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Increasing lifting-bag mesh size to reduce codend occlusion in Australian whiting (*Sillago* spp.) trawls

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Some small-meshed fish-trawl codends require so-called "protective," "strengthening," or "lifting" bags for structural support, but these can occlude mesh openings and reduce size/species selectivity. This study compared two lifting-bag mesh sizes (94 and 216 mm stretched mesh opening; SMO) surrounding a 46-mm SMO codend in an Australian whiting-trawl fishery. During 37 deployments off Newcastle, New South Wales, compared to the 94-mm lifting bag, the 216-mm lifting bag significantly reduced the catches of juvenile eastern school whiting (*Sillago flindersi* <17 cm total length; TL) by ~35% and small unwanted velvet leatherjacket (*Meuschenia scaber*) by ~67%. Total bycatch declined by ~50%. However, ~6% of eastern school whiting ≥17 cm TL also escaped, along with some important byproduct species. Relative size–frequency analysis revealed no significant TL effects for eastern school whiting although there was evidence of fewer individuals being retained with the larger-meshed lifting bag. The data reiterate species-specific lifting-bag effects and the importance of evaluating both conservation benefits and economic impacts when subtly modifying trawl configurations.

KEYWORDS

bycatch reduction, fish trawl, lifting bag, selectivity, *Sillago flindersi*

1 Introduction

Benthic fish trawls are one of the most common active fishing gears used globally but are also among the least selective, typically associated with 25% discarded catches (1). All components of fish trawls cumulatively affect their selectivity, although lateral mesh openings in the codend (where the catch accumulates) ultimately dictate what is retained or escapes (2). Consequently, in many fish-trawl fisheries, minimum codend stretched mesh openings (SMOs) are mandated to control size selection, and typically for the smallest targeted species (2).

Beyond SMO, there are various other often regulated and unregulated technical factors that affect the selectivity of codends (2). Common parameters include mesh orientation (3, 4), twine material (5), diameter [Ø, (6)], circumference (7, 8), short lastridge ropes (9), and attachments designed to either restrict openings (10), prevent wear (11), and/or increase strength (12–14).

Among the latter are attachments surrounding the entire codend, typically made from meshes at least twice the SMO and commonly termed "lifting" (15), "strengthening" (16), or "protective" (12) bags. Such modifications are sometimes required in fisheries where the codend SMOs are small (e.g., <50 mm) and the twine Øs are proportionally narrow and not strong enough to hold catches during retrieval (6). Although correctly configured lifting bags (i.e., to the same circumference as codends) may not restrict lateral openings, they can cover (or occlude or "mask") some meshes and so affect fish escaping (2). Nevertheless, the influences of lifting bags are species- and configuration-specific, ranging from no effects (12) to significant and substantial reductions in size selection (17).

One Australian fishery where lifting bags are routinely used, but have not been assessed for influences on codend selectivity, is the Queensland finfish (stout whiting, *Sillago robusta*) fishery, involving boat seines and otter trawls fishing inshore (~20–90 m) between 24.7 and 28.2°S. Codend SMOs are ~36–40 mm, made from ~2 mm Ø twine and typically surrounded by lifting bags at least 3 m long and comprising SMOs of at least 90 mm (4 mm twine Ø). No data are available on the appropriateness of this lifting-bag SMO in trawls, or if any increase might improve size selectivity.

Recently, in response to individual transferable quota being introduced for combined catches of *S. robusta* and its congeneric, eastern school whiting, *S. flindersi* in the adjacent state of New South Wales (NSW; between 30.8 and 33.5°S), some fishers have Trialled similar configurations of codends used in Queensland and more specifically ~45 mm SMO in boat seines and trawls to target whiting ≥17 cm total length [TL; (15, 18, 19)]. Broadhurst (20) showed that increasing the lifting-bag mesh size to 216 mm improved the selection of 45-mm boat-seine codends for stout whiting, but no work is available describing the impacts to fish trawls. This study aimed to address the stated deficit by comparing two lifting bags made from regionally available mesh sizes (94 and 216 mm) while maintaining codend mesh size (46 mm) and twine Øs between configurations.

