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Gillnet size selectivity of shark and ray species from Queensland, Australia

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Abstract

Gillnets are size-selective fishing gears commonly used by industrial and small-scale fishers, so understanding selectivity can aid fisheries management by identifying suitable mesh sizes to optimize catches of target species while reducing bycatch. Few size selectivity parameters have been estimated for sharks, with even fewer for rays. Size selection parameters were estimated for seven species of sharks and two species of rays from the Queensland East Coast Inshore Finfish Fishery (ECIFF). Size frequency data from a fishery observer program on ECIFF vessels was used to fit a standard size selection model. Mesh size independent parameters, θ_1 and θ_2, were estimated for each species to define selectivity curves for different mesh sizes for each species. Parameter values were compared with previous studies that used the same method. Estimates of θ_1 were similar among species within the same genus, such as *Carcharhinus*, *Rhizoprionodon*, and *Sphyrna*. *Anoxypristis cuspidata* had the largest θ_1 and θ_2 values, likely because of its toothed rostrum that affected catchability in gillnets. Our findings can be used for the ECIFF and other gillnet fisheries to aid in mesh size recommendations and risk mitigation.

KEYWORDS
elasmobranch, fishery, fishing gear, gear selectivity, gillnet, management

1 | INTRODUCTION

Global elasmobranch (shark and ray) catches that exceed sustainable levels have resulted in more than 37% of species being listed as threatened globally (Dulvy et al., 2021). These declines have occurred because of a lack of, or ineffective, management of most stocks (Davidson et al., 2016; FAO, 2018), despite the demonstrated potential for some species to be fished sustainably (Simpfendorfer & Dulvy, 2017; Walker, 1998). Sharks and rays are especially susceptible to overfishing because they have *k*-selected life history strategies (low fecundity, late maturing, and slow growing), that limits their ability to sustain removals or recover from depletion (Kirkwood & Walker, 1986; Millar & Holst, 1997; Prince, 2002). However, using size selectivity can enhance sustainable outcomes to overcome some life history limitations. For example, limiting catch to sexually immature individuals can facilitate a gauntlet effect, to help sustain populations by enabling adults to continue to breed without significant fishing pressure, thereby ensuring ongoing recruitment (Cortés, 2000; Prince, 2002). Thus, in addition to adjusting fishing efforts or catches to achieve sustainable harvest, size selectivity of fishing gear can be used to control the size and maturity of animals caught, and hence contribute to sustainability (Hamley, 1975).

Increases in shark landings in the early 2000s led to rising concerns over shark exploitation within the Great Barrier Reef

World Heritage Area (Ceccarelli et al., 2014), with most sharks and rays caught in gillnet fisheries of the Queensland East Coast Inshore Finfish Fishery (ECIFF). The fishery's main target species are barramundi, threadfin salmon, mackerels, and tropical sharks (Roelofs, 2011). Target shark species include the blacktip shark complex (*Carcharhinus limbatus* and *C. tilstoni*) and spottail shark (*Carcharhinus sorrah*), but at least another 27 shark and 14 ray species are also captured (Harry et al., 2011). From 2006 to 2021, a 600 t competitive total allowable catch in the fishery was divided between two zones, although this limit has not been reached in recent years (Roelofs, 2011). In late 2021, the TAC was reduced to 400 t across five zones but excluded hammerhead sharks that were managed separately. Requiem sharks (family Carcharhinidae) were the largest component of the catch in this fishery and were some of the most at-risk species, which suggested one risk mitigation strategy to use smaller mesh sizes to target smaller (younger) individuals of larger species (the gauntlet approach, Harry et al., 2011). The ECIFF does not currently specify mesh sizes of gillnets for the fishery, although they do specify a maximum mesh size permissible (8-inch stretch mesh) (Australian Government Department of the Environment and Energy, 2018). Thus, stricter specifications of mesh size in the ECIFF could enhance the sustainability of target species and reduce unwanted bycatch. However, data on the size selectivity of gillnets for the species in question are required.

Experimental studies involving multiple panel gillnets of varying mesh sizes can be used to collect size data to fit size selectivity models (Carlson & Cortés, 2003; Kirkwood & Walker, 1986; McLoughlin & Stevens, 1994). These models reveal the probability of capture of a particular species length class given certain mesh sizes of gillnets (Millar & Fryer, 1999; Millar & Holst, 1997) and can be used to determine mesh size to optimize catches at sustainable levels (Hamley, 1975; Millar & Fryer, 1999; Millar & Holst, 1997). Despite the usefulness of these types of studies, only nine studies of gillnet mesh selectivity of sharks and one on rays have been published. These studies reveal similarities in selectivity parameters and suggest species with similar morphology within the same genus have similar size selectivities (Braccini et al., 2022; Carlson & Cortés, 2003; McAuley et al., 2007; Simpfendorfer & Unsworth, 1998). Additionally, knowledge of size selectivity for bycatch species can aid in gear modifications to reduce bycatch, as demonstrated by Thorpe and Frierson (2009) for reduction in *Carcharhinus limbatus* catches. Creating size selectivity models for target and bycatch species can improve management and promote sustainability of a broad range of species (Baremore et al., 2012; Braccini et al., 2022; Ramírez-Amaro & Galván-Magaña, 2019; Thorpe & Frierson, 2009).

