*Fisheries Management and Ecology*, 2004, **11**, 323–333

# Discards from the commercial gillnet fishery for dusky flathead, *Platycephalus fuscus*, in New South Wales, Australia: spatial variability and initial effects of change in minimum legal length of target species

C. A. GRAY & D. D. JOHNSON

*NSW Fisheries, Cronulla Fisheries Centre, Cronulla, NSW, Australia*

D. J. YOUNG & M. K. BROADHURST

*NSW Fisheries, National Marine Science Centre, Coffs Harbour, NSW, Australia*

**Abstract** A scientific observer programme was used to quantify the composition and magnitude of discards in the gillnet fishery for dusky flathead, *Platycephalus fuscus* (Cuvier), in three barrier estuaries in New South Wales, Australia, during the 2001 fishing season. Regulations only permit the retention of legal-sized dusky flathead and legal-sized blue swimmer crab, *Portunus pelagicus* L., and mud crab, *Scylla serrata* (Forskål); all other organisms were discarded. Sampling was stratified into two time periods; before and after 1 July 2001 which coincided with the increase in the minimum legal length (MLL) of dusky flathead from 33 to 36 cm total length (TL). Eighty one catches were sampled, yielding 38 finfish species and two portunid crab species. Legal-sized dusky flathead were the most abundant organism captured, accounting for 23–47% by number and 34–54% by weight of the mean observed catch depending on the estuary and survey period, with a mean catch of 25–59 flathead weighing 13–25 kg per fishing-night. Species composition and relative abundance of catches differed among estuaries, but not between sampling periods. Predominant bycatch species included legal and undersize blue swimmer crab, sea mullet, *Mugil cephalus* L., luderick, *Girella tricuspidata* (Quoy & Gaimard), bream, *Acanthopagrus australis* (Günther) and yellowfin leatherjacket, *Meuschenia trachylepis* (Günther). These five species accounted for 82% of total bycatch by number and 71% by weight, pooled across the three estuaries. More crabs were retained than discarded, with retained legal-size crabs (byproduct) accounting for 16% of total bycatch by number and 13% by weight, with an average of 5–22 crabs weighing 1–6 kg being caught per fishing-night, depending on the estuary. Overall, 7% of dusky flathead captured (number) were below the MLL of 36 cm and discarded, suggesting the nets as currently configured may be relatively selective in catching legal-size flathead. However, 41% of dusky flathead were $<40$ cm TL, indicating that if the MLL for this species is increased to this length as proposed, new nets must be introduced into the fishery. The findings are discussed in terms of making the flathead fishery more sustainable, including alternative management strategies for the fishery.

KEYWORDS: Australia, bycatch management, discard, gillnet fishery, *Platycephalus fuscus*.

## Introduction

Important recreational and commercial fisheries exist for dusky flathead, *Platycephalus fuscus* (Cuvier), in estuaries and coastal embayments throughout south-eastern Australia (Kailola, Williams, Stewart, Reichelt, McNee & Grieve 1993; Gray, Gale, Stringfellow & Raines 2002). In New South Wales (NSW), the commercial fishery catches up to 200 t $yr^{-1}$ of dusky flathead (valued at AUD$0.7 million) (Tanner

Correspondence: Dr Charles Gray, NSW Fisheries, Cronulla Fisheries Centre, PO Box 21, Cronulla, NSW, 2230, Australia
(e-mail: Charles.Gray@fisheries.nsw.gov.au)

& Liggins 1999). While no equivalent estimates of total recreational (line-only) catches of dusky flathead in NSW are available, it is acknowledged that recreational catches exceed reported commercial catches in some estuaries (West & Gordon 1995). There is much dispute among different resource interest groups over the allocation of the flathead resource, and the impacts of different fishing gears and sectors on these and other shared fish stocks in the region. Dusky flathead complete their entire life cycle in estuaries (99% of total reported commercial landings in NSW) and are primarily caught there using bottom-set gillnets (> 90% of total landings), with approximately 40% of the reported commercial catch being taken in specially constructed flathead gillnets. Except for legal-sized blue swimmer crab, *Portunus pelagicus* L., and mud crab, *Scylla serrata* (Forskal), all other organisms caught in flathead gillnets must be discarded. Discarding is often perceived as wasteful, and it can impact on the productivity and functioning of ecosystems and the biomasses and harvested yields of fish stocks (Jennings & Kaiser 1998; Hall 1999; Kaiser & de Groot 2000). Thus, one of the most contentious issues facing the management of the gillnet fishery for dusky flathead concerns the impacts of discarding bycatch, including undersized conspecifics. Fundamental to any assessment of the effects of this fishery on stocks, is the need to identify and quantify spatial, temporal and gear-related variability in the composition, and magnitude of both the retained and discarded components of catches (Alverson, Freeberg, Murawski & Pope 1994; Kennelly 1995; Hall 1999). Such information is also pivotal for developing ways to manage and mitigate bycatch and discard problems, and for determining the most appropriate and ecologically sustainable methods to harvest resources (Broadhurst 2000).