2 Methods

The work was done during eight nights in February and March 2025 using a volunteer vessel (*FV Edward James*) targeting whiting (22–75 m) off Newcastle, NSW (32.9°S; 151.8°E). The vessel towed a single, two-seam trawl (55 m headline and nominal 90 mm SMO throughout) constructed from polyethylene (PE) netting attached to 175 m sweeps and spread by steel V otter boards. Initially, the posterior trawl body was attached directly to the codend, but after four nights an intermediatory lengthener section (~46 mm SMO and 300 transverse (T) meshes × 199 normal (N) meshes) was installed to better facilitate codend retrieval (Figure 1A). The posterior trawl and then the lengthener were selvedged to facilitate attaching the two identical codends with different lifting bags via a 5 m length of rope.

Both codends and lifting bags were made from green PE netting with braided twine; panels of which were measured for 20–40 replicates of SMOs (nearest 0.5 mm) and twine Ø (nearest 0.1 mm) using a legislated gauge and Vernier calipers. Each codend measured 225 T × 100 N and comprised 45.9 ± 0.1 mm SMO and 2.0 ± 0.0 mm Ø twine for a total twine area of ~4.3 m^2 (Figure 1B). Six-mm Ø Dyneema® lastridge ropes were attached along the sides (1:1 with SMO). Both lifting bags had the same stretched lengths (~3.5 m), circumferences (~9.3 m), and twine Øs (4.5 ± 0.1 and 4.6 ± 0.0 mm), but comprised either 93.8 ± 0.3 mm or 216.1 ± 0.6 SMO (and were distinguished as such), with twine areas of 3.1 and 1.4 m^2 (Figures 1C, D).

At the start of each night, one of the codend/lifting bags was attached to the trawl/lengthener and fished during up to three replicate deployments (50.0–107.6 min) before being alternated with the second configuration which was similarly deployed (all between 18:20 and 06:20 h). Technical data collected included the deployment duration (min; time between otter boards on and off the seabed), speed over the ground (SOG; ms^{-1}) and average fishing depth (m) (the latter using Lowrance electronics).

At the end of each deployment, the codend was brought onboard and the total catch volume estimated based on the length and diameter of the contents before being emptied into a water-filled hopper [following Broadhurst (20)]. All whiting were removed and retained, with subsamples (~50 kg) separated by species and used to partition total catch. Subsamples of up to 170 individuals deployment^{-1} were measured for TL (nearest 0.5 cm). Catches of all other retained species were individually weighed and counted. The remaining total bycatch was estimated by separating from the retained and total, and a subsample (e.g., up to two 55-l boxes) was sorted. All subsamples were raised by scaling factors to the total numbers and weights onboard the vessel, producing continuous extrapolated estimates (rather than discrete counts). Excluding sizes, the raw subsample data were not systematically retained, precluding retrospective analyses of the original count data.

2.1 Statistical analyses

The SOG, deployment duration, and fishing depth were analysed raw using linear mixed models (LMM) comprising 'lifting bag' as fixed and 'nights' fished as a random effect. Catches for those species caught across most deployments were standardised (1 h^{-1} trawled), log-transformed, and analysed using the same LMMs, but with depth and its quadratic form included as covariates (owing to a range of fished depths; see Section 3 Results). Models were fitted using the ASReml function in R (21) and inspected using QQ and residual plots, while statistical significance was evaluated at the 5% level using Wald *F*-tests (22).

Relative selectivity curves were fitted to the TL frequencies of eastern school whiting using generalised additive modeling (GAM) within the SELECT package in R (23, 24). Data were first scaled by subsampling fractions to estimate total frequencies deployment^{-1}. Relative selectivity curves encompassed the proportions at sizes (catch share) retained in the codend with the 216-mm lifting bag based on the combined catches with those in the codend with the 94-mm lifting bag via cubic regression splines (25). Fitted-spline confidence intervals were obtained using a 1,000 iteration double bootstrap (26), while a permutation test was used (1,000 resamples) to test for no TL effects due to lifting bag (27). The permutation test was blocked by day to control for temporal and environmental variation, including depth differences among days.

