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[Article]

Undersized *Acanthopagrus butcheri* Caught and Released from Commercial Gill Nets Show High Survival Rates in the Gippsland Lakes, Southeastern Australia

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Abstract.—A substantial decline in the commercial catches and catch rates of black bream *Acanthopagrus butcheri* in the Gippsland Lakes, Australia, signified a depletion of the stock and prompted management to increase the legal minimum length (LML) from 26 cm to 28 cm (total length) in December 2003. The effectiveness of this increase depends on the postrelease survival rate of undersized fish. The present study estimates the rates of release and initial survival (1 h after capture) of undersized *A. butcheri* during commercial fishing by gill nets in the Gippsland Lakes. Field capture and holding trials were also used to estimate initial and delayed survival (72 h after capture). Almost 6,000 *A. butcheri* from 347 gill net shots were caught during 2005–2006. The average total length increased by 1 cm from 2005 to 2006, increasing the proportion of the catch that was retained in 2006 (75%) compared with 2005 (50%). The best estimates of initial and delayed survival were 97.2% (SE, 0.3%) and 94.4% (SE, 3.8%), respectively. The total survival rate, which combines the initial survival rate from observer work with the delayed survival rates from the trials, was estimated as 90.8% (SE, 3.8%). The increase in the LML from 26 to 28 cm afforded significant protection to fish between these size limits, but the level of protection will be short term (1 or at most 2 years) for each year-class because of the growth rate of the species. Released, retained, and postrelease survival rates are discussed for various LMLs and with regard to their implications for fishery management.

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Commercial fishing in the Gippsland Lakes began in the 1870s; by the early 1900s, there were more than 100 fishing operators. Black bream *Acanthopagrus butcheri* has always been one of the main target species in this multispecies fishery. *Acanthopagrus butcheri* first reach maturity at 17 cm (total length), 50% are mature at 19 cm, and 100% are mature at 26–27 cm (Walker et al. 1998); they can take 2–5 years to reach this last size (Morison and Conron 2009). Management arrangements, which have been changing since the 1950s, include changes to the legal minimum length (LML), the area and season closures, and the number of licenses issued. The Gippsland Lakes commercial fishery became a limited-entry fishery in 1976, and in the early 1980s a voluntary catch limit of 50 bins (unspecified number and weight) of *A. butcheri* per fisher per week was temporarily introduced by the commercial fishers in response to concern over declining fish stocks (Morison and Conron 2009).

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Catch data from the Gippsland Lakes fishery have been collected regularly since 1914 (Morison and Conron 2009). Annual landings of *A. butcheri* reached 352 metric tons in 1919 but decreased to only 30 metric tons by 1929; they increased to 548 metric tons in 1974–1975 and then fluctuated until 2000, the largest catch (435 metric tons) occurring in 1983–1984 and the smallest (89 metric tons) in 1996–1997. The total catch was 26 metric tons (valued at AU$242,000) in 2002–2003, 33 metric tons ($340,000) in 2003–2004, 31 metric tons ($292,000) in 2004–2005, and 37 metric tons ($386,000) in 2005–2006 (Morison and Conron 2009). Only 10 fishers were operating in 2006.

The small catches and low catch rates raised concerns about the size of the *A. butcheri* stock in the Gippsland Lakes. In December 2003, the LML for *A. butcheri* was increased from 26 cm to 28 cm to give greater protection to the spawning stock. The effectiveness of this measure (and all management measures that mandate the release of captured fish) depends to a great extent on the postrelease survival (PRS) rates of released fish (Coggins et al. 2007).

Since 2000, most of the *A. butcheri* caught in the commercial fishery have been taken by gill nets (Morison and Conron 2009), but no information on

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their PRS rates has been collected. Previous studies of gill-net PRS in North America have reported varying survival rates across species (review by Chopin and Arimoto 1995), mesh sizes (Bettoli and Scholten 2006), and fish lengths (Bettoli and Scholten 2006). Stock assessment workshops that examined the Gippsland Lakes fishery for *A. butcheri* in 2004 and 2005 acknowledged that the lack of PRS data prevented a robust assessment of the effectiveness of the increased LML.