Gillnets are generally species and size selective (Hamley 1975; Millar & Fryer 1999). However, some gillnets used in the estuarine commercial fishery in NSW are known to catch a wide range of sizes of many species. The discards include several species important in other recreational and commercial fisheries (Gray 2002). There are very few data describing the composition and quantities of the retained and discarded catches taken in the gillnet fishery for dusky flathead. This is of particular concern because the minimum legal length (MLL) of dusky flathead was increased from 33 to 36 cm total length (TL) on 1 July 2001 over concerns raised about stock status (Gray *et al.* 2002). This increase in MLL could potentially lead to a greater level of discarding of small flathead in the gillnet fishery, potentially negating any positive effects of the MLL increase. Given this, and the necessity for all fisheries in NSW to undergo environmental assessments, there was a need to assess what is caught, retained and discarded in the estuarine gillnet fishery for dusky flathead. Such information is generally best obtained using observers to collect data during normal fishing operations, and ideally, such surveys should be stratified across appropriate spatial and temporal scales that incorporate different fishing operations (see Saila 1983; Kennelly 1995).

The aim of this study was to redress the lack of knowledge regarding the composition and quantities of catches (target and non-target species) taken in the estuarine commercial gillnet fishery for dusky flathead in NSW. An observer-based programme was used to quantify spatial and temporal variations in the species, quantities and length distributions of retained and discarded catches taken during normal fishing operations in the three main estuaries throughout the 2001 fishing season. These findings are discussed in terms of managing the fishery and assessing the effects of the recent increase in the MLL of dusky flathead on levels of discarding.

## Materials and methods

### *NSW flathead gillnet fishery*

The fishery in NSW is managed primarily by gear and licence restrictions, and temporal and spatial closures. Flathead gillnets must have a stretched mesh size of 70–80 mm, a maximum depth of 25 meshes and must not fish more than 0.5 m above the substratum. Minimal or no floatation is used and nets usually have a flue. Fishermen must not set > 1450 m of net at any one time. Until mid-2002, flathead nets could be set in five estuaries (Wallis, Smiths, Tuggerah, Illawarra Lakes and St Georges Basin) in NSW, where they were permitted to be set overnight between February and November in Wallis and Tuggerah Lakes, but only between May and August in the other three estuaries. Typically, nets are set just prior to sunset and retrieved at sunrise.

### *Observer survey and sampling procedures*

The observer survey was carried out in Wallis Lake (32° 15′S), Tuggerah Lake (33° 18′S) and Lake Illawarra (34° 31′S) throughout the 2001 fishing season. Each of these barrier estuaries supports other commercial and recreational fisheries. The survey was split into two periods: before and after the increase in the MLL of dusky flathead on 1 July 2001. The two survey periods were from February to June and July to

November in Wallis and Tuggerah lakes, and May and June, and July and August, in Lake Illawarra.

In each estuary, observers accompanied commercial flathead netsmen during the early morning when they retrieved gillnets that had been set overnight, on at least nine randomly selected fishing trips (night-sets) in each of the two survey periods. As each net was retrieved into the boat, all organisms were disentangled from the net. The observer identified, counted and determined the total weight (kg) of all species captured. The total length of dusky flathead and fork length (nearest cm) of key species were also measured. Non-target organisms were generally processed immediately, so that they could be quickly released to minimize further stress and mortality because of handling, whereas much of the retained catch was processed after the entire net was retrieved. The observers also recorded operational data, including net material, mesh (stretched inside) and ply size, length and depth (number of meshes) of nets, fishing (soak) time and location.

