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# Relative efficiency and size selectivity of bottom-set gillnets for dusky flathead, *Platycephalus fuscus* and other species in New South Wales, Australia

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## Abstract

The effects on catches and bycatches due to increases in mesh size were investigated in a bottom-set gillnet fishery for dusky flathead, *Platycephalus fuscus* in New South Wales, Australia. Sampling was done in 2 coastal lagoons during spring 2001 using a gillnet comprised of replicate panels of (i) the commercially-used mesh size (7.0 cm) and (ii) 3 larger mesh sizes (8.0, 8.9 and 9.5 cm). The targeted dusky flathead and 5 important bycatch species (bream, *Acanthopagrus australis,* luderick, *Girella tricuspidata*, sea mullet, *Mugil cephalus*, yellow-finned leatherjacket, *Meuschenia trachylepis* and blue swimmer crab, *Portunus pelagicus*) accounted for approx. 91 % of the total catch. Significant differences in the catch rates of these species were detected among the mesh sizes examined with trends for fewer numbers of total dusky flathead, total bycatch, sea mullet, yellow-finned leatherjacket and under-size bream and luderick evident in the larger mesh sizes. All species were characterised by a significant disequilibrium in the vertical distribution of catches, with the lower 50 % of the gillnet retaining between 56 and 89 % of individuals. Modal lengths of most species increased with mesh size and the selectivities of dusky flathead, bream and luderick were best described by binormal curves with well-separated modes. The results are discussed in terms of the probable capture processes of the main species and appropriate modifications to reduce their unwanted bycatches.

## Kurzfassung

**Relative Effektivität und Größenselektivität von Setznetzen bei dem Flachkopf *Platycephalus fuscus,* und anderen Arten in New South Wales, Australien.**

Es wurden Einflüsse der Maschenvergrößerung auf Fänge und Beifänge in der Setznetzfischerei auf den Flachkopf *Platycephalus fuscus* in New South Wales, Australien, untersucht. Die Probennahmen erfolgten in 2 Küstenlagunen im Frühjahr 2001, und zwar mit einem Kiemennetz, das aus mehreren Netzblättern bestand mit (i) kommerziell verwendeter Maschenweite (7,0 cm) und (ii) 3 größeren Maschenweiten (8,0; 8,9 und 9,5 cm). Die Zielart *Platycephalus fuscus* und 5 wichtige Beifangarten (Meerbrasse *Acanthopagrus australis*, Meerdöbel *Girella tricuspidata*, Meeräsche *Mugil cephalus*, Gelbflossen-Feilenfisch *Meuschenia trachyleptis*, und die Schwimmkrabbe *Portunus pelagicus)* machten 91 % des gesamten Fangs aus. Es gab signifikante Unterschiede bei den Fanganteilen zwischen den untersuchen Maschengrößen, mit einem Trend zu geringerer Anzahl von Flachkopf, Gesamtbeifang, Meer-

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äsche, Gelbflossen-Feilenfisch und untermaßiger Meerbrasse und Meerdöbel in den größeren Maschen. Alle Arten zeigten ein deutliches Ungleichgewicht bei der vertikalen Verteilung der Fänge, wobei die unteren 50 % der Netze zwischen 56 und 89 % der Tiere enthielten. Die Modallängen der meisten Arten wuchsen mit der Maschengröße; die Selektivitäten für Flachkopf, Meerbrasse und Meerdöbel wurden am besten durch binormale Kurven mit gut getrennten Gipfeln beschrieben. Die Ergebnisse wurden in Hinblick auf mögliche Fangvorgänge der Hauptarten und geeigneter Veränderungen zur Reduzierung der ungewünschten Beifänge diskutiert.

## Resumo

**Eficiencia relativa e seletividade de redes de espera de fundo para *Platycephalus fuscus* e outras especies em Nova Gales do Sul, Australia.**

Efeitos do aumento no tamanho de malha em redes de espera de fundo na captura de *Platycephalus fuscus* e fauna acompanhante foram investigados no estado de Nova Gales do Sul, Australia. As amostragens foram realizadas na primavera 2001 em duas lagoas costeiras, utilizando-se redes de espera de fundo compostas por replicas de paineis de (i) tamanho de malha comercial (7.0 cm) e (ii) 3 malhas de tamanho maior (8.0, 8.9, 9.5 cm). A especie alvo *P. fuscus* e outras 5 especies importantes de fauna acompanhante (*Acanthopargus australis*, *Girella tricuspidata*, *Mugil cephalus*, *Meuschenia trachylepis* e o siri-azul *Portunus pelagicus*) corresponderam a aproximadamente 91 % da captura total observada. Diferencas significativas nas taxas de captura destas especies foram observadas entre os diferentes tamanhos de malha utilizados, onde uma tendencia de numeros menores de captura total para estas especies em malhas maiores se mostrou evidente. Todas as especies em questao foram caracterizadas por um desequilibrio na distribuicao de captura vertical, com 50 % da parte inferior da rede de espera retendo entre 56 a 89 % dos individuos. O tamanho da moda de comprimento da maioria das especies aumentou com o tamanho de malha e a seletividade para *P. fuscus*, *A. australis* e *G. tricuspidata* foram melhores representadas em curvas binormais com modas distintas. Os resultados sao discutidos em termos do provavel processo de captura das principais especies e modificacoes apropriadas para se reduzir a captura da fauna acompanhante desprezada.