3 Results

In total, 21 and 16 deployments with the 94- and 216-mm lifting bags were completed during eight nights across similar deployment durations (1.8 ± 0.1 h) and SOGs (1.5 ±

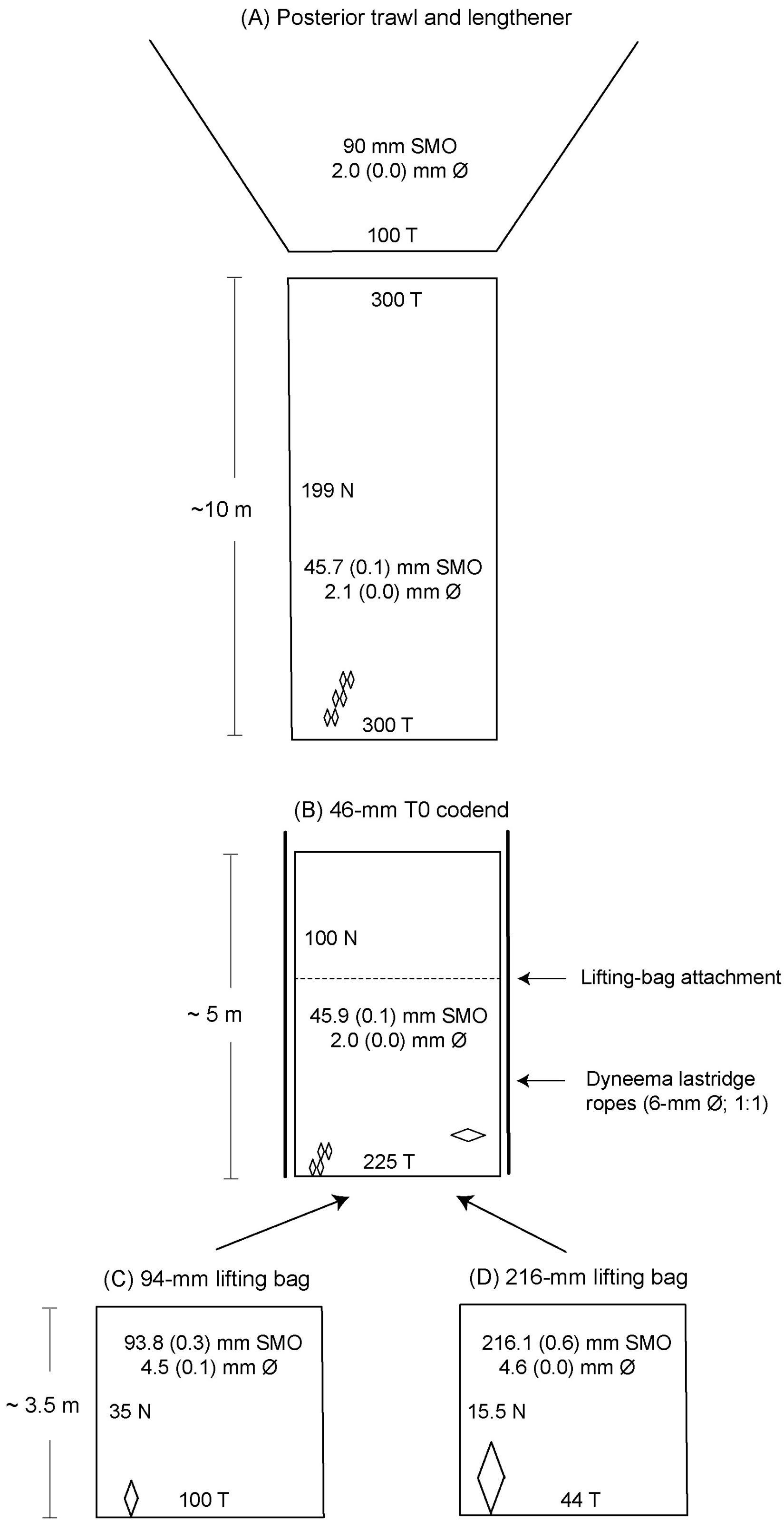

FIGURE 1
Schematic diagrams of the **(A)** posterior trawl and lengthener, **(B)** 46-mm codend, and **(C)** 94- and **(D)** 216-mm lifting bags. SMO, stretched mesh opening; T, transversal meshes; N, normal meshes; B, bars; Ø, diameter; and PE, polyethylene.

TABLE 1 List of species (common and Latin names) caught in descending total weights and their numbers and % weights (wt) discarded during 37 deployments of a fish trawl attached to 46-mm [stretched mesh opening (SMO)] codends with either of two lifting bags (94 and 216 mm SMO; see Figure 1) off Newcastle, New South Wales, Australia, during February and March 2025.