In this study, the term byproduct was defined as the total retained crab bycatch, and the term total bycatch refers to the sum of the total crab byproduct and the total discarded bycatch. Mesh size refers to the stretched mesh opening.

### Data analyses

*Variations in catch composition.* Nonparametric multivariate analyses were used to test for spatial and temporal differences in the composition (numbers of each species) of catches. The general procedures followed those outlined by Clarke (1993) and Clarke & Warwick (2001). Similarity matrices based on the Bray-Curtis similarity measure were generated for the catch abundance data and a two-dimensional multidimensional scaling (MDS) ordination plot based on the number of each species caught was used to display the amount of variation in the composition of catches within each estuary compared with that among estuaries. Catches that grouped together in the MDS ordination were most similar. An iterative optimisation procedure that successively refined the initial MDS configuration was used to achieve the best-fit (global minimum) and 10 repeats of this procedure were made to ensure a global minimum was achieved. The stress value is a measure of goodness-of-fit of data. One-way analysis of similarity (ANOSIM) tested for spatial and temporal differences in the composition of catches were displayed in the MDS. This test is a randomised permutation procedure that compares within sample similarity with among sample similarity. Similarity percentage analysis was used to quantify the species that were most responsible for the similarity of catches within each estuary and survey period. The ratio of similarity/standard deviation is a measure of how consistently each species contributed to the similarity measure within each estuary and sampling period. Taxa that displayed a high ratio and a high contribution can be considered good for discriminating species (Clarke & Warwick 2001).

*Effects of net material on catches.* Multivariate and univariate analyses were also used to assess the effects of net material on catches. One person in Wallis Lake simultaneously fished with one multi-monofilament net, and one nylon net, with both nets having similar dimensions; 70 mm mesh, 725 m in length, 25 meshes deep and hanging ratio of 0.5, but the twine diameter of the multi-monofilament net was 0.46 mm ($0.5 \times 8$ strand ply) and for 0.60 mm (6 ply) nylon net. Catches from six fishing-nights were compared. No other direct assessment of net material on catches was made as nets were often configured differently (e.g. height, colour, mesh size), and were fished at different times and areas, thus confounding any direct comparisons.

*Variations in catch rates.* Two-factor analysis of variance (ANOVA) was used to test for differences in the weights and quantities of catches among the three estuaries and between the two survey periods. Analyses were made at two levels: (i) catches per fishing-night and (ii) standardised catches per 100 m length of net. The latter analysis was carried out because commercial gillnets were of different lengths and this was undesirable to test for differences in the relative abundances of organisms among estuaries and survey periods. Data were transformed to log $(x + 1)$ to stabilize variances (Cochran's test) and Student–Newman–Keuls test was used to determine differences among means following ANOVA. When variances remained heterogeneous following transformation, $P$ was set at 0.01 to reduce type I errors (Underwood 1981). The ratio of weight of the retained dusky flathead catch to weight of the total bycatch (all other organisms caught) was calculated for each estuary for each period following the procedures detailed in Cochran (1963).

*Estimates of total catches in each estuary.* Estimates of the total catches (+1SE) for the entire gillnet fishery for dusky flathead in each estuary were determined for the survey period following the standard method for estimating a total and standard error across multiple randomly sampled strata (Cochran 1963). The observed

mean catch rates per fishing-night were multiplied by the reported number of nights fished by all flathead netsmen in each estuary in each survey period between February and November 2001 (see Gray, Kennelly, Hodgson, Ashby & Beatson 2001 for details). The total reported fishing effort (i.e. total number of nights fished using flathead gillnets) was obtained from the forms that commercial operators are required to submit to NSW fisheries combined with post-survey interviews.

*Length compositions of catches.* Observed length compositions of catches of dusky flathead, sea mullet, *Mugil cephalus* L., bream, *Acanthopagrus australis* (Günther), luderick, *Girella tricuspidata* (Quoy & Gaimard) sand whiting, *Sillago ciliata* (Cuvier) and yellowfin leatherjacket, *Meuschenia trachylepis* (Günther) were scaled to represent the total catch across all three estuaries. Length composition data were weighted according to the ratio of total fishing effort to sampling effort in each period and estuary and then summed to provide a total distribution across all three estuaries. Size of blue swimmer crab was not recorded during the survey.