The PRS rate of *A. butcheri* has been estimated for the Gippsland Lakes recreational hook-and-line fishery (Grixti et al. 2008) as well as for the haul seine fishery in Corner Inlet and Port Phillip Bay (Knuckey et al. 2002). Both of these studies suggest that the PRS for *A. butcheri* is high; however, in the recreational hook-and-line fishery, a high rate of PRS is dependent on a high shallow-hooking rate.

The present study had three objectives: (1) to determine, by onboard observation, the released and retained rates for *A. butcheri* caught by gill nets in the Gippsland Lakes; (2) to estimate, from onboard observation and field trials, the PRS of *A. butcheri* captured by gill nets; and (3) to use the results from (1) and (2) to estimate the level of PRS among *A. butcheri* caught by gill nets in the Gippsland Lakes at previous, current, and potential future LMLs.

Methods

Onboard Observations

Details of the fishing activities of four commercial fishers who were regularly fishing for *A. butcheri* with gill nets in the Gippsland Lakes (Figure 1) were recorded during normal fishing practices in October 2005 and again between February and May 2006. Observation days for participating fishers were chosen at random. If the selected fisher was unavailable, then another fisher was chosen randomly. Observers recorded the fishing location, the number of gill nets deployed (each net was given a code number for that day), and the length of each net, its mesh size, the time it was set, the time it was cleared, and the average water depth in which it was set. Observers also recorded the number and sizes of all *A. butcheri* caught, whether they were released or retained, the condition (alive or dead) of released undersized fish, and the mesh size of the net in which the fish were caught. Fish were categorized as dead if there was no operculum movement.

Fishers in the Gippsland Lakes use a range of mesh sizes depending on the target species (Table 1). The fishers observed in 2005 were using mesh sizes suitable for targeting legal-size *A. butcheri* (M4; mesh size, 95–102 mm). In 2006 an attempt was also made to observe the release rates of *A. butcheri* caught by smaller mesh sizes when fishers were targeting other species. All *A. butcheri* above the LML were retained, and all those under it were released.

Postrelease Survival Trials

Four trials were conducted to estimate the PRS for *A. butcheri* after their capture in gill nets. Field trials aimed to replicate, as far as possible, the trial design used for estimating the PRS for *A. butcheri* caught by recreational fishers (Grixti et al. 2008). These trials involved replicate trips and the separate estimation of "initial" survival (survival for 1 h after release) and "delayed" survival (survival for 3 d after release). For the present trials, fish were caught by the two of the M4 gill-net sizes (95 and 98 mm) used by Gippsland Lakes commercial fishers when targeting *A. butcheri* (Morison and Conron 2009). Control fish were caught with a seine net close to the site where the gill nets were set.

For the first two trials in October 2005, fish were caught in an area of the Gippsland Lakes (Cunninghame Arm) where commercial fishers had suggested there would be high numbers of undersized *A. butcheri*. Gill nets were set at 2030 hours and cleared between 0000 and 0500 hours the following day. For trials 3 and 4 in April 2006, fish were obtained from Lake King near the mouth of the Mitchell River; the nets were set at dusk and cleared at dawn.

Acanthopagrus butcheri caught by the gill and seine nets were measured for total length (to the nearest cm, rounded down) and fin-clipped for identification of capture method. They were then placed in holding cages (0.25-cm-diameter soft-mesh cages measuring 70 cm deep × 62 cm long × 62 cm wide) that were moored beside the fishers' boats. Initial survival was assessed after 1 h in these cages. Fish were categorized as initial mortalities if there was no operculum movement. After each hour of fishing, all initial survivors were transported from the fishers' boat in water-filled, aerated 50-L plastic tubs (maximum of 30 fish per tub during transport) to holding tanks moored nearby in the estuary. The time between removing a fish from the holding cage and placing it in the moored holding tank was, on average, 10 min. The four moored holding tanks (plastic tubs with lids 110 cm high and 110 cm in diameter) had buoys for flotation and small holes throughout the walls and base to allow water exchange. The maximum holding capacity was set at 40 fish per tank (with a target of 10 seine-net-caught control fish and 30 gill-net-caught fish) based on a previous study using these tanks for estimating PRS for recreationally caught *A. butcheri* (Grixti et al. 2008).