Common name	Latin name	Wt (kg)	No.	% discarded (wt)
Eastern school whiting[1]	*Sillago flindersi*	15,246.0	224,404	0.0
Yellowtail scad[1]	*Trachurus novaezelandiae*	9,947.0	191,748	100
Gurnard	*Chelidonichthys* and *Lepidotrigla* spp.	2,041.0	81,071	100
Stout whiting[1]	*Sillago robusta*	1,864.0	32,016	0.0
Velvet leatherjacket	*Meuschenia scaber*	1,641.3	121,454	100
Eastern fiddler ray	*Trygonorrhina* sp	1,380.0	895	100
Red bullseye	*Priacanthus macracanthus*	1,364.8	56,006	100
Longspine flathead	*Platycephalus longispinis*	1,180.4	20,093	100
Eastern fortescue	*Centropogon australis*	905.0	52,189	100
Squid[1]	*Loligo* spp.	461.0	4,003	0.0
Crested flounder	*Lophonectes gallus*	410.7	19,397	100
Painted grinner	*Trachinocephalus myops*	373.4	5,234	100
Stingaree	*Urolophus* spp.	373.1	2,224	100
Bluespotted flathead[1]	*Platycephalus caeruleopunctatus*	362.6	831	20.3
Goatfish[1]	*Upeneus* spp.	249.6	3,649	31.0
Octopus[1]	*Octopus* spp.	245.5	1,257	0.0
Balmain bug[1]	*Ibacus peronii*	243.2	3,358	68.5
Common stinkfish	*Foetorepus calauropomus*	240.3	3,513	100.0
Port Jackson shark	*Heterodontus portusjacksoni*	203.0	648	100.0
Blue mackerel[1]	*Scomber australasicus*	179.4	1,974	53.7
Painted stinkfish	*Eocallionymus papilio*	158.0	3,117	100.0
Narrowbanded sole	*Synclidopus macleayanus*	157.8	2,778	100.0
Common silverbiddy[1]	*Gerres subfasciatus*	146.6	2,212	65.9
Common toadfish	*Tetractenos hamiltoni*	136.9	4,280	100.0
Gummy shark[1]	*Mustelus antarcticus*	133.0	49	0.8
Many banded sole	*Zebrias scalaris*	118.0	1,340	100.0
Eastern smooth boxfish	*Anoplocapros inermis*	103.0	415	100.0
Marbled flathead	*Platycephalus marmoratus*	92.0	501	100.0
Violet roughy	*Hoplostethus stathami*	84.5	2,542	100.0
Eastern king prawn[1]	*Melicertus plebejus*	75.0	3,202	100.0
Eastern shovelnose ray	*Aptychotrema rostrata*	73.1	238	100.0
Rough flutemouth	*Fistularia petimba*	73.0	513	100.0
Eastern striped grunter	*Pelates sexlineatus*	61.0	610	100.0
Gray nurse shark	*Carcharias taurus*	60.0	1	100.0
Redfish[1]	*Centroberyx affinis*	60.0	1,743	100.0
Rough golden toadfish	*Lagocephalus lunaris*	60.0	510	100.0
Beaked salmon	*Gonorynchus greyi*	59.6	305	100.0
Numb ray	*Hypnos monopterygius*	55.0	13	100.0
Sand eel	*Apterichtus flavicaudus*	41.0	307	100.0
Tailor[1]	*Pomatomus saltatrix*	36.2	213	80.1

(Continued)

TABLE 1 (Continued)

Common name	Latin name	Wt (kg)	No.	% discarded (wt)
Snapper[1]	*Chrysophrys auratus*	28.5	445	100.0
Red mullet[1]	*Upeneichthys lineatus*	27.5	Na	0.0
Sydney skate	*Dipturus australis*	27.0	54	100.0
Tiger flathead[1]	*Platycephalus richardsoni*	27.0	108	100.0
Shortfin pike	*Sphyraena novaehollandiae*	26.0	262	100.0
Mud flathead	*Ambiserrula jugosa*	25.0	200	100.0
Eastern red scorpionfish	*Scorpaena jacksoniensis*	23.0	229	100.0
Whaler shark[1]	*Carcharhinus* spp.	22.0	3	0.0
Angel shark	*Squatina australis*	19.0	4	100.0
Whitleys gurnard perch	*Neosebastes whitleyi*	19.0	3,770	100.0
Lemon tongue sole	*Paraplagusia unicolor*	18.0	180	100.0
Smalltooth flounder[1]	*Pseudorhombus jenynsii*	18.0	112	100.0
Striped catfish	*Plotosus lineatus*	18.0	227	100.0
Smooth toadfish	*Tetractenos glaber*	17.5	443	100.0
Silver trevally[1]	*Pseudocaranx georgianus*	16.4	112	100.0
Mado	*Atypichthys strigatus*	16	320	100.0
Freespine flathead	*Platycephalus speculator*	11	54	100.0
Seargent baker	*Aulopus purpurissatus*	10	100	100.0
Pilchard[1]	*Sardinops sagax*	2	104	100.0
Teraglin[1]	*Atractoscion atelodus*	2	2	0.0
Largetooth flounder[1]	*Pseudorhombus arsius*	1.1	5	0.0
Dusky flathead[1]	*Platycephalus fuscus*	1	Na	100.0
Southern eagle ray	*Myliobatis tenuicaudatus*	Na	10	100.0

