed, allow the majority of unmeshed fish to escape.

Tarwhine that were captured within the codend of the modified seine showed significant improvements in the reduction of undersize individuals. However, the influence of the posterior wings on retained juveniles influenced the total catch distribution. Corresponding with conclusions formed by Broadhurst et al. (2006), increasing the mesh size throughout the posterior wings and the bunt and codend, may improve the overall efficiency of the total seine in removing juvenile target species from the catch Flattail mullet that were caught throughout all gears were mainly landed during 'blind dig' deployments. The use of the modified seine significantly decreased the capture of these individuals which have limited commercial value. Owing to the morphological attributes of this species, few individuals were caught in the modified codend; however, individuals were nonetheless captured in the posterior wing sections of the seine. An increase in mesh size in these areas would have almost eliminated the capture of these species. Similarly, total sand whiting numbers caught in the modified seine were reduced, with catches in the posterior wings maintained. Sand whiting, a highly valuable species targeted at various locations throughout NSW during the year, require the use of mesh smaller than the modified seine used here. Conclusions formed in chapters 3 and 4, indicate a suitable mesh size of approximately 57–mm to reduce the capture of unwanted juveniles of this species. This complements previous suggestions indicating fishers require a range of mesh sizes for use during periods where target species are mixed or variable.

Caringidae species (i.e., bigeye and silver trevally), are species which have no MLTL, and were assessed in terms of their MCTL (Table 1). One hundred percent of bigeye trevally and more than 97% of silver trevally captured were greater or equal to their MCTL in all gears. Compared with the conventional seine, the 102–mm modified seine shifted the percentage length frequency retained for individuals greater than 300 mm, from 13 to 42% respectively; indicating the modified seine reduced the capture of individuals below this size. Swallowtail dart size distributions above the MCTL were greatly improved in the modified seine. 0.6% of dart captured in the total modified seine were smaller than the MCTL, in comparison with 10.5% captured in the total commercial seine. These data also provide rationale for an increase in mesh size, when targeting mixed species populations.

The summaries provided above indicate that during periods where sea mullet are not targeted, a simple increase in mesh size could be beneficial in reducing the catches of juveniles of a number of species, whilst maintaining adult targeted catches. However, the strong contributory influence of the posterior wings on the catches during these deployments, indicate these areas may also require similar increases in mesh size. Whilst there is the added problem of meshing and net convolution in these areas, another alternative that may prove to be beneficial could be to reduce the mesh sizes in the posterior wings, maintaining an increase in mesh size in the bunt and further enhance the concentration of fish towards the bunt, an area deemed suitable for modifications to current gear configurations to improve size selection.

6.0 SURVIVAL, PHYSIOLOGICAL STRESS AND PHYSICAL DAMAGE TO YELLOWFIN BREAM (*Acanthopagrus australis*) AFTER SIMULATED ESCAPE THROUGH A 102–MM BEACH SEINE CODEND

6.1.0 Introduction

Of the species targeted in the NSW beach seine fisheries, yellowfin bream are valued in the top 4 species by weight and are the third most valuable, averaging approximately AU$ 400, 000 in 2004/05. Estuarine and oceanic deployed beach seines per annum for this period landed approximately 46 and 52 tonnes respectively, of yellowfin bream. Ocean based beach seines target mono–specific schools of migratory adults during their annual spawning run, but at other times of the year, unpublished data indicate that catches landed from certain operations may infrequently contain juveniles of this target species. As described in Chapter 4, estuary deployed beach seines incidentally catch large quantities of juvenile conspecifics, which is both temporally and spatially variable. The perceived mortalities of these individuals and the associated impacts on fish stocks, has increased attention and focus on methods to mitigate these issues.

As described earlier, commercial beach seining operations are managed ultimately through: restrictions on mesh sizes, dimensional limitations on the gears used, and minimum size limits for the target species. The benefits of these management controls in reducing the mortality of juveniles and conserving stocks, will only be apparent if a large percentage of juveniles survive the processes of capture and subsequent escape (for reviews see; Chopin and Arimoto, 1995; Broadhurst et al., 2006a).

Morphological relationships were plotted in Chapter 3, and an increase in mesh size from 51–mm to 102–mm (hung on the diamond), was identified as an appropriate modification to allow the majority of juvenile yellowfin bream to escape whilst maintaining legal sized individuals during mono–specific targeting of the species. Subsequently, trials were undertaken at South West Rocks between February–March of 2005 and July–September of 2006. With support from local fishers, the modified gear was deployed during both the day and night targeting benthic species including yellowfin bream, tarwhine and luderick (Chapter 5).

Nonetheless, there is a lack of published data available concerning the fate of juvenile fish that escape through the meshes of a beach seine. The following laboratory experiments were done to assess and quantify 1) the survival, 2) physical damage and 3) physiological stress to yellowfin bream after simulated capture and escape through a 102–mm seine codend.