The fish were monitored for delayed PRS at 0700 and 1700 hours each day for 3 d while in the holding

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FIGURE 1.—Map of the Gippsland Lakes.

tanks. The undersized *A. butcheri* caught by seine nets acted as controls and tested whether fin clipping, transport, and confinement affected survival. These controls underwent the same handling, transport, and confinement as fish caught with gill nets. Only *A. butcheri* between 15 and 27 cm TL were used in the trials, so as to minimize the effects of captivity on PRS, in particular the effects of aggressive behaviors among fish of different sizes. The allocation of fish to holding tanks was consistent with a split plot design (Quinn and Keough 2002) with holding tanks as the sample unit. Water temperature (C°), salinity (mg/L), and dissolved oxygen (% saturation) were measured with a YSI Model 85/100FT both inside and outside of the holding tanks at 0700 and 1700 hours during the 3-d holding period.

TABLE 1.—Mesh sizes and mesh size categories used in the logbooks for *A. butcheri* captured in the Gippsland Lakes, 2005–2006.

Mesh size (mm)	Mesh size category
63.5	M2
69.9	M2
76.2	M3
95.3	M4
96.8	M4
98.4	M4
101.6	M4

Statistical Analysis

Onboard observations.—The data were analyzed in SAS 9.1. Released and retained catch rates were

TABLE 2.—Number of days of commercial fishing observed, net lifts, total soak time and total number of *A. butcheri* caught by year, month, and mesh size.

Year	Month	Mesh size category	Days	Net lifts	Soak time (km/h)	Number caught
2005	Oct	M4	16	233	597	4,554
2006	Feb	M2	1	5	4	13
		M3	1	5	4	19
		M3 and M4	1	1	1	0
		All	1	11	9	32
	Mar	M2	2	9	11	15
		M3	2	11	12	56
		M4	1	12	14	196
		All	3	32	38	267
	Apr	M4	5	39	136	975
	May	M2	1	1	0	0
		M4	4	31	74	113
		All	4	32	74	113
Total			29	347	854	5,941

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calculated as the total number of *A. butcheri* released or retained per kilometer per hour of fishing. A Kolmogorov–Smirnov test was used to test that data were normally distributed and Levene's test and box-and-whisker plots were used to assess whether the variances were homogeneous. As the data were not normally distributed and could not be normalized by transformation, nonparametric tests were used. Nonparametric analyses of variance examined the effect of mesh size (Kruskal–Wallis test) and year (Wilcoxon two-sample test) on the mean catch rate for undersized (released) fish, the mean catch rate for retained fish, and mean fish length. For comparison between years, only the data from the M4 nets (Table 1) were used because other mesh sizes were not used in 2005. For the same reason, the comparison among mesh sizes only used data from 2006. Chi-square frequency analysis was used to examine the effect of year, mesh size (M2, M3, or M4) and fish length on initial survival. To compare fish lengths, fish sizes were treated as separate categories (≤24, 24, 25, 26, and 27 cm).

Postrelease survival trials.—The probabilities and standard errors of initial, delayed, and total survival were calculated by the methods of Wilde et al. (2003), which are designed for studies of recreational fishing tournaments in which all captured fish are monitored for initial survival. Survival is calculated by dividing the number of surviving fish by the total number of captured fish and takes into account the decreasing number of fish available for the delayed assessment because of initial mortality. Because 100% of these tournament-caught fish are monitored for initial survival, there is no sampling error for the initial survival estimate. However, in the present investigation the estimate of initial survival included an error term (the standard error of the proportion) because these fish did not represent 100% of the population. The probabilities of delayed survival included a finite-population correction.

Simple logistic regression analysis and odds ratio tests were used to explore the relationships between the independent variables year and fish length and the response variables initial and delayed survival. The mean fish lengths from the mesh and seine nets were compared with analysis of variance (ANOVA). The released, retained, and PRS rates were used to produce an estimate of the PRS rate among *A. butcheri* caught by gill nets in the Gippsland Lakes at current, previous, and alternative (27-cm) LMLs.