Given the potential benefits of adjusting gillnet sizes to improve the sustainability of sharks and rays caught in the Queensland ECIFF, we estimated size selectivity parameters for a range of target and bycatch species. We used data collected during observer studies on commercial gillnet vessels using a variety of mesh sizes to estimate selectivity parameters for use in stock assessments and ecological risk assessments to evaluate optimal mesh sizes for the fishery. Multi-panel gillnets were not used to collect the data, rather the use of different mesh sizes by fishers was the basis for data collection. This enabled the testing of whether size selection parameters could be estimated using a less structured approach to sampling. By comparing the results to other similar studies of sharks and rays, we were able to test if the results from this approach were similar to those from specialized nets and also to identify patterns in selectivity parameters that may allow inference to other species for which experimental studies have not been performed.

2 | MATERIALS AND METHODS

2.1 | Data collection

Between June 2006 and July 2009, observers worked on commercial (industrial) gillnet vessels within the ECIFF that operated along the Queensland East Coast. As catch composition was the primary goal of this research gillnet mesh size was the only net characteristic recorded among fishing vessels (Harry et al., 2011). Mesh sizes used by fishers ranged from 4.5 to 8 inches, with most nets being 600 m in length, although some fishers were licensed to use up to 1200 m of 6.5-inch mesh. Catch composition and length of individual shark and ray species were recorded within each mesh size on board vessels (Harry et al., 2011). Unlike some other published studies of mesh selectivity in sharks, we did not use multi-panel nets with different mesh sizes in a random order (Baremore et al. 2012; Braccini et al., 2022; Carlson & Cortés, 2003; McAuley et al., 2007). Instead, given the variety of mesh sizes used within the ECIFF, we selected the most common mesh sizes. This approach may have resulted in violations of some assumptions of this method, so we tested if this affected our results by comparing our results to those of previous studies on the same or similar species (Carlson & Cortés, 2003; Kirkwood & Walker, 1986; McAuley et al., 2007; McLoughlin & Stevens, 1994; Simpfendorfer & Unsworth, 1998).

2.2 | Data analysis

The method described by Kirkwood and Walker (1986) was used to fit size selectivity models for seven shark species (*Carcharhinus amboinensis*, *C. brevipinna*, *C. fitzroyensis*, *C. tilstoni*, *Rhizoprionodon acutus*, *R. taylori*, and *Sphyrna lewini*) and two ray species (*Glaucostegus typus* and *Anoxypristis cuspidata*). Data from 4.5-inch and 6.5-inch mesh for each species were used for the selectivity model because these two mesh sizes had sufficient numbers of individuals caught. This method fits length data to a gamma distribution for each mesh size using a maximum likelihood function:

$$L = \sum_{i=1}^{I} \sum_{j=1}^{J} \left[n_{ij} \ln\left(\mu_j S_{ij}\right) - \mu_j S_{ij} \right],$$

where the number of sharks in length class j caught in mesh size i was represented by n_{ij}:

$$\mu_j = \frac{\sum_{i=1}^{I} n_{ij}}{\sum_{i=1}^{I} S_{ij}},$$

and S_{ij} is the relative selectivity of a shark of length class *j* caught in mesh size *i*. Selectivity was modeled as a function of shark length class (l_j) and the probability density function of the gamma distribution of mesh size *i* was described by α and β:

$$S_{ij} = \left(\frac{l_j}{\alpha_i \beta_i}\right)^{\alpha_i} exp\left(\alpha_i - \frac{l_j}{\beta_i}\right).$$

Values of α and β were calculated from the mesh size (m_j), a scaling parameter (θ_1) to relate the mode of the gamma distribution (α, β) to mesh size, and the variance (θ_2):

$$\alpha_i \beta_i = \theta_1 m_i,$$

and

$$\beta_i = -0.5\left(\theta_1 m_i - \left(\theta_i^2 m_i^2 + 4\theta_2\right)^{0.5}\right).$$

Values of θ_1 and θ_2 were estimated using a nonlinear optimization function in Microsoft Excel (Version 16.25). These values were then compared with θ_1 and θ_2 from previous studies that also used the same method.

Confidence intervals of parameter estimates were estimated with bootstrapping (Simpfendorfer & Unsworth, 1998). Length–frequency data were randomly resampled 1500 times for each mesh size, fitted with the mesh selectivity model, and 95% confidence intervals were approximated using the 2.5th and 97.5th percentiles of θ_1 and θ_2. Bootstrapping and confidence intervals were calculated using Microsoft Excel (Version 16.25).