[1]Economically important species. Na, not available.

0.0 ms^{-1}) (LMM, $p > 0.05$). The fished depths (26.1–67.7 m) were similar between treatments during most nights, but means were slightly different overall (45.4 ± 1.7 vs. 37.1 ± 1.9 m; LMM, $p < 0.01$) necessitating depth and its quadratic in the catch LMMs.

The total catch was 39.9 t; of which 18.6 t (mostly whiting) was retained and 21.2 t (or 53.1%) discarded (Table 1; Figure 2A). More than 63 species were recorded, although eastern school whiting (all retained) and yellowtail scad, *Trachurus novaezelandiae* (all discarded), dominated all catches (37.1 and 24.2%, respectively; Table 1). These two species along with 11 others (excluding stout whiting which were only caught in few deployments) formed the basis of catch analyses (Tables 1, 2).

The LMMs revealed that compared to the 94-mm lifting bag, the 216-mm lifting bag facilitated the escape of significantly more juvenile eastern school whiting (<17 cm TL by 34.4 and 35.5% for numbers and weights) and unwanted velvet leatherjacket, *Meuschenia scaber* (66.7% by weight) from the codend (LMM, $p < 0.05$; Table 2, Figure 2B). Several other small unwanted species, including gurnard, *Chelidonichthys* and *Lepidotrigla* spp., and red bullseye, *Priacanthus macracanthus* also had lower (non-significant) mean catches in the codend with the larger-meshed lifting bag which contributed to significant reductions in the total number and weight of bycatch (by 58.3 and 54.9%, LMM $p < 0.05$; Table 2, Figure 2A). However, the number of eastern school whiting ≥17 cm TL and the number and weight of retained octopus, *Octopus* spp. were also significantly lower (by 4.7, 41.8, and 41.3%, respectively, LMM, $p < 0.05$) and there were non-significant mean reductions in the numbers and weights of retained squid, *Loligo* spp. (37.7% and 36.9%) and goatfish, *Upeneus* spp. (32.5% and 38.7%) ($p > 0.05$; Table 2). Catches of species with individuals mostly larger than the codend SMO, including longspine flathead, *Platycephalus longispinis*, bluespotted flathead, *P. caeruleopunctatus*, and Balmain bugs, *Ibacus peronii*, remained similar (albeit variable) regardless of lifting-bag mesh size (LMM, $p > 0.05$; Table 2).

Eastern school whiting were caught across a narrow size range (mostly 18–24 cm TL) and in sufficient numbers to converge a GAM (Figure 2C). There were no significant TL effects, although the spline showed a slightly lower catch share of the smallest fish in the codend with the 216-mm lifting bag (permutation test, $p > 0.05$; Figure 2C).