6.2.0 Materials and methods

Two laboratory experiments were done in the aquaria facilities of the National Marine Science Centre, Coffs Harbour between December 2005 and April 2006. The experiments aim to assess survival and quantify the physiological stress and physical damage to yellowfin bream after simulated escape through a 102–mm beach seine codend. The null hypotheses tested were no significant differences in mean cortisol and glucose levels (indicators of secondary and chronic stress), percentage scale–loss and mortality between treatment and control fish.

6.2.1 Fish collected for the studies

Approximately 220 yellowfin bream (ranging in TLs of 150–250 mm) were used in each of the experiments. Fish were collected from the Clarence River using short deployment of a prawn trawl and transported to the National Marine Science Centre's aquaria facilities between December 2005 and January 2006. This method of collection provided fish ranging from 200 mm to 250 mm TL. Similarly, fish were transported from Palmers Island (Searle Aquaculture) at TLs ranging between 150–200 mm. Fish were held at the NMSC tank farm in 3000–L polyethylene circular holding tanks for a period of up to 4 months and fed a diet of fish pellets and chopped prawns at a rate of 1% biomass per day.

6.2.2 Stocking experimental tanks

The holding tanks (3000 L capacity) were lowered to 1000 L and fish lightly anaesthetised (Barker et al., 2002) using benzocaine (ethyl–p–aminobenzoate, 25–35 mg L^{-1} in seawater). One hundred and ten fish were selected at random using 10 L buckets and two individuals placed randomly in each of the 48 x 113L experimental plastic tanks, and 2 individuals in each of the 7 spare experimental tanks (Fig. 31).

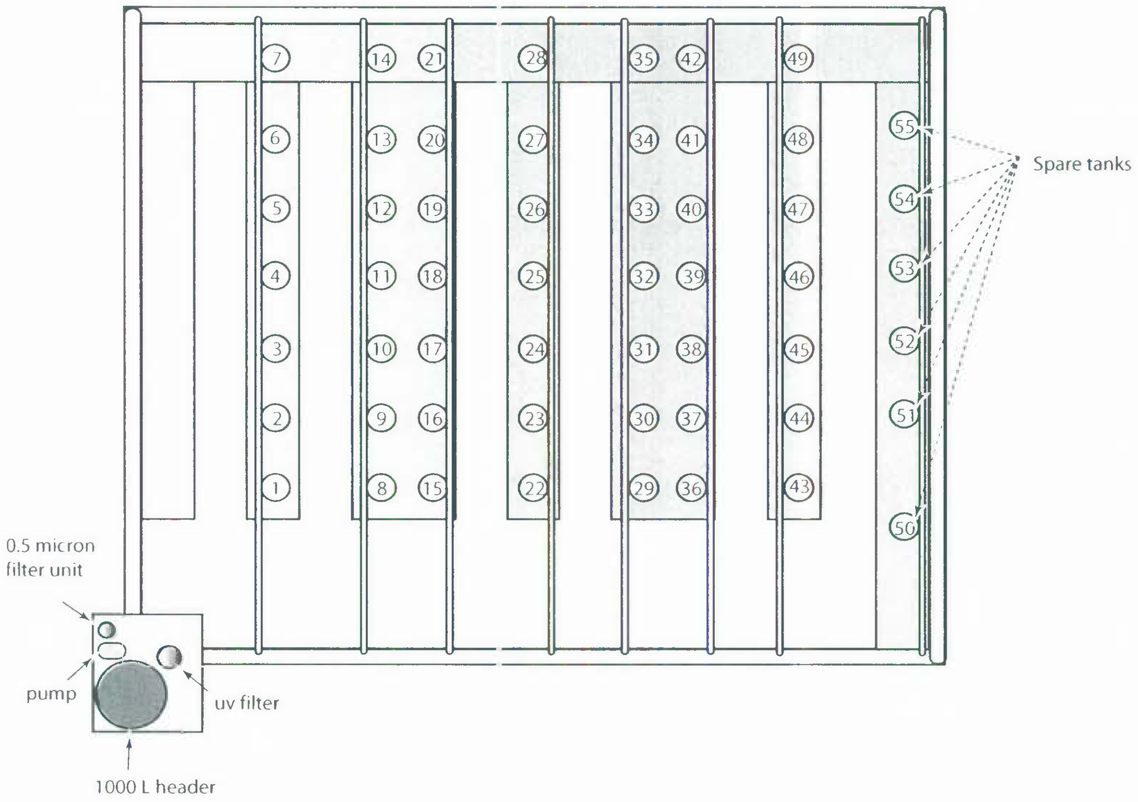

Figure 31 Aquarium room setup

All experimental tanks were supplied with seawater (ambient temp –approx 23°C) at a rate of 30 L min^{-1} and aerated using stone diffusers. Tanks were arranged and numbered sequentially in a 12–hour photoperiod room in the NMSC aquaria laboratory. Tanks were covered with 16–mm black polyamide meshing, to prevent fish escaping, and were surrounded in circumference with black plastic to maintain even light penetration and reduce the stress associated with excessive illumination. All tanks were monitored daily for a period of two weeks and, if required, mortalities substituted with replacement fish from the spare experimental tanks.