Results

Onboard Observations

Data were obtained on 5,941 *A. butcheri* from 347 gill-net lifts during the fishing operations of four commercial fishers over 29 d of fishing between 10 October 2005 and 17 May 2006 (Table 2). Fewer data were obtained during the austral summer months (December to February) because there was little fishing for *A. butcheri*. Net soak times varied slightly, depending on fisher and time of year, but nets were usually set around dusk and cleared at dawn.

The lengths of the *A. butcheri* that were caught generally increased with mesh size, with mean ± 2 SE lengths of 21.5 ± 2 cm for the 63.5-mm mesh, 21.7 ± 1 cm for the 69.9-mm mesh, 24.3 ± 0.8 cm for the 76.2-mm mesh, 28.2 ± 0.3 cm for the 95.3-mm mesh, 27.8 ± 0.4 cm for the 96.8-mm mesh, 28.4 ± 0.2 cm for 98.4-mm mesh, and 28.8 ± 0.3 cm for 101.6-mm mesh. These differences in length were significant (Kruskal–Wallis test: $\chi^2 = 238.7$, df = 5, $P < 0.001$). The length distributions were the same for the predominant M4 mesh sizes (98 and 102 mm) when the years 2005 and 2006 were combined. However, the *A. butcheri* caught during 2006 were significantly larger than those caught during 2005 (Figure 2;

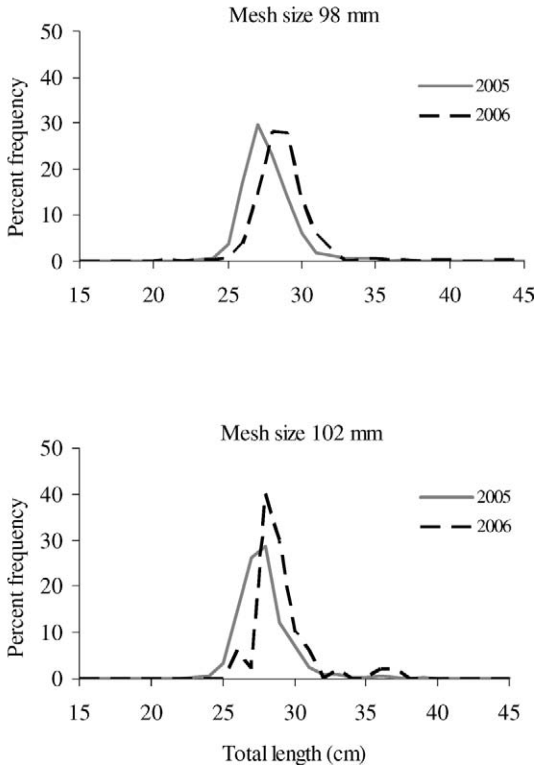

FIGURE 2.—Length-frequency distributions of *A. butcheri* from the Gippsland Lakes that were caught by 98-mm and 102-mm mesh sizes, by year of sampling.

Wilcoxon test: $T = 14.3$, $P < 0.001$ for the 98-mm nets, $T = 4.84$, $P < 0.001$ for 102-mm nets). The average size of the *A. butcheri* caught by these mesh sizes increased from 27.8 cm (SE, 0.033 cm) in 2005 to 28.7 cm (SE, 0.081 cm) in 2006. This increase, which is probably attributable to increased growth, resulted in a higher proportion of the catch being retained in 2006 (75%) than in 2005 (50%).

The catch rate for released fish was significantly lower in 2006 than in 2005 (Wilcoxon test: $T = 5.20$, $P < 0.001$), whereas that of retained fish (M4 nets) was not significantly higher in 2006 than in 2005 ($T = 1.34$, $P = 0.18$) (Table 3). For 2006 the retained catch rate was significantly higher for the M4 nets than for the smaller-mesh nets (Kruskal–Wallis test: $\chi^2 = 47.13$, df $= 2$, $P < 0.001$), but there was no significant difference among mesh sizes in the catch rate for released fish ($\chi^2 = 1.29$, df $= 2$, $P = 0.524$).