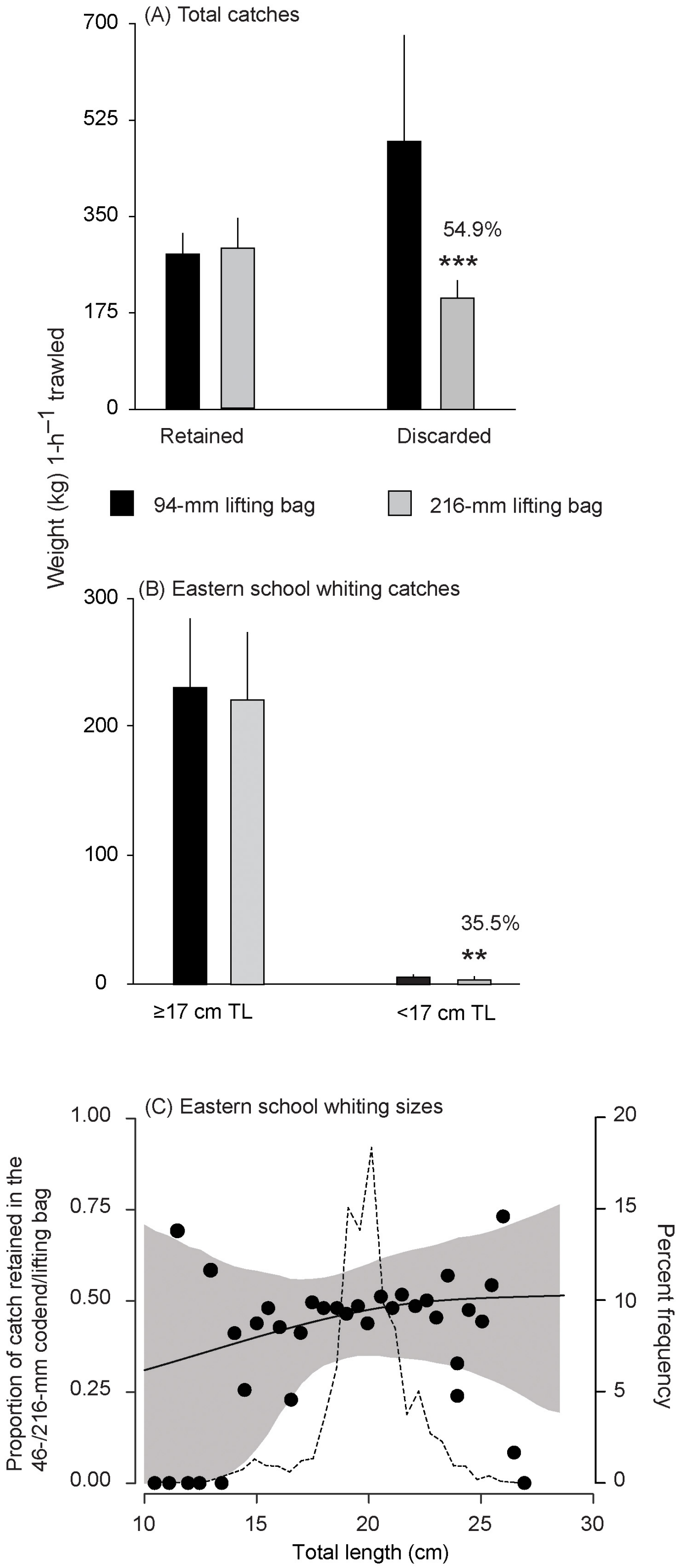

FIGURE 2
Differences in mean (+SE) weights 1-h^{-1} trawled between codends with two different lifting bags (94- and 216-mm) for the weights of **(A)** total catches and **(B)** eastern school whiting, *Sillago flindersi*, and **(C)** relative size−frequency distributions for the latter (dashed line, $n = 5{,}109$ measured), with the proportions (black circles) and fitted splines (solid curve with shaded 95% confidence intervals) for the share of scaled-up catches for each total length (over both treatments) that were retained in the codend with the 216-mm lifting bag. $^{**}p < 0.01$; $^{***}p < 0.001$.

TABLE 2 Summaries of significance from Wald F-tests assessing the importance of lifting-bag mesh size on catches and the means (±SE) 1 h deployment^{-1}.