6.3.0 Experiment 1. Quantifying short–term mortality

Water levels in the 3000–L circular tanks were lowered to allow fish to be randomly removed using buckets. Within 2 minutes of disturbance, five fish were randomly selected and tested for baseline cortisol levels. This was achieved by securing individuals dorsally in a foam block and blood extracted using 21 gauge heparinised syringes. Within 1 hour, labelled samples stored on ice had plasma separated by centrifugation (at 5000 rpm), and further frozen to allow blood chemistry analyses on fishes stress, (see Exp. 2).

A pump assembly (1500 GPH bilge pump fitted inside a 250 mm storm–water pipe) was submerged in the experimental tanks and activated, forcing water from 10 strategically placed holes located on a 40 mm hose fixed 90° to the storm–water pipe (Figure 31 B). The water flow produced (0.38 m/s $^{-1}$; measured using a PC1–SS Pigmy velocity meter) a circular motion of water, simulating the fatigue generated by fish whilst herding in a seine haul. After 10 minutes of swimming against the flow, most fish became exhausted to a point where they drifted around the tank in the direction of the flow.

A small–meshed aluminium cage and net assembly were sequentially placed in the experimental tank, and a white perspex sheet inserted behind the net assembly and held in position. The net assembly was then rotated clockwise, consecutively herding and forcing the fish to pass through the meshes (Fig. 32D). The cage and net assembly were then removed with corresponding times recorded on appropriate data sheets.

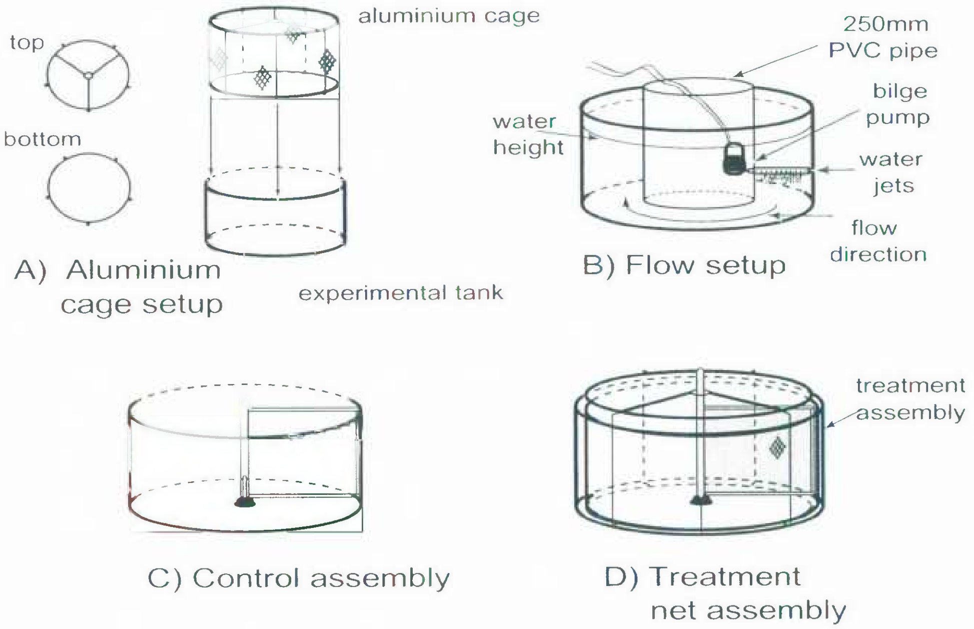

Figure 32 Diagrammatic representation of the experimental tanks fitted with the A) aluminium cage, B) flow setup, C) aluminium guiding panel (control) and D) the aluminium guiding panel (treatment net assembly).

6.3.1 Control fish

Control fish had the flow of water increased to achieve a circular movement of water to fatigue the fish (32B). After 10 minutes the centre of the cage (without the net assembly) was rotated to maintain identical disturbance to the treatment fish (control fish did not 'escape' through the meshes). The cage assembly was then removed from the tank (Fig. 32C). The corresponding times were recorded on appropriate data sheets. Therefore, the method was identical to the treatment fish, excluding being forced through the treatment mesh. Fish that were not treated in any manner (i.e., individuals in the spare tanks) were used to determine baseline glucose and cortisol levels at T0 and T96.

6.3.2 Periodical checks

Fish were checked periodically at 09:00, 13:00 and 17:00 hours each day after treatment for mortalities. Relevant data were recorded at these times. Any mortalities were immediately removed and substituted with replacement fish held in the 'spare' experimental tanks.

6.3.3 Mortalities

Fish that suffered mortalities in experiment 1, if any, were to have their physical injuries quantified (i.e., scale–loss) using a silhouette and a methylene blue solution to highlight damaged areas (see Experiment 2).

6.4.0 Experiment 2. Quantifying physical and physiological changes

Following identical procedures as described for Experiment 1, 110 yellowfin bream were randomly placed in 48 experimental tanks and 7 spare tanks and monitored for 14 days. Fish were allocated as either 'control' or 'treatment' and sampled at replicated times to assess scale loss, or obtain blood chemistry samples (see below). After scale loss assessment (see below) or following blood sampling, each fish was weighed and measured for total length, maximum width and maximum height to the nearest half centimetre.