## Introduction

Dusky flathead, *Platycephalus fuscus*, are an important euryhaline species targeted by recreational and commercial fishers throughout estuaries and coastal lagoons in New South Wales (NSW), Australia. There are no available estimates of total recreational catches, although the commerical sector lands up to 200 t each year, with most fish caught using bottom-set gillnets (7.0-cm mesh) in coastal lagoons (Gray 2002). Operators working with these nets are prohibited from retaining any incidental catch (collectively termed 'bycatch') which often comprises under-size dusky flathead (minimum legal size (MLS) is currently 36 cm total length (TL)) and juveniles and adults of other commercially and recreationally important fish such as sparids, mugilids and monocanthids (Gray 2002; Gray *et al.* 2002). The fate of these discarded individuals is mostly unknown, but the potential for at least some mortalities has raised concerns over possible negative impacts on the yield of interacting commercial and recreational fisheries.

The issue of bycatch has been successfully addressed in many different types of fisheries via the development and application of more selective fishing gears and methods (Alverson *et al.* 1994). Compared to the majority of fishing gears, gillnets typically are highly selective and can be regulated to retain fish of optimal size and within a narrow size range (see Hamley 1975 for a review). However, their efficiency and selectivity are influenced by many biological and technical factors. These include spatial and temporal variabilities in the vertical and horizontal distributions of fish (Hamley 1975; Acosta 1994) and their sizes, morphology, behaviour and condition (Hay *et al.* 1986; Hovgård 1996a; Poulsen *et al.* 2000), water visibility (Hansson and Rudstam 1995), net length (Rudstam *et al.* 1984; Acosta 1994), soak time (Minns and Hurley 1988; Losanes *et al.* 1992), hanging ratio (Accosta and Appledoorn 1995), twine size and material (Jensen 1995; Hovgård 1996b), and perhaps most importantly, the size of mesh used (Hamley 1975).

Management of the bottom-set gillnet fishery for dusky flathead in NSW involves a range of input controls that encompass some of the factors listed above. Operators are restricted in space (5 coastal lagoons are open to commercial bottom-set gillnetting) and time (fishing is only allowed at night and between 4 and 10 months of the year) and are allowed to set up to 2 bottom gillnets with a height less than 25 meshes and a combined stretched length less than 1500 m. Legal mesh size has arbitrarily been set at 7.0 cm (stretched mesh) and although not enforced, the majority of fishers use a hanging ratio of 0.5.

Despite the regulations above, there have been no formal studies done to quantify selectivity of the existing gillnets or the effects of any changes in configurations on the catches of various species in this fishery. Such information is essential as a first step in regulating the optimal size at first capture of dusky flathead and to minimise bycatch. Further, there is a current proposal to increase the MLS of dusky flathead to 40 cm TL and so there is an urgent need to quantify the selection processes for this species and determine if compensatory changes to fishing gears are required. Given that the size of mesh is one of the principle factors influencing the performance of gillnets, our aim in the present study was to determine the relative efficiency and selectivity of the existing gear and three incremental increases in mesh size for the targeted dusky flathead and various bycatch species.

## Materials and methods

This study was done in two coastal lagoons (Tuggerah Lake 33° 19' S, 151° 30' E and Lake Illawarra, 34° 31' S, 150° 51' E ) in NSW between May and August 2001 using a 4-m research dory and similar-size commercial gillnetters all rigged with the same gillnet. The gillnet was 1300 m in length and was comprised of 3 replicate panels of 4 different mesh sizes made from 0.5-mm ∅ multifilament nylon. The nominal mesh sizes were the current legal size of 7.0 cm and 8.0, 8.9 and 9.5 cm. These mesh sizes were validated by measuring (using a set of dial calipers) 30 randomly located meshes (stretched length between the inside knots) in the various treatment panels (mean mesh sizes ± standard error of 7.02 ± 0.008, 8.00 ± 0.005, 8.93 ± 0.005 and 9.52 ± 0.004 mm, respectively). All panels measured 100 m in length, approx. 1.6 m in depth and were attached to float lines (6-mm ∅ polyethylene rope with 31 evenly-spaced 60 × 33.5-mm cylinder floats) and lead lines (6-mm ∅ polyethylene rope with 45 evenly-spaced, 50-g lead weights) at hanging ratios of 0.5 (as per commerical configurations). To prevent leading of fish (and therefore maintain independence of treatment panels), adjacent panels were separated by10-m float and lead lines.

Fishing was done according to normal commercial operations. The gillnet was set on the bottom in a straight line at random locations in each lagoon between 16:30 and 17:30 h each day (during daylight) and left to fish overnight. To ensure equal soak time, the first panel set on each evening was retrieved first the following morning (between 06:00 and 07:00 h – during daylight). To eliminate confounding due to position, replicate panels were randomly assigned after each set. We completed 10 replicate nightly sets of the gillnet at both locations. Data collected from treatment panels were: the weights, numbers and sizes of all species of fish; numbers of legal- and under-size species of fish; numbers and weights of all species of crustaceans; vertical distribution of catches of fish (*i. e.* upper or lower 50 % of the panels); and the general method of capture (*i. e.* gilled at the head, mouth or entangled).