## Results

### Fishing and sampling effort

A total of 81 gillnet samples, 27 from Wallis Lake, 32 from Tuggerah Lake and 22 from Lake Illawarra were observed, which represented 3.5, 2.8 and 9.6% of the total reported commercial fishing effort (nightly sets of flathead gillnets) in each estuary, respectively. Total reported fishing effort in 2001 was greatest in Tuggerah Lake and least in Lake Illawarra, with fishing effort being greater in the first half of the year in both Wallis and Tuggerah Lakes. Throughout 2001, 15 flathead netsmen reported working in Wallis Lake, 17 in Tuggerah Lake and nine in Lake Illawarra.

Nets used in Wallis and Tuggerah lakes were predominantly 70 mm mesh whereas at Lake Illawarra they were 76 and 80 mm mesh. Multi-monofilament and nylon nets were used at Wallis and Tuggerah lakes, whereas only multi-monofilament nets were used at Lake Illawarra. The depth of nets used ranged from 12 to 25 meshes. Neither nets nor fishing practices changed upon the change in MLL of flathead.

### Catch composition

Legal-sized dusky flathead was the most abundant organism captured, accounting for 23–47% of the total mean nightly catch by number and 34–53% by weight, depending on the estuary and survey period (Fig. 1). Forty species (38 finfish and two portunid crabs) were observed in bycatches: 18 species in Wallis Lake, 28 species in Tuggerah Lake and 17 species in Lake Illawarra. Bycatches were dominated by a small number of species, notably blue swimmer crab, sea mullet, bream and luderick, which are important in other recreational and commercial fisheries. These species accounted for up to 83% of the total observed bycatch (pooled across all three estuaries) in this fishery. Retained legal-sized crabs (byproduct) accounted for 3–49% of total bycatch by number and 1–12% by weight, depending on the estuary and period. The mean ($\pm$1SE) ratio of weight of retained dusky flathead catch to weight of total bycatch (including byproduct) in each estuary was: 1:1.11 (0.19) in Wallis Lake, 1:2.07 (0.30) in Tuggerah Lake and 1:2.46 (0.92) in Lake Illawarra. There was a trend for total bycatch weight to increase with weight of retained dusky flathead catch in Tuggerah Lake ($r_{(32)} = 0.408$, $P < 0.05$), but not in Wallis Lake ($r_{(27)} = 0.365$, $P > 0.05$) or Lake Illawarra ($r_{(22)} = 0.268$, $P > 0.05$) (Fig. 2).

Catch composition differed significantly among all three estuaries (ANOSIM, Global $r = 0.177$, $P < 0.001$, pairwise comparisons $P < 0.001$ in all cases), although there was considerable variation in the

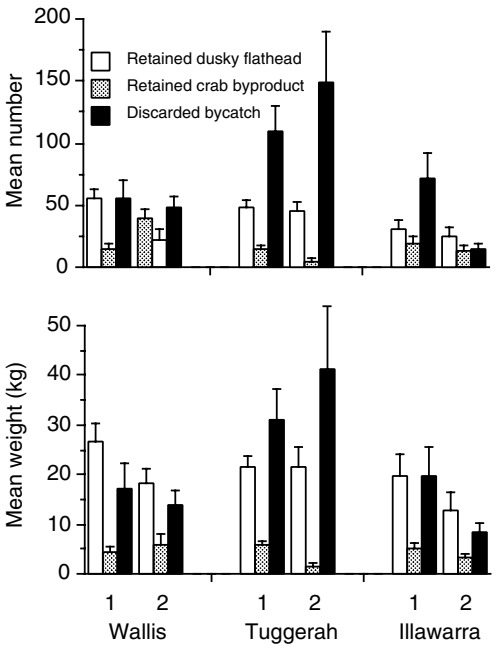


**Figure 1.** Mean (+1SE) catch rate by number and weight of retained dusky flathead, crab byproduct and discarded bycatch in the two survey periods in each estuary.