6.4.1 Quantifying physical damage

At each sampling time, fish in 3 of the treatment and control tanks were surgically anaesthetised using benzocaine (50 –75 mg L^{-1}) within 2 minutes, 24, 48 and 72 hours (T0, T24, T48 and T72) of treatment. These fish were carefully removed by the mouth using gloved hands and individually checked for signs of scale loss/damage following methodologies described in Main and Sangster (1988) and Broadhurst et al., (1999a). Both sides of the fish were divided into 5 sub–areas using clear plastic silhouettes placed over the fish (of the same size as that sampled) (Fig. 33), and checked for percentage scale loss to the nearest 5%.

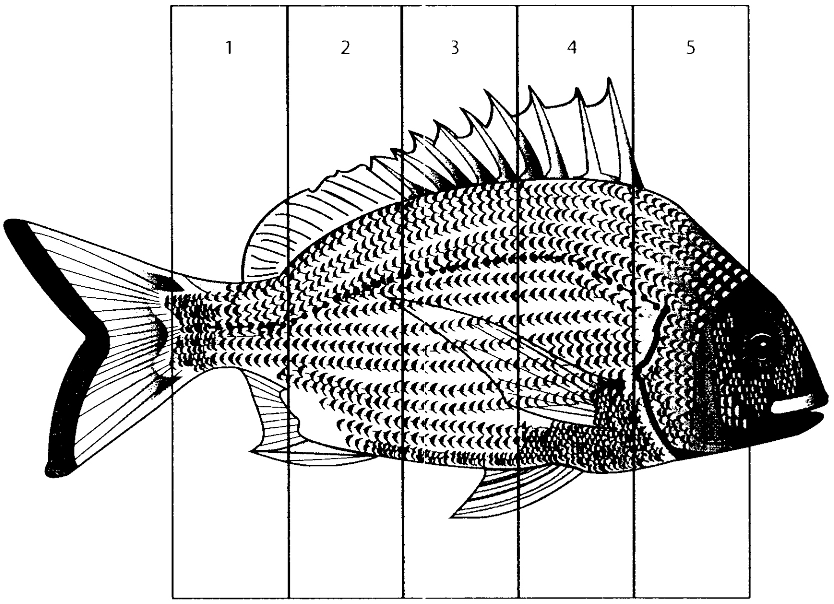

Figure 33 Yellowfin bream (*Acanthropagrus australis*) profile and zones used to determine percentage scale loss.

6.4.2 Quantifying physiological changes

At each sampling time, fish in 4 of the treatment and control tanks were removed and secured dorsally in a foam block. Using 21 gauge heparinised syringes, blood was extracted through caudal puncture and transferred to labelled vials and placed on ice. Blood samples had plasma separated by centrifugation (at 5000 rpm for 3 minutes). Blood extraction was completed within 2 minutes, 24, 48 and 72 hours (T0, T24, T48 and T72) of the designated treatment. Samples were sent to Gippsland Vetnostics for blood chemistry analyses of cortisol (ng mL^{-1}) and glucose (mmol L^{-1}) concentrations, to provide quantitative data on the stresses incurred with the relevant treatment types.

6.4.3 Monitoring longer–term mortality

Upon completion of the required treatments and observations regarding scale–loss and blood chemistry analyses, fish were returned to the 3000–L holding tanks. These fish were monitored for a period of 6 weeks, post treatment.

6.4.4 Statistical analyses

Data for percentage scale loss for each of the zones in experiment 2 were ln(x+1) transformed, tested for heteroscedasity using Cochrane's test and then analysed in the appropriate 3–factor ANOVA. Treatment of fish, (i.e. those that passed through the 102–mm mesh or control setup) and sample time (i.e., time at 0, 24, 48 and 96 hours) were considered fixed factors in these analyses; tanks were random and nested in the treatment and sample time and two random fish per tank were the replicates.

Data for mean cortisol concentrations in the blood in experiment 2 were tested for heteroscedasity and then analysed in the appropriate 3–factor ANOVA. Treatment of fish and sample time were considered fixed factors; tanks were random and nested in the treatment and sample time and two random fish per tank were the replicates.

6.5.0 Results

6.5.1.0 Experiment 1

6.5.1.1 Quantifying short–term mortality

Fish were removed from the 3000 L holding tanks and placed in the experimental tanks on the 14th April, 2006 (day 1) and left to acclimatise for 14 days. Fish were checked twice daily for mortalities.

6.5.1.2 Acclimatisation period

Two fish died after 3 days (day 4), one fish from each of tanks 25 and 52. Both fish had severe physical trauma (i.e., scale damage >75% and the fish in tank 52 displayed evidence of predation by the remaining bream in the tank). The remaining fish in tanks 25 and 52 were removed and replaced with 2 spare fish that were held in the 3000 L holding tanks. Within a further 24 (day 5) and 48 hours (day 6), there was one mortality in tanks 14 and 32. Tank 14 showed evidence of some scale loss (~30%) and also had marks indicating predation by the remaining bream. The fish in tank 32 displayed no evidence of physical trauma; however microscopic examination identified severe gill pathology, associated with the presence of protozoan parasites, namely 'cryptocaryon'.