Fish were measured to the nearest 0.5-cm total or fork length (FL), depending on the morphology of the caudal fin. Species with convex caudal fins (*i. e.* flathead) were measured to TL. Although all MLS of fish in NSW refer to TL, to reduce the possibility of bias in TL measurements owing to damaged fin rays in species with concave caudal fins, these were measured to FL in the field. Random samples of undamaged individuals of relevant species were then measured to index FL against TL (using regression analyses) and to provide estimates of MLS in FL.

### Analyses of catch data

Catches were pooled over the 3 replicate treatment panels for each mesh size on each night, ln(x+1) transformed (to account for multiplicative effects), tested for heteroscedasticity using Cochran's test and then analysed in the appropriate orthogonal analyses of variance (ANOVA). The factors chosen in this model were locations (lagoons) and mesh size (random and fixed, respectively). To increase the power of the test for the main effect of mesh size, where the interaction term was non-significant at $P < 0.25$, it was pooled with the residual (Winer 1971). Significant differences detected in these analyses were investigated by Student-Newman-Keuls (SNK) multiple comparisons of means. Numbers of fish caught in the upper and lower 50 % of the panels were pooled among mesh sizes and locations. $\chi^2$ tests were used to test the hypothesis of no vertical disequilibrium in catches.

### Analyses of size selectivity

Size-frequencies of individual species gilled in the different treatment panels were pooled across all sets. Where there were sufficient data, the parameters for various log-linear models describing unimodal selection curves (normal scale, normal location, gamma and lognormal) were estimated by maximum likelihood method (using GillNet Software, ConStat, http://www.constat.dk) according to the methods described in several recent studies (Millar and Holst 1997; Madsen *et al.* 1999). Binormal selection curves were also fitted to these data. Selection curves were fitted under the assumption that fishing power was proportional to mesh size (Hamley and Regier 1973; Borgström 1989; Millar and Holst 1997). The various curve fits for each species examined were assessed by visual examination of residual plots and referring deviance residuals and associated degrees of freedom to a $\chi^2$ distribution.

## Results

A total of 6925 individuals comprising 42 species were captured during the study, but only 6 species (accounting for more than 91 % of the total catch) were caught in sufficient quantities to enable analyses. These included: dusky flathead ($n$ = 711); bream, *Acanthopagrus*

Table 1: Linear regressions between total length (TL) and fork length (FL) for bream, luderick and sea mullet. All lengths in cm; n = number of specimens; $r^2$ = coefficient of determination.

| Species | TL range measured | *n* | Regression | $r^2$ |
|---|---|---|---|---|
| Bream | 20 – 40 | 121 | TL = 0.785 + 1.092FL | 0.987 |
| Luderick | 22 – 38 | 293 | TL = 0.072 + 1.072FL | 0.970 |
| Sea mullet | 22 – 47 | 97 | TL = 0.324 + 1.111FL | 0.987 |

*australis* (*n* = 494); luderick, *Girella tricuspidata* (*n* = 3133); sea mullet, *Mugil cephalus* (*n* = 1012); yellow-finned leatherjacket, *Meuschenia trachylepis* (*n* = 390); and blue swimmer crab, *Portunus pelagicus* (*n* = 570).

Significant positive linear relationships were detected between TL and FL for bream, luderick and sea mullet (species with concave caudal fins) (Table 1). Based on MLS of 25, 25 and 30 cm TL, the MLS in FL of these species were calculated (to the nearest 0.5 cm) as 22, 23.5 and 27 cm, respectively. Catches were separated into legal- and under-size individuals and analysed accordingly. Because yellow-finned leatherjacket has no MLS and sizes were not recorded for blue swimmer crab, analyses of these species were limited to total catch.

### *Analyses of catch data*

ANOVA failed to detect any significant differences in catches of dusky flathead for the main effect of mesh size (Table 2), although panels made from the three larger mesh sizes caught slightly fewer total and legal-size fish than the commercially-used 7.0-cm mesh (reductions of up to 38 %) (Figures 1A and 1C). In contrast, the mean weight of total dusky flathead was similar among the 4 different mesh sizes (Figure 1B). Significant F ratios for the main effect of mesh size were detected for the numbers of total species, total bycatch, legal-size bream, under-size luderick, yellow-finned leatherjacket and catches of all categories of sea mullet (Table 2). SNK tests showed that panels made from 9.5-cm mesh retained significantly fewer total species than all other panels (relative reduction of up to 29 %) (Figure1D; Table 2). Compared to panels of the commercially-used 7.0-cm mesh, those with 9.5-cm mesh retained significantly less bycatch and yellow-finned leatherjacket and although not significant, mean catches from the 8.0- and 8.9-cm mesh were also lower (Figures 1E and 1O; Table 2). Similarly, SNK tests failed to detect any definitive order among the different mesh sizes for the numbers of legal-size bream, although catches were significantly greater in panels of 8.9- and 9.5-cm mesh than in panels of 7.0-cm mesh (relative increase of 83 %) (Figure 1G; Table 2). Compared to panels of 7.0- and 8.0-cm mesh, those with 8.9- and 9.5-cm mesh retained significantly fewer under-size luderick (relative reductions of between 93 and 99 %) (Figure 1K; Table 2). The numbers of all categories of sea mullet were significantly fewer in panels of 8.0-, 8.9- and 9.5-cm mesh than in 7.0-cm mesh (relative reductions of between 80 and 93 %) (Figures 1L, 1M and 1N; Table 2).