The initial rate of survival among *A. butcheri* released from gill nets ranged from 97% for M4 nets in 2005 to 89% for M2 nets in 2006 (Table 3). The average initial survival rate was 97% (SE, 0.3%) across all observed net shots. The initial rate of survival did not vary significantly among mesh sizes (M2, M3, and M4; chi-square test: $\chi^2 = 0.212$, df $= 2$, $P = 0.899$) or between years ($\chi^2 = 0.0485$, df $=1$, $P = 0.96$). Initial survival increased significantly as fish length increased ($\chi^2 = 12.10$, df $= 4$, $P = 0.017$), 82% of the fish less than 24 cm being released alive compared with 94–98% of those between 24 and 27 cm.

Postrelease Survival Trials

The catches of control fish were low (29 in total), and no control fish were obtained in two of the trials (Table 4). The mean length of control fish caught by seine net was 24 cm, compared with 27 cm for fish caught by mesh net. This difference was not significant (ANOVA: $F = 2.39$, df $= 1$, $P = 0.084$).

There was a relatively low initial survival rate in the first trial (Table 4). Measurements of dissolved oxygen levels made 2 h after the nets were pulled indicated that these gill nets had unknowingly been set over an area with low oxygen levels (<5%) in the deeper parts of the water column, which was the likely cause of the low initial survival rate. This low-oxygen water was not observed in normal fishing areas and was considered to be unrepresentative. All mortalities occurred in the first 12 h after release, 91% of released fish surviving longer than 1 h.

Trial 2 was conducted in a different section of Cunninghame Arm, but only six *A. butcheri* were captured. Additional fish captured by a commercial fisher on the same morning near the mouth of the Tambo River were therefore collected to increase the sample size. These fish also came from gill nets that had been deployed the previous day at 1800–1900 hours. The total handling and transport time for these fish was 30 min, which was 20 min longer than that experienced by the control (seine net) fish. Furthermore, the Tambo River fish were caught in water with a salinity of about 15 mg/L and transferred to holding tanks in which the salinity was 23–24 mg/L. The differences in the conditions experienced by the Tambo River fish and those in the control group meant that the results of the second trial could not be interpreted easily. Fish from the Tambo River effectively had no controls and provided a worst-case survival estimate that in practice could not be differentiated from 100% survival (i.e., trial conditions may have been responsible for all of the observed mortality).

In trial 3, 1 of the 33 *A. butcheri* caught in the gill nets was an initial mortality; the remaining 32 were transferred to the tanks to estimate delayed survival. No control fish were caught by haul seine. There was only the one mortality among the gill-net-caught fish over the 3 d of this trial.

In trial 4, 42 *A. butcheri* were caught in the gill nets.

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TABLE 3.—Catch rates (number of fish$\cdot$km$^{-1}\cdot$h^{-1}) and initial survival of *A. butcheri* for components of the catch, by year and mesh size category.

Year	Mesh size category	Catch rate: Released alive	Catch rate: Released dead	Catch rate: Total released	Catch rate: Retained	Catch rate: Total	Number released alive	Number released dead	Initial survival (%)	SE (%)
2005	M4	7.7	0.2	7.9	7.8	15.7	2,224	60	97.4	0.3
2006	M2	10.6	1.3	11.8	0	11.8	25	3	89.3	6
	M3	14.7	0.4	15.1	1.3	16.4	67	2	97.1	2
	M4	3.4	0.1	3.5	10.5	14.1	308	13	96	1.1
	All	4.1	0.2	4.3	9.9	14.1	400	18	95.7	1
All	M4	6.6	0.2	6.8	8.5	15.3	2,532	73	97.2	0.3
	All	6.8	0.2	7	8.3	15.3	2,624	78	97.1	0.3

There were no initial mortalities, so all of these fish were transferred to the tanks to estimate delayed survival. The three fish caught by haul seine (controls) were added to the tanks. There was a single mortality of a gill-net-caught fish over the 3 d of this trial.

Across all trials, the initial survival rate was 93.9% (Table 4). But if the results from the first trial (in which unusually low dissolved oxygen levels may have reduced survival rates) are excluded, the combined estimate was 97.5%. Similarly, across all trials the delayed survival rate was 92.3%. But if the result from the second trial (for which the additional transport stress and change in salinity possibly reduced survival rates) is excluded, the estimate was 94.4%. There was no mortality among control fish in any trial.