There were no mortalities on days 7, 8 and 9. One mortality was identified on day 10, in tank 25, the remaining fish was removed and the tank restocked with 2 spare fish. On day 11 there were 3 mortalities, two in the morning and one in the afternoon (one fish from tanks 1, 3 and 14. The fish were removed and the tanks restocked. There were no mortalities on days 12, 13 and 14.

6.5.1.3 Treatment of fish

On 28th April (treatment–day 1), the treatment of fish was initiated, with 48 tanks treated as per experimental design. Tank 1 and tank 25 were aborted from the experiment (due to the earlier mortalities associated with these tanks) and replaced with spare tanks 52 and 53.

Tanks 50 and 55 were used to test baseline blood samples.

One larger yellowfin bream held in Tank 17 (treatment) jumped over the net assembly upon insertion and was replaced with a spare fish from tank 54. Both fish were then treated as per the experimental design. A yellowfin bream also leaped the cage assembly from tank 51 and landed heavily on the laboratory bench. The tank was then aborted.

Upon visual inspection of tank 19, one fish was identified as near fatal (before treatment). The fish showed evidence of severe scale damage (>75%), and subsequently died during the 10 minutes of simulated fatigue. The tank was aborted and replaced with tank 49.

The fish in the tanks were monitored for 10 days after the required treatment. Of the 110 yellowfin bream used in experiment 1, there was one mortality (treatment fish) from tank 29. The fish was removed and further assessed for scale–loss. The majority of the scale–loss was attributable to zones 2, 3 and 4. The total estimated percentage scale loss was determined as equalling 27%. The tank was restocked from the 3000–L holding tanks.

6.5.2.0 Experiment 2

6.5.2.1 Acclimatisation

One hundred and ten yellowfin bream were removed from the 3000 L holding tanks and placed randomly into the 55 experimental tanks held in the NMSC aquaria facilities on the 4th April, 2006 (acclimatisation day 1). Fish were checked mornings and afternoons for mortalities, and fed 2–6 fish pellets every second day. Fish were fed in relation to their aggression and appetite. On day 4, there were 2 mortalities identified during the morning check, one fish from tanks 26 and 37. Fish were replaced as described above. There was one mortality on day 5 identified from tank 6. The fish was also replaced. There were no mortalities attributed to days 6, 7, 8, 9 and 10.

6.5.2.2 Quantifying physical damage

On the 15th April (treatment day 1), the treatment of fish was initiated. Half of the tanks (n= 24) were treated on day 1 and half (n= 24) on day 2 due to time limitations. Tanks were checked for mortalities and sampled as per experimental design. No mortalities were attributable to either the control or treatment fish. Summaries of F ratios determining the effects of treatment on physical damage are provided in Table 16.

Table 16 Experiment 2: summaries of F ratios from analyses of variance to determine the effects of different treatments on yellowfin bream scale–loss (i.e., control vs. fish that passed through the simulated seine net), days and tanks. (**) significant at $P < 0.01$; (ns) non significant.

Treatment	df	Zone no 1	Zone no 2	Zone no 3	Zone no 4	Zone no 5	All zones
Treatment of fish (TF)	1	0.80 **	0.01 ns	0.51 ns	0.57 ns	1.00 **	0.12 ns
Days (D)	3	0.56 ns	2.15 ns	1.72 ns	0.68 ns	1.00 ns	1.08 ns
Tanks (T)	8	1.00 ns	4.77 ns	3.16 ns	1.67 ns	1.00 ns	5.35 ns
TF x D	3	1.07 ns	0.25 ns	0.34 ns	0.56 ns	1.00 ns	0.21 ns
Residual	16						

Scale–loss was evident in both control and treatment fish and was quite variable among zones and tanks. Although non–significant, control fish show a greater mean percentage scale loss than treatment fish across all zones, with the exception of zone 4 (Fig. 34D). There were no significant interactions between control and treatment fish across all zones, days and tanks (Fig 34 A-F). Differences in mean scale–loss of fish in the control and treatment tanks were 3.44 and 2.97 %, respectively (Fig. 34F).