No other significant differences were detected for the main effect of mesh size (Table 2). However, the mean numbers of total bream and luderick were greater in panels made from the 8.0-cm mesh (compared to panels of 7.0-cm mesh) and lower in the two largest mesh sizes (Figures 1F and 1I). Numbers of legal-size luderick were incrementally greater in pan-

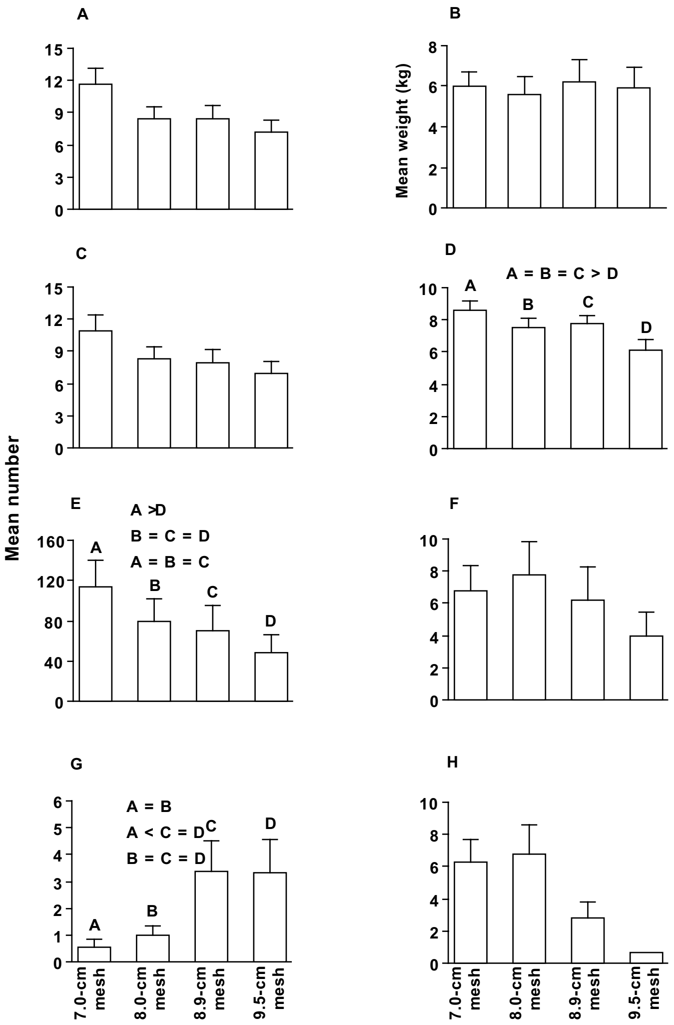
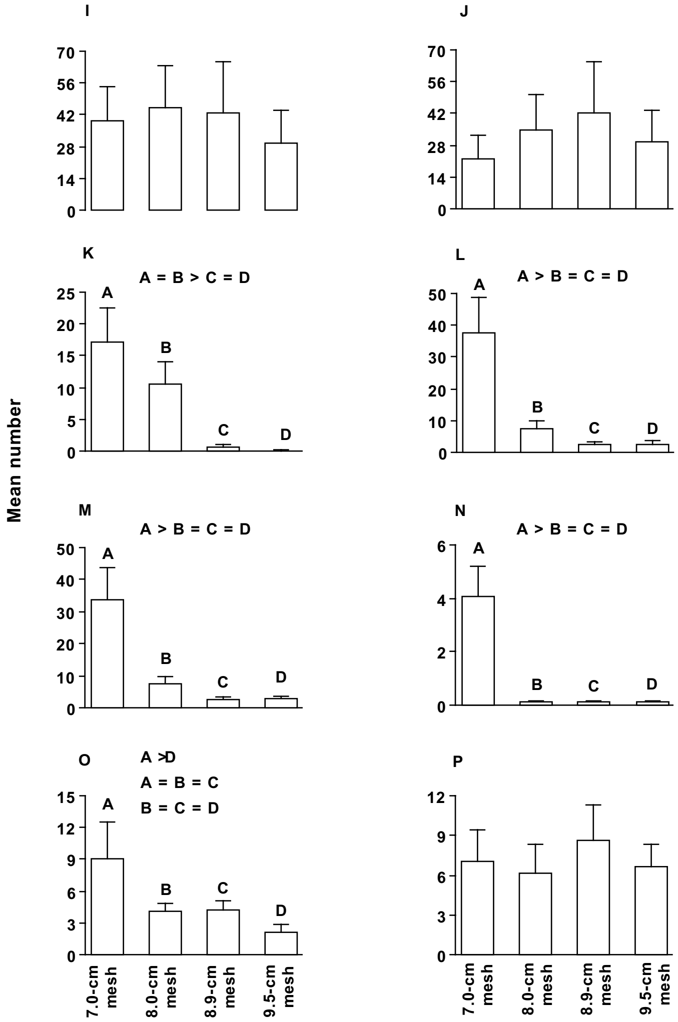