Variable	Wald F	94-mm lifting bag	216-mm lifting bag
Retained catches			
No. of total	1.7	6,491.2 (891.3)	8,108.8 (1,335.7)
Wt of total	0.0	280.3 (37.4)	291.4 (54.2)
No. of total whiting	0.1	3,727.7 (179.1)	4,132.3 (753.8)
Wt of total whiting	0.0	248.9 (34.2)	275.0 (51.9)
No. of eastern school whiting <17 cm TL	11.4**	205.8 (49.4)	134.9 (83.1)
Wt of eastern school whiting <17 cm TL	11.1**	6.2 (1.5)	4.0 (2.4)
No. of eastern school whiting ≥17 cm TL	6.4*	3,320.7 (466.1)	3,163.1 (733.7)
Wt of eastern school whiting ≥17 cm TL	2.2	231.4 (53.6)	221.8 (52.4)
No. of bluespotted flathead ≥33 cm TL	0.3	10.1 (2.8)	7.0 (2.2)
Wt of bluespotted flathead ≥33 cm TL	0.5	5.7 (1.6)	3.7 (1.2)
No. of Balmain bugs ≥10 cm CW	1.9	4.6 (1.1)	7.8 (1.8)
Wt of Balmain bugs ≥10 cm CW	2.4	0.9 (0.2)	1.3 (0.3)
No. of squid	0.2	71.3 (14.1)	46.5 (11.7)
Wt of squid	0.9	8.4 (1.8)	5.3 (1.1)
No. of goatfish	0.2	30.6 (10.4)	20.7 (0.1)
Wt of goatfish	0.2	3.1 (1.1)	1.9 (0.8)
No. of octopus	6.4*	23.9 (3.6)	13.9 (2.8)
Wt of octopus	5.7*	4.6 (0.7)	2.7 (0.5)
Discarded catches			
Wt of total	5.2*	487.6 (192.3)	203.0 (31.4)
No. of total	14.2***	13,040.8 (2,895.1)	5,876.9 (1,136.5)
No. of yellowtail scad	0.0	4,908.8 (2,637.9)	1,359.5 (412.3)
Wt of yellowtail scad	0.0	283.4 (183.7)	58.2 (15.5)
No. of gurnard	3.4	1,469.3 (210.5)	1,031.9 (211.5)
Wt of gurnard	1.5	34.3 (6.0)	26.7 (4.9)
No. of velvet leatherjacket	1.3	3,538.4 (1,695.3)	714.7 (385.7)
Wt of velvet leatherjacket	6.3*	41.8 (16.8)	13.9 (7.4)
No. of red bullseye	0.0	952.7 (424.3)	612.0 (209.3)
Wt of red bullseye	0.0	21.6 (8.7)	16.8 (5.7)
No. of longspine flathead	0.0	311.7 (69.3)	310.4 (76.3)
Wt of longspine flathead	0.0	18.7 (4.2)	17.8 (4.7)
No. of painted grinner	0.0	72.7 (18.8)	111.8 (42.2)
Wt of painted grinner	0.9	4.2 (0.9)	8.7 (2.5)
No. of Port Jackson shark	0.4	9.6 (2.8)	10.5 (6.3)
Wt of Port Jackson shark	0.7	3.7 (1.0)	2.9 (1.1)

The "nights" fished was included as a random blocking effect in all models while depth was included as a covariate.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
TL, total length; CW, carapace width.

4 Discussion

The data here contribute to those collected during one previous regional study comparing the same two lifting-bag mesh sizes in Scottish seines (20) and the few international studies assessing trawl lifting-bag effects; most of which have compared presence vs. absence (12, 14, 17) or circumference (13), rather than different mesh sizes. Like this previous work, there were species-specific effects that appear to have been driven by morphology and relative sizes, which ultimately will help to inform appropriate future configurations. However, prior to this discussion, some methodological constraints warrant consideration.

First, trawling for whiting in NSW occurs both diurnally and nocturnally (8, 19). However, the data here were restricted to nocturnal deployments, simply because this was when most fish were being targeted by the volunteer trawler during the sampled months. There may be species-specific differences in escape responses for the key species, with greater visibilities of the codend and lifting bag meshes during the day (28). For example, during diurnally deployed boat seines, Broadhurst (20) showed a similar increase in the escape of small stout whiting from the 216-mm lifting bag, but not eastern school whiting. While there are considerable differences between seines and trawls in terms of their deployment and fishing and especially SOGs (i.e., 0.3 vs. 1.5 ms^{-1}), these catch differences serve to illustrate that at least some species-specific diel effects might occur for trawls.

A second consideration is that the trawl lengthener was increased halfway through the work. This slight alteration was confounded with nights and so it was not possible to quantify any size- or species-selective effects. Nevertheless, any variability should be consistent between lifting bags and was captured within nights as the random blocking term. Last, owing to weather conditions and logistics, the vessel targeted whiting across different depths, which is typical but does introduce some variability. For this reason, depth was included as a covariate to adjust for the power of the fixed effect of interest (lifting bag).