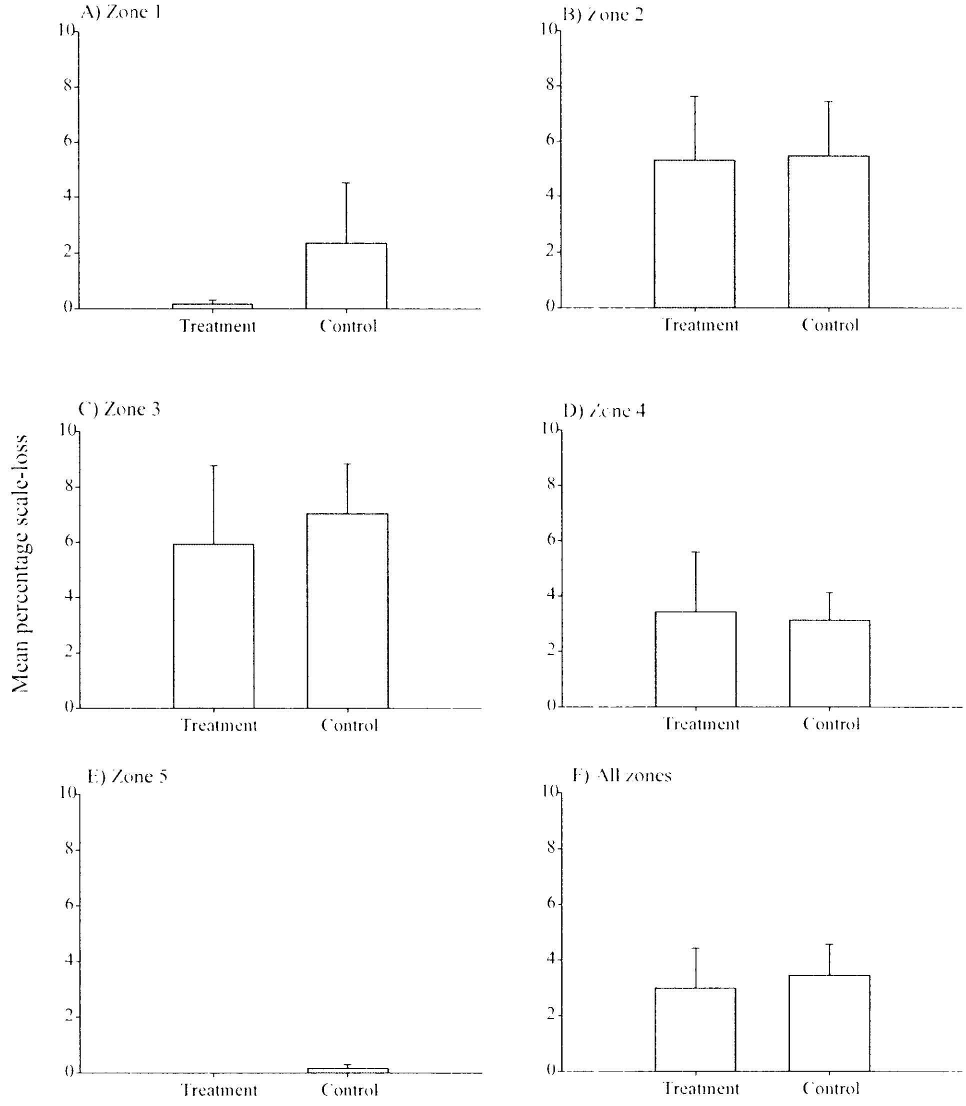

Figure 34 Differences in mean percentage scale–loss (±SE) between the control and treatment fish in experiment 2 for: A) zone no 1, B) zone no 2, C) zone no 3, D) zone no 4, E) zone no 5 and F) all zones combined.

6.5.2.3 Quantifying physiological changes

Samples removed to test the blood chemistry of control and treatment fish in experiment 2 were analysed for glucose and cortisol levels. Analyses of physiological changes to the blood chemistry of fish have been used in previous studies to determine the stress associated with varying treatments (Mazeaud et al., 1977; Pankhurst and Sharples, 1992). Summaries of F ratios determining the effects of treatment on physiological damage are provided in Table 17.

Table 17 Summaries of F ratios from analyses of variance to determine the effects on physiological damage (cortisol and glucose levels) due to different treatments of fish (i.e., control v treatment, days and tanks.

Treatment	df	Cortisol	Glucose
Treatment of fish (TF)	1	1.22	0.82
Days (D)	3	1.56	0.69
Tanks (T)	24	1.43	1.15
TF x D	3	0.29	0.65
Residual	31		

There were no significant interactions detected for mean percentage cortisol or glucose levels in the blood between control and treatment fish (Fig. 35).

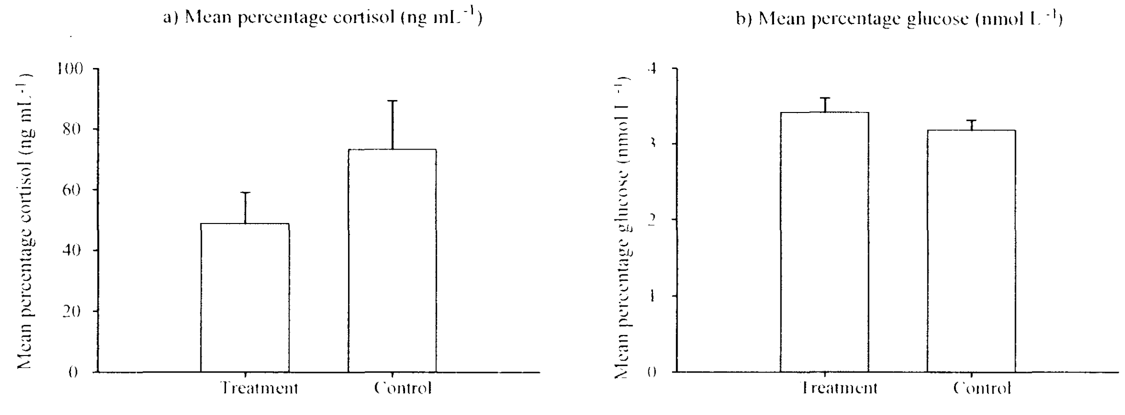

Figure 35 Differences in a) total mean percentage cortisol (ng ml $^{-1}$) and b) glucose (mmol L $^{-1}$) (+SE) between the control and treatment fish in experiment 2.