Figure 1: Differences in mean numbers (+ standard error) between the 7.0-, 8.0-, 8.9- and 9.5-cm mesh panels for (A) numbers and (B) weights of total dusky flathead and numbers of (C) legal-size dusky flathead, (D) total species (E) total bycatch, (F) total bream (G) legal-size bream, (H) under-size bream (*cont'd next page*)

els of 7.0-, 8.0- and 8.9-cm mesh and then lower in the 9.5-cm mesh (Figure 1J). All panels caught similar quantities of blue swimmer crab (Figure 1P). Several variables had significant F ratios for the main effect of locations, but no interactions were detected (Table 2).

$\chi^2$ tests detected significant disequilibrium in the vertical distribution of catches pooled among the various treatment panels. The bottom 50 % of the gillnet retained 69.3 % of the total catch ($\chi^2$ = 905.56, $P < 0.01$), 88.6 % of dusky flathead ($\chi^2$ = 353.50, $P < 0.01$), 78.7 % of bream $\chi^2$ = 159.67, $P < 0.01$), 70.1 % of luderick ($\chi^2$ = 479.69, $P < 0.01$), 56.5 % of



(Figure 1*cont'd):* (I) total luderick, (J) legal-size luderick, (K) under-size luderick, (L) total sea mullet, (M) legal-size, (N) under-size sea mullet, (O) yellow-finned leatherjacket, and (P) blue swimmer crab. Letters above histograms indicate direction of significant differences detected in SNK tests.

sea mullet ($\chi^2$ = 14.76, $P < 0.01$) and 55.81 % of yellow-finned leatherjacket ($\chi^2$ = 5.23, $P < 0.05$).

### *Analyses of size selectivity*

Modal lengths of most species increased with mesh size. Dusky flathead were represented by the widest length range (up to 62 cm) with catches across all mesh sizes mostly comprising legal-size individuals (Figure 2A). Under-size bream comprised the majority of catches in

Table 2: F ratios from ANOVAs to determine effects on catches due to fishing with four different mesh sizes (7.0, 8.0, 8.9 and 9.5 cm) at two locations (Tugerah Lake and Lake Illawarra). All data were ln(x+1) transformed. ** = $P < 0.01$; * = $P < 0.05$. Pld indicates that the interaction was non-significant at $P < 0.25$ and the sums of squares pooled with the residual. The df for the F-test for the main effect of mesh size when the interaction was pooled = 3, 75. Number of under-size sea mullet was tested using a Type I error-rate of a = 0.01 because Cochran's test of the transformed data was still significant at $P = 0.05$.

**Dusky flathead**

| | | Total | | No. of | | Total bycatch | |
|---|---|---|---|---|---|---|---|
| Treatment | df | no. | wt | legal-size | species | no. | wt |
| Locations (L) | 1 | 4.60* | 2.85 | 4.84* | 17.08** | 1.85 | 5.38* |
| Mesh size (M) | 3 | 2.24 | 0.22 | 2.18 | 5.31** | 4.16* | 2.28 |
| M × L | 3 | $0.41^{\text{pld}}$ | $0.23^{\text{pld}}$ | $0.55^{\text{pld}}$ | $0.64^{\text{pld}}$ | $0.17^{\text{pld}}$ | $0.27^{\text{pld}}$ |
| Residual | 72 | | | | | | |

**Bream**

| | | Total | | No. of | |
|---|---|---|---|---|---|
| Treatment | df | no. | wt | legal-size | under-size |
| Locations (L) | 1 | 16.42** | 12.07* | 13.47** | 7.66** |
| Mesh size (M) | 3 | 1.80 | 0.57 | 5.19** | 4.32 |
| M × L | 3 | $0.27^{\text{pld}}$ | $0.08^{\text{pld}}$ | $0.71^{\text{pld}}$ | 2.31 |
| Residual | 72 | | | | |

**Luderick**

| | | Total | | No. of | |
|---|---|---|---|---|---|
| Treatment | df | no. | wt | legal-size | under-size |
| Locations (L) | 1 | 6.73* | 6.33* | 9.26** | 0.66 |
| Mesh size (M) | 3 | 1.06 | 0.21 | 0.18 | 16.19** |
| M × L | 3 | $0.24^{\text{pld}}$ | $0.16^{\text{pld}}$ | $0.18^{\text{pld}}$ | $0.13^{\text{pld}}$ |
| Residual | 72 | | | | |