Notwithstanding the above considerations, there were clear effects associated with increasing lifting-bag mesh size that can be explained by the size and shape of the affected species. Specifically, eastern school whiting are fusiform, and fish at the desired minimum commercial size of 17 cm TL have a maximum girth of ~95 mm and similar to the perimeter of the 46 mm mesh, which allowed at least some to push through if openings were available (29). The availability of open meshes can be approximated by considering relative inner surface twine areas as proxies for occlusion. Specifically, the 94-mm lifting bag had an inner surface area of ~1.6 m^2 (i.e., total surface area of 3.1 $m^2 \div 2$) that was ~70% of the codend inner surface area (2.2 m^2), likely occluding a substantial proportion of codend meshes through direct contact and partial blocking. The 216-mm lifting bag had an inner surface area of ~0.7 m^2 (~32% of codend area) and would have at least doubled the unobstructed mesh area available for escape.

The considerable improvement in the escape of juvenile whiting and small fish overall (contributing to the ~50% reduction in bycatch) associated with reducing mesh occlusion aligns with the general trend observed by most previous authors (13, 14, 17). For example, off the Orkney Islands, Kynoch et al. (17) found that covering 110- and 120-mm codends with 265-mm lifting bags reduced L_{50}s for haddock, *Melanogrammus aeglefinus*, by ~6%. Similarly, Demirci et al. (14) observed a 10% reduction in the L_{50} of brushtooth lizardfish, *Saurida undosquamis*, when a 45-mm codend was covered with a 91-mm lifting bag in the Mediterranean Sea. In contrast, Tosunoglu et al. (12) noted that an 84-mm lifting bag had minimal impact on the L_{50}s of sparids (*Diplodus* and *Pagellus*) in a 40-mm codend. The magnitudes of these differences would at least partially reflect species morphology. Whiting and gadoids are fusiform and should be more affected by occlusion than deep-bodied species such as sparids.

Beyond body shape, the size of fish is also likely important. For example, although not measured for TL, the mean weight of the ventrally compressed velvet leatherjacket was only 13.5 g, which would correspond to many individuals with bodies smaller than the 46-mm mesh. Simply increasing openings allowed more velvet leatherjackets to escape, contributing to a greater reduction of total bycatch (by ~50%). Relative body size is less likely to similarly affect the escape of invertebrates like cephalopods, with many octopus larger than the 46-mm mesh able to compress and squeeze through with less occlusion. Although not significant, similar reductions were observed for squid. One important consideration is that these species are both economically important across all sizes and likely to have very low post-escape survival (30). In addition to loss of some income, increasing lifting-bag mesh size to 216 mm could increase their unaccounted fishing mortality. This outcome represents the difficulty of optimising selectivity in a multi-species trawl fishery, and warrants consideration for not only considering optimal lifting bags but also codend mesh sizes.

Notwithstanding the escape of some cephalopods and ~6% of eastern school whiting ≥17 cm TL, the data here support using a lifting-bag mesh size up to 216 mm, albeit with some modifications that might help to control selectivity. Owing to the reduction in twine area, the 216-mm lifting bag is not as strong and might not be expected to last as long as the 94-mm mesh. This latter mesh size is often chosen simply because there is an abundance of new and old (~90 mm) fish-trawl codends in southeastern Australia that can be used. Using a larger mesh would require new material to be sourced and ideally in a thicker twine diameter, which would have some concomitant effect on occlusion.

Future work warrants assessing for the effects of increasing twine Ø in larger-mesh lifting bags because this might offset marginal losses of some larger whiting and the cephalopods, while balancing desired effects on smaller unwanted fish. Such work, along with data here, reiterates the need to refine trawl selectivity through attention to all gear components, and not solely minimum SMO (31). Under individual transferable quota management where minimising juvenile capture directly improves economic efficiency, adopting appropriately configured larger-meshed lifting bags represents a practical, low-cost modification that simultaneously addresses conservation and commercial objectives.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the author, without undue reservation.

Ethics statement

The animal study was approved by NSW DPIRD Fisheries Animal Care and Ethics Committee (FISH ACEC-0803 Testing selective fishing gears in NSW commercial fisheries). The study was conducted in accordance with the local legislation and institutional requirements.

Author contributions

MB: Project administration, Visualization, Supervision, Validation, Data curation, Formal analysis, Methodology, Investigation, Funding acquisition, Conceptualization, Software, Writing – original draft, Writing – review & editing, Resources.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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