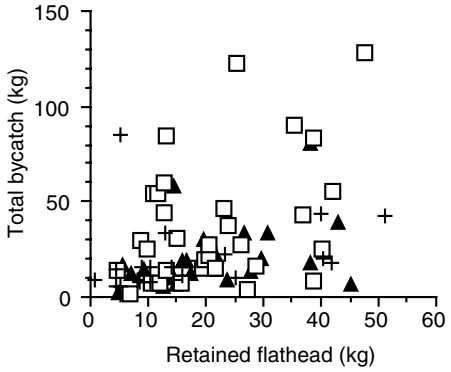


**Figure 2.** Relationships between weight of retained dusky flathead catch and total non-target bycatch in each estuary. ▲ Wallis Lake; □ Tuggerah Lake; + Lake Illawarra.

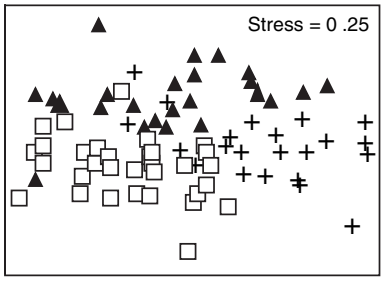


**Figure 3.** MDS ordination plot showing the relationship between the amounts of variation in the composition of catches within each estuary compared with the differences among estuaries. ▲ Wallis Lake; □ Tuggerah Lake; + Lake Illawarra.

composition of catches within each estuary and some overlap among estuaries (Fig. 3). There was no significant difference ($P > 0.05$) in the composition of catches between the two survey periods within each estuary ($r = 0.036$, 0.211, 0.073 in Wallis, Tuggerah and Illawarra, respectively). Legal-sized dusky flathead contributed greatest to the similarity measure of catches in all three estuaries (Table 1). Other species that were relatively abundant and contributed significantly to the similarity of catches within each estuary, and therefore considered good indicator species, were legal and undersize blue swimmer crab, sea mullet, bream and luderick. Estuary catfish, *Cnidoglanis macrocephalus* (Valenciennes), were also important in distinguishing catches in Wallis Lake, black sole, *Synaptura nigra* (Macleay), in Tuggerah Lake and yellowfin leatherjacket in Lake Illawarra (Table 1). The five most important species accounted for 82–94% of the similarity of catches between each estuary (Table 1).

No significant difference was detected in the composition of catches taken in multi-monofilament vs nylon nets fished simultaneously in Wallis Lake (ANOSIM, $r = 0.042$, $P > 0.05$). Fifteen species were observed in catches, with legal-sized dusky flathead, legal and undersize blue swimmer crab, sea mullet and bream dominating catches in both nets. Catch rates of these species did not differ significantly between nets (ANOVA, $P > 0.05$).

### *Variations in catch rates*

There was significant variability (ANOVA, $P < 0.05$) in the nightly catches of legal-size and undersize dusky flathead, total bycatch, total retained crab byproduct and total discarded bycatch (Table 2). Catches of legal-size dusky flathead varied between periods, with more being caught in period 1. Significant differences in the numbers and weights of undersize dusky flathead caught before and after the MLL change were detected (ANOVA, $P < 0.05$), but this varied among estuaries (Tables 2 and 3). More undersize flathead were caught in the latter survey period in Wallis Lake. Rates of capture of the retained byproduct, discarded and total bycatch also varied among estuaries or survey periods. The greatest number and weight of total bycatch was in Tuggerah Lake (Fig. 1). A mean of 25–59 dusky flathead (weighing 13–26 kg) and 28–154 total bycatch individuals (weighing 13–43 kg) were caught per fishing-night (Fig. 1). Retained crab byproduct accounted for 5–22 (weighing 1–6 kg) of the total nightly bycatch (Fig. 1). Similarly, a mean of 0.1–3.4 undersized dusky flathead were caught per night, depending on the estuary and survey period.

Significant spatial and temporal variability was also detected for the standardized catches (per 100 m of net) of the predominant species caught as bycatch (Table 3). The mean number of legal-sized dusky flathead caught per 100 m of net per night varied between 2.59 and 4.85, while that of total bycatch varied between 3.44 and 11.72 individuals (Table 3). Except for legal and undersize blue swimmer crab, sea mullet, luderick, bream and yellowfin leatherjacket, less than one individual of each of the other bycatch species was caught on average per 100 m of net per night in any estuary (Table 3).