**Sea mullet**

| | | Total | | No. of | |
|---|---|---|---|---|---|
| Treatment | df | no. | wt | legal-size | under-size |
| Locations (L) | 1 | 7.48* | 5.50* | 4.82* | 5.48* |
| Mesh size (M) | 3 | 12.72** | 6.82** | 5.87** | 6.72* |
| M × L | 3 | 0.60 | 0.30 | 0.36 | 0.37 |
| Residual | 72 | | | | |

| | | **Yellow-finned leatherjacket** | | **Blue swimmer crab** | |
|---|---|---|---|---|---|
| Treatment | df | no. | wt | no. | wt |
| Locations (L) | 1 | 2.12 | 0.04 | 8.27* | 10.11** |
| Mesh size (M) | 3 | 2.85* | 0.64 | 0.29 | 0.29 |
| M × L | 3 | $0.95^{\text{pld}}$ | $0.79^{\text{pld}}$ | $0.14^{\text{pld}}$ | $0.09^{\text{pld}}$ |
| Residual | 72 | | | | |

the two smallest mesh sizes (Figure 2B). The modal length of luderick retained in panels of 7.0-cm mesh was close to the MLS and increased well beyond this in panels made from 8.9- and 9.5-cm mesh (Figure 2C). Sea mullet showed a similar trend with panels made from the

Table 3: Binormal model fits and selectivity estimates for species captured in sufficient quantities in the various panels. The model deviance, df and associated P are provided in square brackets. Modal lengths for dusky flathead are total length, while those for bream and luderick are fork length. The corresponding estimated total lengths for these latter two species are provided in brackets. All measurements in cm.

| | **Dusky flathead** | | **Bream** | | **Luderick** | |
|---|---|---|---|---|---|---|
| | [237.15: 205: 0.06] | | [103.40: 94: 0.24] | | [237.48: 121: 0.0001] | |
| Mesh size | Modal length | Spread | Modal length | Spread | Modal length | Spread |
| 7.0 | 39.47 | 3.09 | 17.52 (19.91) | 1.17 | 21.07 (22.66) | 1.38 |
| 8.0 | 45.11 | 3.54 | 20.02 (22.84) | 1.34 | 24.07 (25.87) | 1.58 |
| 8.9 | 50.19 | 3.94 | 22.27 (25.1) | 1.49 | 26.78 (28.78) | 1.76 |
| 9.5 | 53.57 | 4.20 | 23.77 (26.74) | 1.59 | 28.58 (30.71) | 1.87 |

larger two mesh sizes retaining mostly legal-size individuals, although at much lower numbers (Figure 2D). The size-frequency distribution of yellow-finned leather jacket remained similar among the panels with different mesh sizes (Figure 2E).

Dusky flathead, bream and luderick were captured in sufficient quantities to permit meaningful estimation of parameters for selectivity curves (Figure 3; Table 3). Most small dusky flathead were observed to be gilled behind their heads, while larger fish were entangled across the entire anterior body. Bream and luderick were mostly gilled in the panels with meshes stretched tightly across their heads and anterior bodies. Some larger individuals of all species, and particularly dusky flathead, were often entangled in more than one mesh.

The selectivity models applied to these data and associated estimates of modal length (optimal selection length) and spread are provided in Table 3. The selectivities of all three species were best described by binormal curves (Figure 3; Table 3). All unimodal curves (normal scale, normal location, gamma and lognormal) fitted to these data had considerably elevated model deviances and, in the majority of cases, showed severe lack of fit ($P < 0.00001$). Although the binormal curves for luderick (Figure 3C) failed the goodness of fit test (Table 3) this model was considered the most appropriate, since all corresponding unimodal curves had model deviances up to 1.4 times greater ($P < 0.00001$).

## Discussion

The catches of dusky flathead recorded in the present study are comparable to those from normal commercial operations (which typically range between 1 and 24 fish per 300 m of gillnet) and were not significantly different among the different mesh sizes examined. This latter result provides some evidence to indicate that it should be possible to increase the minimum mesh size in this fishery and still maintain commercially-viable catches, but reduce fishing mortality of under-size conspecifics. For example, the selectivity of the commercially-used 7.0-cm mesh was < 0.6 for the existing MLS of dusky flathead and optimal for the proposed increase in MLS (to 40 cm TL). Increasing the mesh size to 8.0 cm would