Logistic regression analysis indicated that year and fish length had no significant effect on survival (initial survival against year: Wald $= 0.00$, df $= 1$, $P = 0.964$; initial survival against fish length: Wald $= 0.00$, df $= 1$, $P = 0.963$; delayed survival against year: Wald $= 0.01$, df $= 1$, $P = 0.909$; delayed survival against fish length: Wald $= 0.00$, df $= 1$, $P = 0.919$).

Total PRS Estimates

Estimating total PRS required a decision on whether to use the initial survival estimates from the onboard observations or the field trials (although the estimates were similar). The estimates derived from the onboard observations were preferred as they represented actual commercial fishing data and were based on a much larger number of net shots and fish than the field trial estimates. Mesh size did not significantly affect initial survival. For consistency (only the M4 mesh size was used to determine delayed survival) and because M4 is the predominant mesh size used to catch *A. butcheri*, the initial survival rate for that mesh size determined during onboard observation (97.4% in 2005, 96% in 2006, and 97.2% for both years combined) was used to assess total fishery PRS.

The onboard estimates of initial survival and the trial estimates of delayed survival were combined to produce total survival estimates of 90.9% (SE, 3.8%) in 2005, 89.7% (SE, 4.6%) in 2006, and 90.8% (SE, 3.8%) for both years combined. The effect of three different LMLs on the proportions of the catch that are retained and released can be seen for the catch as a whole (Figure 3). For the size composition and release rates observed in 2005, a 28-cm LML would result in an estimated 44% of the catch being released alive, compared with 4% for a 26-cm LML. For the size composition and release rates recorded in 2006, the comparable values are 27% and 8%.

Discussion

Postrelease Survival

Total PRS estimates for *A. butcheri* caught and released from gill nets were derived by combining the estimates of initial survival from the onboard observations with those of delayed survival from the field trials. The estimated PRS rate of greater than 90% is

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TABLE 4.—Results of postrelease survival trials for *A. butcheri* caught in gill nets and control fish caught by haul seines.

Trial	Number captured	Dead when captured	Initial survival (%)	SE (%)	Held in tanks	Alive after 3 d	Dead within 3 d	Delayed survival (%)	SE (%)	Total survival (%)
1	43	10	76.7	6.5	33	30	3	90.9	5.1	69.8
2	62	0	100	0	62	54	8	87.1	4.3	87.1
3	33	1	96.1	3	32	31	1	96.9	3.1	93.9
4	42	0	100	0	42	41	1	97.6	2.4	97.6
All trials	180	11	93.9	2.4	169	156	13	92.3	3.7	86.7
All trials, adjusted[a]	170	1	97.5	1	107	102	5	94.4	3.5	91.9

[a] Excludes trial 1 in the calculation of initial survival and trial 2 in the calculation of delayed survival (see text for details).

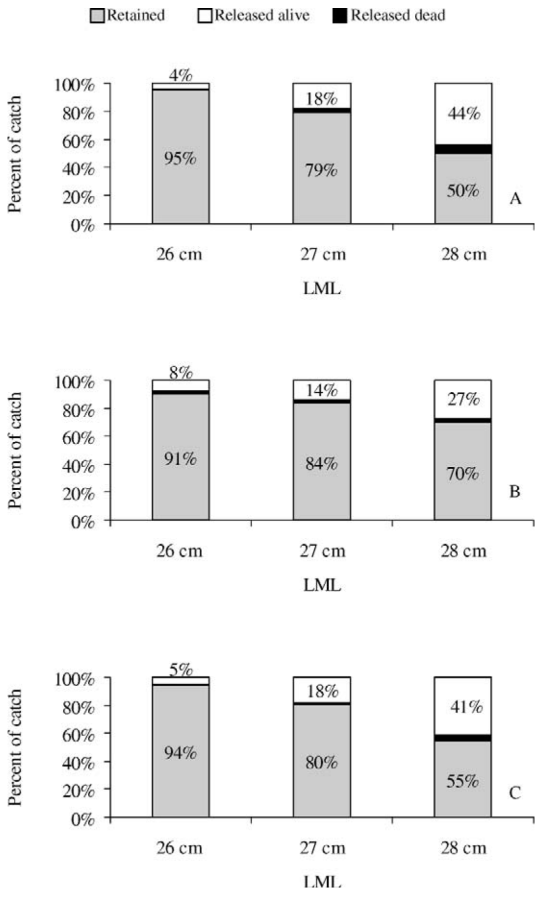

FIGURE 3.—Fates of *A. butcheri* captured by gill nets in the Gippsland Lakes at legal minimum lengths (LMLs) of 26, 27, and 28 cm using data on release rates for **(a)** 2005, **(b)** 2006, and **(c)** both years combined. All estimates are based on a combined postrelease survival rate of 90.8%.