### *Length compositions of catches*

The length compositions of catches of dusky flathead were similar before and after the change in MLL and in all three estuaries. Dusky flathead smaller than the

**Table 1.** The ten species that contributed greatest to the similarity matrix of catches taken in flathead nets in Wallis Lake, Tuggerah Lake and Lake Illawarra. Analyses based on non-transformed data. Species listed in order of greatest contribution. Mean catch per fisher-night, the ratio of average similarity to standard deviation and the percent contribution of each species to the similarity measure in each estuary are presented

| Species | Mean catch per fishing night | Ratio (similarity/SD) | Percentage contribution | Cumulative contribution |
|---|---|---|---|---|
| Wallis Lake (average similarity 45.01) | | | | |
| Dusky flathead (legal-size) | 48.15 | 2.45 | 62.93 | 62.93 |
| Blue swimmer crab (legal-size) | 17.48 | 0.72 | 11.91 | 74.83 |
| Bream | 10.52 | 0.94 | 7.43 | 82.26 |
| Sea mullet | 13.52 | 0.56 | 5.27 | 87.53 |
| Blue swimmer crab (undersize) | 5.78 | 0.78 | 4.70 | 92.23 |
| Estuary catfish | 3.22 | 0.39 | 1.73 | 93.96 |
| Luderick | 3.33 | 0.43 | 1.12 | 95.17 |
| Fanbelly leatherjacket | 1.59 | 0.44 | 1.04 | 96.21 |
| Sand whiting | 1.93 | 0.40 | 0.97 | 97.17 |
| Dusky flathead (undersize) | 1.85 | 0.38 | 0.89 | 98.06 |
| Tuggerah Lake (average similarity 41.21) | | | | |
| Dusky flathead (legal-size) | 47.03 | 2.00 | 47.00 | 47.00 |
| Sea mullet | 35.91 | 0.73 | 14.69 | 61.70 |
| Luderick | 31.72 | 0.60 | 7.55 | 69.25 |
| Blue swimmer crab (legal-size) | 10.50 | 0.67 | 6.94 | 76.19 |
| Bream | 15.22 | 0.71 | 6.48 | 82.67 |
| Blue swimmer crab (undersize) | 11.06 | 0.58 | 5.96 | 88.64 |
| Black sole | 5.16 | 1.02 | 4.46 | 93.09 |
| Dusky flathead (undersize) | 2.22 | 0.55 | 1.33 | 94.42 |
| Sand whiting | 1.84 | 0.52 | 0.94 | 95.36 |
| Yellowfin leatherjacket | 3.59 | 0.44 | 0.85 | 96.21 |
| Lake Illawarra (average similarity 41.96) | | | | |
| Dusky flathead (legal-size) | 28.64 | 1.62 | 49.32 | 49.32 |
| Blue swimmer crab (legal-size) | 17.00 | 1.32 | 28.05 | 77.37 |
| Blue swimmer crab (undersize) | 6.00 | 0.80 | 7.01 | 84.37 |
| Yellowfin leatherjacket | 10.91 | 0.68 | 6.41 | 90.78 |
| Luderick | 7.68 | 0.61 | 3.48 | 94.26 |
| Sea mullet | 17.36 | 0.32 | 3.03 | 97.30 |
| Bream | 2.27 | 0.47 | 0.87 | 98.16 |
| Black sole | 0.50 | 0.25 | 0.35 | 98.51 |
| Sand whiting | 0.41 | 0.33 | 0.26 | 98.77 |
| Silver biddy | 0.50 | 0.30 | 0.24 | 99.01 |

**Table 2.** Summary of results of two-factor analyses of variance comparing catch per night fished across the three estuaries and two survey periods. 'Estuary' and 'period' were treated as fixed factors. Mean square values and their level of significance are given. Data transformed to log $(x + 1)$ to stabilize variances