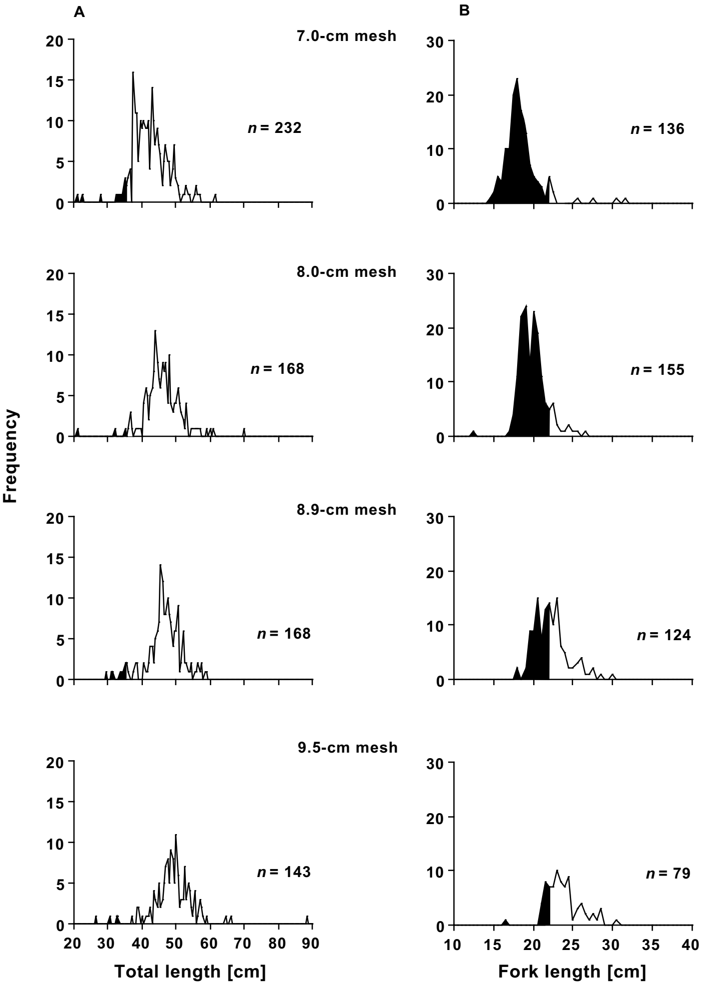
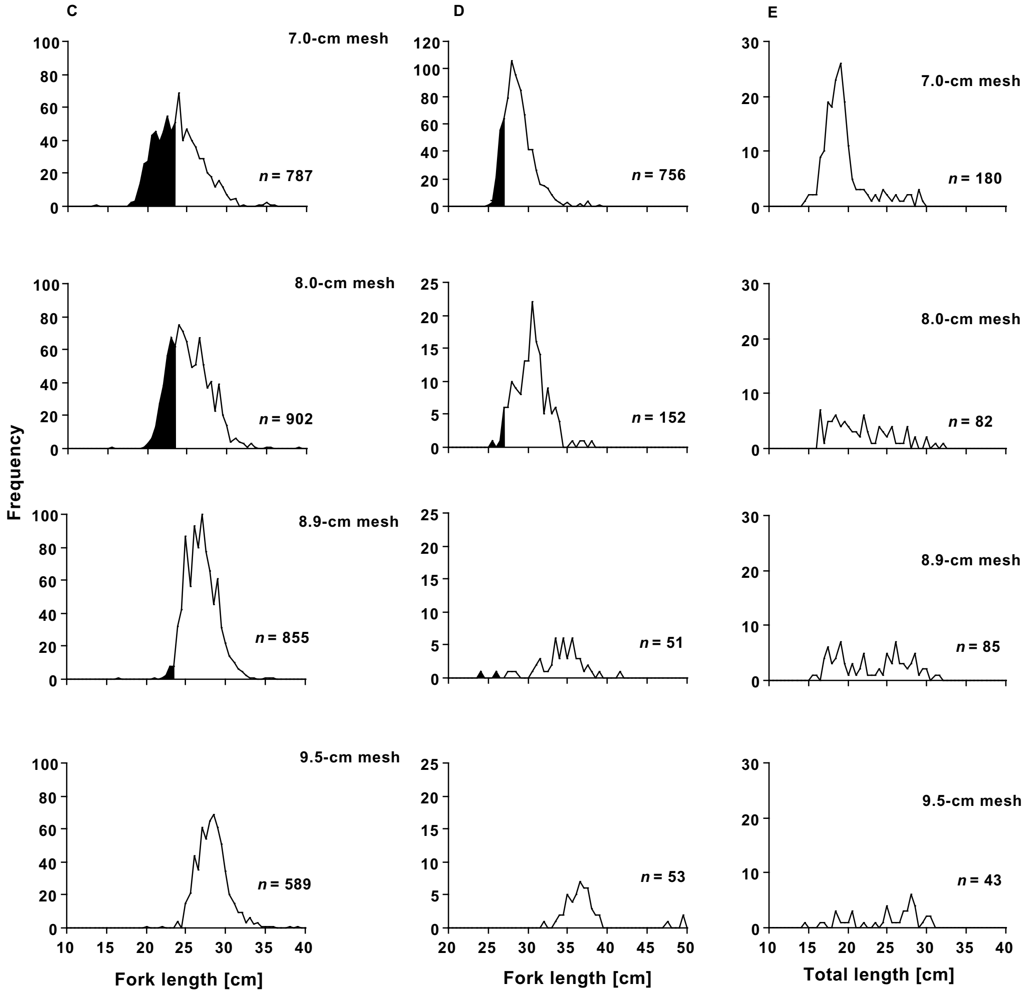


Figure 2: Observed size-frequency distributions of (A) dusky flathead, (B) bream, (C) luderick, (D) sea mullet, and (E) yellow-finned leatherjacket for the 4 mesh sizes examined. Black shading indicates undersize individuals.

substantially reduce the probability of capturing fish below these sizes (< 0.14 and 0.43, respectively) and an increase to 9.5 cm would virtually preclude their capture (probabilities of < 0.05 and 0.09, respectively). The use of a mesh size such as 9.5 cm would also result in fewer smaller legal-size fish (*e.g.* 36 to 54 cm TL) being retained, but the results presented here indicate this might be compensated for by the apparent presence of relatively larger individuals in the sampled areas.