among the highest reported for a teleost caught by gill nets. A review by Chopin and Arimoto (1995) of commercial fishing gears reported that gill-net survival can vary considerably between species. Some previously reported survival rates are 72% for spotted sea trout *Cynoscion nebulosus* (Murphy et al. 1995), 68–77% for lake trout *Salvelinus namaycush* (Gallinat et al. 1997), more than 95% for Chinook salmon *Oncorhynchus tshawytscha* (Vander Haegen et al. 2004), and more than 82% at the time of net retrieval for over 60 different species in a multispecies fishery (Gray 2002). The net shots observed onboard commercial fishing vessels were representative of commercial fishing practices by Gippsland Lakes fishers with respect to the areas fished, soak times, and depths fished and thus are considered to be representative of the fishery as a whole. Commercial fishers said that the initial survival rates during observed fishing trips were consistent with their experiences and observations over a long time; they were not in the position to observe delayed survival rates.

TABLE 4.—Extended.

Trial	SE (%)	Number of controls	Deaths of controls
1	11.6	26	0
2	4.29	0	0
3	6.16	0	0
4	2.38	3	0
All trials	6.1	29	0
All trials, adjusted[a]	4.5		

Gill nets are highly selective for particular fish lengths (Hamley 1975; Millar and Fryer 1999; Shoup et al. 2003). The results of the present study were typical, mean fish length increasing as mesh size increased (e.g., Madson et al. 1999; Broadhurst et al. 2003; Stewart et al. 2004). There was no overall difference in the mean lengths of *A. butcheri* caught by the two main mesh sizes (98 and 102 mm), but the growth of fish over the 6 months of the study is likely to have been the reason for the significant increase in the mean length of fish caught by these mesh sizes in 2006. This growth also increased retained rates from 2005 to 2006 by 25%. The size distribution for the two main mesh sizes was bell-shaped, and most fish were within 4 cm of the mean. In all likelihood, the mean length of the *A. butcheri* that were captured would have increased if larger mesh sizes had been used, which could have reduced release and increased postrelease survival rates. However, the retained rate would have dropped, at least for some time, while the dominant year-class in the fishery (27–28 cm during this study) grew to the sizes most vulnerable to capture. Decreasing catch rates have been reported with increasing mesh sizes for dusky flathead *Platycephalus fuscus*, undersized yellowfin bream (also known as surf bream) *Acanthopagrus australis*, striped mullet *Mugil cephalus* (Broadhurst et al. 2003), and eastern sea garfish *Hyporhamphus australis* (Stewart et al. 2004).

Mesh size was not found to significantly affect the initial survival of undersized *A. butcheri*. Fish caught in nets with an M2 mesh had a slightly lower initial survival rate than those caught by M3 and M4 mesh, but the sample size for M2 was too small to detect a significant difference. Initial survival was lower for *A. butcheri* smaller than 24 cm TL than for fish between 24 and 27 cm. Bettoli and Scholten (2006) reported similar results for paddlefish *Polyodon spathula*, mesh size and fish length not significantly ($P \geq 0.098$) affecting initial survival.

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The net soak times used to collect fish for the first two PRS trials were about two-thirds of the normal time in the fishery to avoid a potentially adverse public reaction to gill netting in the Cunninghame Arm during daylight hours. For all observer and trial data, the initial and delayed survival estimates were derived with no known time of entanglement; thus, the potential effect of soak time on PRS could not be isolated. In the first trial, adverse dissolved oxygen levels were considered to be responsible for the relatively low initial survival rates recorded, which apparently had a greater impact on survival than the beneficial effect that might have been expected from a shorter soak time. However, for the other three trials, the initial survival rates averaged more than 97% and were similar to the initial survival rates reported by observers. Despite the similarity in initial survival rates, delayed survival may have been overestimated to an unknown extent because of the shorter potential entanglement times for the first two PRS trials (the results for delayed survival from trial 2 were not used in the combined total estimate). However, the authors felt that the estimate of delayed survival was representative of the fishery because trial 1 had a lower delayed survival rate than trials 3 and 4 (which had typical fishery soak times) and because entanglement appeared to influence survival acutely through asphyxiation. Longer soak times have previously been linked to lower survival for paddlefish, but the trend is strongly linked to water temperatures above 15°C (Bettoli and Scholten 2006).