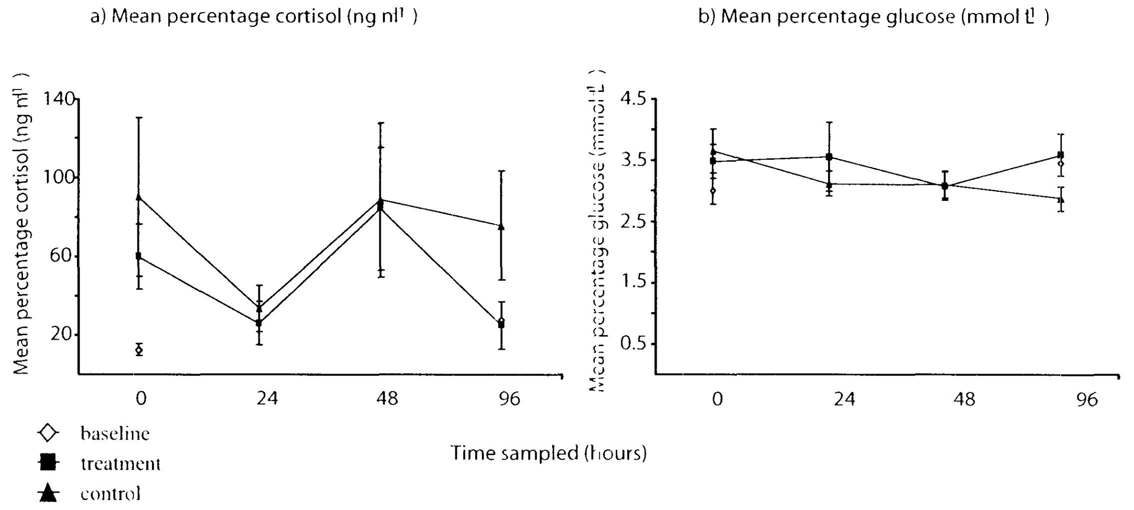

Figure 36 Differences in a) mean percentage cortisol (ng mL ^{1}) and b) glucose (mmol L ^{1}) (±SE) between the control (Δ) and treatment (□) fish at time periods: 0, 24, 48, 96 hours. Baseline levels (◇) are also provided at 0 and 96 hours.

No significant relationships were formed between the mean percentage cortisol and glucose concentrations in control and treatment fish (Fig 35A, B). Mean cortisol levels of treatment fish were below that of the control fish (difference of 48 and 73 (ng mL ^{1}), indicating that fish were suffering some degree of stress associated with handling or confinement. Although non–significant, glucose levels in control fish were less than those in treatment fish 3.8 to 3.5 (mmol mL ^{1}).

Mean percentage cortisol levels (ng mL ^{1}) were plotted (Fig. 36a), illustrating the changes in concentrations over time. Within 2 minutes of capture from the experimental tanks, 4 fish were selected and tested for baseline cortisol levels. Mean baseline cortisol levels at T0 equalled 12.66 (ng mL ^{1}).

Both control and treatment fish elevated within the treatment period (T0) to 33 and 59 (ng mL ^{1}), respectively. Within 24 hours of treatment, cortisol levels decreased to 26 and 33, but re–elevated after 48 hours to a substantial 88 and 84 (ng mL ^{1}). After 96 hours of treatment, cortisol levels in both control and treatment fish decreased to 75 and 25 (ng mL ^{1}) respectively. Baseline cortisol levels of fish untreated but housed in experimental tanks at (T 96) equalled 28 (ng mL ^{1}), similar to the levels recorded in treatment fish after the same period of time.

Mean percentage glucose levels (mmol mL) were plotted (Fig. 36b), illustrating changes in concentrations over time. No significant interactions were detected between control and treatment glucose levels.

6.5.2.4 Monitoring longer–term survival

Upon completion of experiments 1 and 2, fish were returned from the experimental tanks to the 3000–L holding tanks and monitored for the next 6 weeks. Although no fish were identifiable as either control or treatment, there were no mortalities sustained during this period.

6.6.0 Discussion

6.6.1 Experiment 1

Experiment 1 examined the effects of simulated escape through meshes on the short–term survival of yellowfin bream. There was only one mortality associated to the treatment of fish; however, due to the mortalities sustained during the acclimatisation period, this may be indicative of stress related to being confined in holding and experimental tanks. This relates to the findings of Gustaveson et al., 1991; Pankhurst and Sharples, 1992; Chopin and Arimoto, 1995; Broadhurst et al., 1999a) which indicate that the effects of confinement and/or experimental methodologies contribute to stress levels and overall mortality. It was visually noted that fish once transported to the experimental tanks, were flighty and erratic in behaviour, indicating that both treatment and control fish were stressed in this environment.