The selectivity of dusky flathead was best described by a binormal curve, with two well-separated modes and considerable spread over larger sizes. This selection curve reflects their



*(Figure 2, continued)*

overall morphology and the processes by which different-size individuals were retained in the meshes. Dusky flathead have a laterally compressed, tapered anterior body characterised by prominent morphological discontinuities (*e.g.* large teeth, opercullar spines, maxillaries, etc). Many fish larger than the optimal selection lengths for each mesh size were observed to be tangled and meshed across various sections of the head. This occurred across a substantial size range of individuals and was probably augmented by the low hanging ratio (0.5) of the gillnet (Hamley 1975). In contrast, small fish were able to enter meshes and were mostly wedged behind the head (*i. e.* at the abdomens). Comparably wide ranges of selectivities

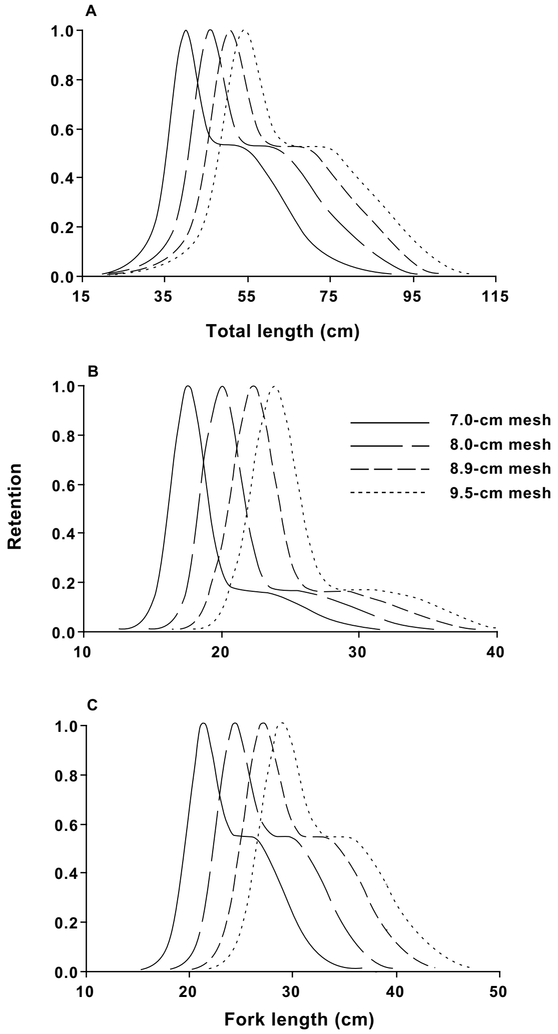


Figure 3: Estimated binomial selection curves for (A) dusky flathead, (B) bream, and (C) luderick for the 4 mesh sizes examined.

(attributed to morphological features) have been observed for other species of flathead (*e.g. Neoplatycephalus richardsoni*) captured in trawls (Broadhurst and Kennelly 1995).

Bream and luderick had relatively narrower selection ranges. These species have much greater body depths than dusky flathead and so their estimated optimal selection lengths were also lower among the mesh sizes examined. Like dusky flathead, however, their selection curves showed separate modes, indicating at least two different capture processes and more specifically, gilling behind the head and entangling in more than one mesh. While increases in mesh size had no significant effect on the total catches of these species, concomitant increases in optimal selection lengths meant that fewer under-size individuals (particularly luderick) were susceptible to capture by the two larger mesh sizes.

Because the size distributions of the majority of species comprising bycatch were within the selectivity of the various mesh sizes examined and these species occurred across similar habitats as the targeted dusky flathead, the catch-to-bycatch ratio remained similar with increasing mesh size. It is apparent, therefore, that in terms of reducing bycatch, simple increases in mesh size may not be the most appropriate gear-related modification. Other technical and biological parameters influencing selectivity of the gear need to be investigated. Given the morphology of dusky flathead, one option may be to increase lateral openings of meshes via a greater hanging ratio (*e.g.* up to 0.8). Previous studies have shown that this reduces the likelihood of fish being entangled and therefore their selection range (Hamley 1975; Acosta and Appeldoorn 1995).

Other changes to gears to reduce bycatch might involve lowering the fishing height of the gear to reduce the encounter probability of some individuals. For example, although all species were caught in significantly greater numbers in the lower 50 % of the gillnet, dusky flathead showed the greatest disequilibrium in vertical distribution. Given the figures from the present study, a 50 % reduction in the fishing height of the gear would reduce the catch of dusky flathead by approx. 11 %, but this could facilitate reductions in the bycatch of individual species by between approx. 21 % (for bream) and 44 % (for yellow-finned leatherjacket). More detailed information on size-related vertical distributions, schooling behaviour and movements of key species would need to be collected to help quantify the effects of such changes on efficiency of the gear.

Whilst it is likely that changes can be made to the configurations of gillnets used in this fishery to regulate size at first capture of dusky flathead and reduce mortality of unwanted conspecifics, some non-target species will still be caught incidentally. Unless large proportions of these discarded individuals survive the process of capture, it would be appropriate to amend the management of this fishery so that fishers are legally permitted to retain bycatch of legal-size. Such a strategy would reduce what can only be regarded as a waste of fisheries resources.

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