Implications for LML Management

The level of protection that an LML affords a population of *A. butcheri* fished by gill nets depends on the length composition of the catch. This was variable over the short study period, and the initial effect of increasing the LML from 26 to 28 cm (which was implemented in December 2003) would have depended on the length composition of the catch and the release rates in the fishery at that time; both are unknown. In October 2005, eight times more fish were being released with an LML of 28 cm than would have been released under the previous 26-cm limit. However, by 2006 the higher LML was resulting in less than four times as many fish being released because the fish had grown over the 6-month period. A 25% increase in the retained catch rate from 2005 to 2006 was further evidence of this growth. Comparison of commercial and recreational total catches (retained and released) in the Gippsland Lakes *A. butcheri* fishery would help demonstrate the effect of LML management on the fish population; recreational total catch estimates have not been made, however. The present paper identifies the need for such information if robust LML assessments are to be made.

Size measurements and estimates of age made from *A. butcheri* collected during prerecruit surveys (Morison and Conron 2009) found that the growth rates of this species in the Gippsland Lakes have been steadily increasing over the last 10 years. More rapid growth rates mean that fish reach the LML at younger ages. Consequently, the protection afforded by the 2-cm increase in the LML had a shorter influence than it would have if growth had been slower (at the growth rates observed during this study, most fish at or close to 26 cm would reach the new 28-cm LML in only 1 or at most 2 years. These results demonstrate that a length-frequency distribution calculated at one point is not a reliable indicator of future impacts when LMLs are changed. A dynamic model that utilizes up-to-date length-frequency distributions, current release and retain rates, and the total PRS rate from the present study would better predict the impacts of LMLs on the Gippsland Lakes *A. butcheri* population.

A legal maximum length has also been proposed as a management measure for the Gippsland Lakes *A. butcheri* population. The present study did not consider the PRS for larger fish, so whether a maximum length would protect such fish is hard to predict. There are contradictory indications about the effect of fish length on initial survival from the observer work (fish smaller than 24 cm had lower survival than fish 24–27 cm), the delayed survival from trials (which showed no significant effect), and anecdotal evidence from fishers (larger fish become more entangled in mesh nets than fish close to the current LML, which increases asphyxiation). Thus, extrapolation of the present study's PRS rate estimate to large fish sizes (e.g., >35 cm) may be unreliable. Previous research has reported that survival does not change as fish length increases (Bettoli and Scholten 2006). Additional data on the survival rate of larger *A. butcheri* after release from gill nets is needed to assess the benefit of a maximum length. Additional management changes aimed at protecting mature fish, often prompted by decreasing catch rates, should carefully consider why catches have dropped. If recruitment is not limited by the adult stock but instead by spawning success, then LML management alone may not be enough to meet management objectives. Given the selectivity characteristics of mesh nets, managers should consider gear restrictions as another means of managing PRS indirectly via reduced discard rates.

In conclusion, the combination of M4 gill nets and a 28-cm LML undoubtedly increases the proportion of released fish that would have been harvested with a 26-cm LML. The high total survival rate estimates and

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changes in retained rates observed in the present study suggest that released fish have a good chance of rerecruiting to the fishery. *Acanthopagrus butcheri* first reach maturity at 17 cm, 50% are mature at 19 cm, and 100% are mature at 26–27 cm (Walker et al. 1998). The higher LML (28 cm) may therefore allow an extra year or two of spawning before fish are harvested. As fish grow from 26 to 28 cm, natural and released fish mortality will mean that the commercial catch may decrease in terms of numbers, but this may be somewhat offset over the long term by an increased yield per recruit and greater spawning biomass in the fishery. These effects are yet to be quantified, however.

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