| Source | d.f. | Dusky flathead legal-size | Dusky flathead undersize | Total bycatch | Retained crab byproduct | Discarded bycatch |
|---|---|---|---|---|---|---|
| Number caught per-night fished | | | | | | |
| Estuary | 2 | 0.153 ns | 0.219 ns | 0.774** | 0.549* | 1.450** |
| Period | 1 | 0.479* | 0.676** | 0.507* | 3.544** | 0.344 ns |
| Estuary × period | 2 | 0.099 ns | 0.325* | 0.202 ns | 0.435 ns | 0.578* |
| Error | 48 | | | | | |
| Weight caught per-night fished | | | | | | |
| Estuary | 2 | 0.073 ns | 0.056* | 0.383* | 0.147 ns | 0.740** |
| Period | 1 | 0.338* | 0.135** | 0.246 ns | 1.446** | 0.044 ns |
| Estuary × period | 2 | 0.124 ns | 0.051* | 0.058 ns | 0.131 ns | 0.150 ns |
| Error | 48 | | | | | |

d.f., degrees of freedom.
*$P < 0.05$; **$P < 0.01$; ns, $P > 0.05$.

**Table 3.** Mean (+1SE) catch per 100 m of net set in each estuary of retained legal size dusky flathead, total bycatch, total retained crab byproduct, total discarded bycatch and the ten most abundant components of total bycatch species across the three estuaries and two time periods

| | Wallis Lake | | Tuggerah Lake | | Lake Illawarra | | |
|---|---|---|---|---|---|---|---|
| | Period 1 | Period 2 | Period 1 | Period 2 | Period 1 | Period 2 | ANOVA |
| Number | | | | | | | |
| Dusky flathead retained (legal) | 4.78 (0.51) | 4.60 (0.92) | 3.14 (0.32) | 2.59 (0.44) | 4.08 (1.17) | 2.76 (0.50) | ns |
| Total bycatch | 6.16 (1.24) | 7.81 (0.97) | 8.73 (1.63) | 9.37 (2.42) | 11.72 (2.32) | 3.44 (0.80) | ns |
| Retained crab byproduct | 1.17 (0.30) | 1.87 (0.54) | 1.06 (0.23) | 0.30 (0.14) | 2.82 (1.01) | 1.82 (0.49) | E, P |
| Discarded bycatch | 4.99 (1.29) | 5.94 (1.11) | 7.66 (1.57) | 9.07 (2.42) | 8.90 (1.83) | 1.63 (0.37) | E, ExP |
| Sea mullet | 1.58 (0.84) | 0.98 (0.39) | 2.66 (0.71) | 2.08 (0.78) | 3.16 (1.41) | 0.05 (0.02) | ns |
| Blue swimmer crab (legal) | 1.07 (0.31) | 1.82 (0.53) | 0.95 (0.23) | 0.29 (0.14) | 2.82 (1.01) | 1.82 (0.49) | E, P |
| Luderick | 0.36 (0.15) | 0.35 (0.17) | 1.36 (0.78) | 3.18 (1.14) | 1.96 (0.95) | 0.10 (0.05) | ns |
| Bream | 1.07 (0.36) | 1.17 (0.50) | 0.94 (0.30) | 1.27 (0.46) | 0.40 (0.17) | 0.08 (0.03) | E |
| Blue swimmer crab (undersize) | 0.42 (0.13) | 0.72 (0.24) | 1.00 (0.20) | 0.19 (0.10) | 1.10 (0.29) | 0.49 (0.24) | ns |
| Yellowfin leatherjacket | 0.43 (0.33) | 0.09 (0.05) | 0.29 (0.17) | 0.14 (0.05) | 1.60 (0.63) | 0.36 (0.13) | E, P* |
| Estuary catfish | 0.30 (0.11) | 0.50 (0.23) | 0.09 (0.07) | 0.16 (0.07) | 0.00 (0.00) | 0.00 (0.00) | E* |
| Sand whiting | 0.21 (0.08) | 0.29 (0.24) | 0.09 (0.03) | 0.20 (0.05) | 0.09 (0.04) | 0.03 (0.02) | ns* |
| Dusky flathead (undersize) | 0.04 (0.03) | 0.46 (0.13) | 0.16 (0.04) | 0.14 (0.05) | 0.04 (0.02) | 0.05 (0.03) | E, ExP* |
| Black sole | 0.09 (0.04) | 0.01 (0.01) | 0.39 (0.07) | 0.24 (0.07) | 0.04 (0.02) | 0.10 (0.05) | E* |
| Weight (kg) | | | | | | | |
| Dusky flathead retained (legal) | 2.29 (0.32) | 2.15 (0.45) | 1.42 (0.14) | 1.25 (0.22) | 2.64 (0.75) | 1.37 (0.27) | ns* |
| Total bycatch | 1.93 (0.49) | 2.09 (0.27) | 2.60 (0.47) | 2.61 (0.71) | 3.12 (0.69) | 1.37 (0.19) | ns |
| Retained crab byproduct | 0.36 (0.08) | 0.50 (0.15) | 0.39 (0.08) | 0.09 (0.04) | 0.72 (0.25) | 0.43 (0.11) | E, P |
| Discarded bycatch | 1.57 (0.47) | 1.59 (0.28) | 2.20 (0.46) | 2.52 (0.71) | 2.39 (0.57) | 0.94 (0.16) | ns |
| Sea mullet | 0.69 (0.40) | 0.37 (0.16) | 0.92 (0.23) | 0.74 (0.28) | 1.14 (0.51) | 0.02 (0.01) | ns |
| Blue swimmer crab (legal) | 0.27 (0.08) | 0.44 (0.13) | 0.25 (0.06) | 0.07 (0.03) | 0.72 (0.25) | 0.43 (0.11) | E, P* |
| Luderick | 0.08 (0.04) | 0.10 (0.05) | 0.35 (0.19) | 0.70 (0.25) | 0.48 (0.24) | 0.03 (0.01) | ns |
| Bream | 0.18 (0.06) | 0.19 (0.07) | 0.13 (0.04) | 0.17 (0.06) | 0.07 (0.03) | 0.01 (0.01) | ns |
| Blue swimmer crab (undersize) | 0.05 (0.02) | 0.09 (0.03) | 0.15 (0.04) | 0.02 (0.01) | 0.21 (0.07) | 0.09 (0.03) | ns* |
| Yellowfin leatherjacket | 0.05 (0.04) | 0.01 (0.00) | 0.04 (0.02) | 0.02 (0.00) | 0.23 (0.11) | 0.04 (0.01) | E* |
| Estuary catfish | 0.15 (0.06) | 0.27 (0.13) | 0.07 (0.05) | 0.19 (0.08) | 0.00 (0.00) | 0.00 (0.00) | ns* |
| Sand whiting | 0.06 (0.03) | 0.07 (0.06) | 0.03 (0.01) | 0.06 (0.01) | 0.03 (0.01) | 0.01 (0.01) | ns* |
| Dusky flathead (undersize) | 0.01 (0.00) | 0.10 (0.03) | 0.04 (0.01) | 0.04 (0.01) | 0.01 (0.01) | 0.01 (0.01) | P, ExP* |
| Black sole | 0.01 (0.00) | 0.00 (0.00) | 0.05 (0.01) | 0.04 (0.01) | 0.00 (0.00) | 0.01 (0.01) | E* |