Overall, yellowfin bream that passed through the seine mesh demonstrate no significant or added stresses, indicating fish escaping from the gear during the seine retrieval are affected only in a minor capacity. These results provide justification for using a seine net increased to 102–mm to allow juveniles to escape from the catch, without disrupting the physical condition or health of yellowfin bream escapees to a degree that may result in significant mortalities.

6.6.2 Experiment 2

6.6.2.1 Physical damage

Physical damage was assessed for both treatment and control fish through analyses of scale–loss. The mean percentage scale–loss was quite low for treatment and control fish < 3 and < 3.5 %, respectively. This indicates that the null hypothesis of no significant difference between treatments and scale–loss can be accepted.

6.6.2.2 Physiological changes

Baseline cortisol and glucose levels in the blood chemistry of untreated fish housed in the experimental tanks were relatively high and variable (mean of 12.6 and 28.0 at T0 and T96 respectively). The majority of reported values for cortisol in 'unstressed' fish can be variable in response to different husbandry and handling protocols (Pankhurst and Sharples, 1992) and may be quite variable amongst species. Previous studies indicate baseline levels of cortisol in 'unstressed' rainbow trout can range from as low as 2 ng mL^{-1} (Bry, 1982; Woodward and Strange, 1987), and as high as 10–30 ng mL^{-1} (Rance et al., 1982; Laidley and Leatherland, 1988). Underwater sampling of normally active snapper (*Pagrus auratus*), by SCUBA divers, describe mean cortisol concentrations ranging between 1.7 and 8.0 ng mL^{-1} (Pankhurst and Sharples, 1992). Similarly, red sea bream, *Pagrus major*, exhibit mean cortisol levels of 12.2 ng mL^{-1} in resting fish (Chopin et al., 1996).

The variability and the high levels found in the baseline cortisol levels in Experiment 2 indicate that the fish housed in the experimental tanks were stressed in some degree and this may have ultimately influenced the results. Variability amongst individuals meant that no significant interactions were revealed. Therefore the null hypothesis of no significant differences in physiological stresses between treatment types is accepted. Although the results only provide a minimal understanding of the total impact on the individuals examined, it is reasonable to conclude that increasing the mesh size of current seine configurations to improve size selection does not significantly impact on the physical or physiological condition of yellowfin bream escapees.

7.0 SUMMARY OF SALIENT POINTS AND CONCLUSIONS

- Beach seines are one of the oldest large-scale, active fishing gears commonly used throughout the world, targeting a range of teleost fish and cephalopods.
- There are limited data sets available that quantify the spatial and temporal variability in bycatches.
- The NSW beach seine fisheries are managed by input controls, including limitations on minimum and maximum mesh sizes.
- Regulations restricting the type, size and use of fishing nets were introduced in the 1940's.
- Legal mesh sizes were derived from industry developed gears and practices that were common when particular fisheries became established.
- However, little work has been done to determine if the mesh sizes currently enforced are appropriate to allow juveniles to escape from NSW beach seines.
- Estuarine deployed beach seine catches may comprise large quantities of juvenile conspecifics.
- Concerns for the catch of beach seines primarily involve the discarding and potential mortality of juvenile species unintentionally captured.
- To ensure environmental sustainability, it is essential the fishing gears used to capture target species are selective, (i.e., reduce the capture and mortality of juveniles whilst maintaining target species catches).
- Morphometric relationships of key species were assessed to help determine appropriate mesh sizes.
- Beach seine estuary trials, of determined mesh sizes, were completed in the Clarence River to gain knowledge of the key areas of selection and reduce the capture of juveniles.
- Catch data were quantified and collated from conventional and modified gears, providing information regarding the selectivity of key species.
- Results indicate that the mesh sizes currently legislated for NSW estuaries are inappropriate in removing juveniles from the catch.
- The majority of individuals captured in estuary and ocean deployed beach seines are landed in the bunt/codend.
- Simple modifications to beach seines, (i e. increasing mesh size throughout the bunt and posterior wings), is an appropriate strategy for significantly improving the size selection of some species and reducing unwanted bycatch.
- Indications are that posterior wings have a broad species-specific influence on the seine's overall performance and selection characteristics.
- Beach seine catches are seasonally, temporally and spatially variable.

- Ocean deployed beach seines primarily target mono–specific populations of adult fish during winter spawning migrations, mainly sea mullet.
- On occasions during non–migratory periods, mixed species targets are more common, and may contain juvenile conspecifics.
- Greater than 90% of the catches landed in ocean beach seines are retained in the bunt and codend.
- Laboratory experiments examining the fate of juvenile bream escaping through the meshes of beach seines indicate no significant or added stresses.
- The results from laboratory experiments support increasing the mesh size of current seine configurations to improve size selection without significantly impacting on the physical or physiological condition of yellowfin bream that escape through the meshes.