Significant results of two-factor analyses of variance are also presented. Estuary and period were both treated as fixed factors, data transformed to log $(x+1)$ to stabilize variances, except '*' where variances remained heterogeneous and the critical $P$-value was set at 0.01.
E, estuary; P, survey period; ExP, estuary × period interaction; ns, no significant differences.

current MLL of 36 cm TL accounted for 7.2% of all dusky flathead observed in catches (Fig. 4).

### *Estimated total catches and bycatches*

It was estimated that a total of 46 t of dusky flathead and 65 t of total bycatch, of which 10 t was retained crab byproduct, was caught in flathead nets in the three estuaries (Table 4). Estimated total catches and bycatches were much less in Lake Illawarra compared with Wallis and Tuggerah lakes because of a restricted 4-month fishing season in the former estuary. Apart from legal-size blue swimmer crabs, a greater weight of each species and total bycatch was caught in Tuggerah Lake compared with Wallis Lake.

## Discussion

### *Composition and quantities of retained and discarded catches*

Dusky flathead were the most abundant species in catches, numerically accounting for 31% of observed total catches, pooled across the three estuaries. The increase in the MLL of dusky flathead to 36 cm TL appeared to have little impact on the discarding rates of undersized dusky flathead, except in Wallis Lake where there was a slight trend for more undersized flathead to be discarded after the MLL increase. The general lack of change in discarding rates of undersize flathead from before to after the MLL change may