The Kirkwood and Walker method was chosen because it has been shown to work well for a wide variety of shark species, thus allowing easy comparison of results. Assumptions of the model (Kirkwood & Walker, 1986) included (1) a gamma distribution represents the shape of the selectivity curve. The gamma distribution creates a skewed dome-shaped distribution that is inclusive of a wide range of size classes and is a standard that has been used by many other studies (Carlson & Cortés, 2003; Márquez-Farias, 2005; McLoughlin & Stevens, 1994; Simpfendorfer & Unsworth, 1998); (2) length at maximum selectivity is proportional to mesh size, a relationship described and demonstrated by Hamley (1975), Millar and Holst (1997), and Millar and Fryer (1999), and supported by other findings from gillnet size selectivity studies (Simpfendorfer & Unsworth, 1998, Carlson & Cortés, 2003, McAuley et al., 2007, Thorpe & Frierson, 2009); (3) sampling occurs across the whole population; (4) for a given species, the variance is constant for each mesh size; (5) catches within each length class are independent observations from a Poisson distribution as demonstrated by Hamley (1975); and (6) all mesh sizes have equal fishing power. Assumptions 3, 4, and 6 were checked using data collected during the study and are reported in the Results.

We estimated size selectivity curves of the two mesh sizes for each species and four additional mesh sizes (5-, 6-, 7-, and 8-inch mesh), to compare effects of mesh size on size selection. We did not calculate selectivity curves for mesh sizes greater than 8 inches, the maximum permitted for the ECIFF. Size at birth and maturity (male and female) was from life history studies, where they were available, from Queensland.

3 | RESULTS

Sampling over 297 days with a total of 1452 km-net-hours yielded 4345 individual sharks and rays. Thirty-eight species of elasmobranchs were captured (Harry et al., 2011), nine with sufficient data to enable an analysis of size selectivity (Table 1). The nine species analyzed were from four families (Carcharhinidae, Sphyrnidae, Glaucostegidae, and Pristidae) and two orders (Carcharhiniformes and Rhinopristiformes). The largest catches were *Carcharhinus tilstoni* (19.3%), *Sphyrna lewini* (8.8%), and *Rhizoprionodon acutus* (7.9%) (Table 1). Two species are threatened in Australian waters (*Anoxypristis cuspidata*, *S. lewini*), and six species are threatened globally (Table 1).

Length frequencies varied among species and between mesh sizes (Figure 1). Larger mesh sizes caught larger individuals. Length–frequency distributions for *A. cuspidata* and *S. lewini* included a wider range of lengths than other species. For one-third of the species (e.g., *A. cuspidata*, *Glaucostegus typus*, *Carcharhinus fitzroyensis*), length–frequency distributions were bimodal for the 4.5-inch mesh. In general, for many species, numbers were not equal between mesh sizes. For the remaining two-thirds of species, length–frequency distributions were positively skewed. Thus, meeting assumptions of the Kirkwood and Walker (1986) method. Unlike the other *Carcharhinus species* in this study, *C. brevipinna* was the only species not available across all size ranges for fishing, likely failing to meet the fourth assumption for the Kirkwood and Walker (1986) method.

Selectivity parameter estimates (θ_1 and θ_2) varied widely among species (Table 2). θ_1 values were the lowest and did not differ significantly between *Rhizoprionodon acutus* and *S. lewini*, whereas θ_2 was significantly larger for *S. lewini* than *Rhizoprionodon acutus*. θ_1 did not differ significantly between *R. taylori* and *C. tilstoni*, and θ_2 also did not differ significantly between the two species despite substantial differences in maximum size. θ_1 of *Glaucostegus typus* differed significantly from all other species, whereas θ_2 did not differ significantly from most other species. θ_1 did not differ significantly between *C. amboinensis*, *C. fitzroyensis* or *C. brevipinna*, and θ_2 did not differ significantly for the former two species. However, θ_2 for *C. brevipinna* was significantly lower than all other species, except *R. acutus*. *Anoxypristis cuspidata* had significantly larger θ_1 and θ_2 than all other species.

Most species had similar size selectivity curves for 4.5- and 6.5-inch mesh sizes, except for *A. cuspidata*, which had a much higher peak selectivity and broader distribution (~1050 mm for 4.5-inch mesh) than all other species (Figures 2 and 3). Selectivity curves were generally similar, with relatively small differences in peak selectivity (e.g., range = 500–650 mm for the 4.5-inch mesh). Selectivity curves were most similar for morphologically similar and related

TABLE 1 Family, species name, common name, component of catch (%); Harry et al. (2011), number sampled, length (mm) at birth and maturity for males (M) and females (F) or both, maximum length (mm), Global Red List status (Dulvy et al., 2021), and Australian Red List (Kyne et al., 2021) for seven shark and two ray species caught by 4.5-inch and 6.5-inch mesh size gillnets in the Queensland East Coast Inshore Finfish Fishery between June 2006 and July 2009 (IUCN, 2019; Simpfendorfer et al., 2019).

Family	Species name	Common name	Component of catch (%)	Number Sampled	Length at birth (mm)	Length at maturity (mm)	Maximum length (mm)	Global red list status	Australian red list status
Carcharhinidae	*Carcharhinus amboinensis*	Pigeye shark	1.3	158	600–750	2100 (M) 2150 (F)	2800	VU	LC
	Carcharhinus brevipinna	Spinner shark	3.3	666	660–770	2090 (M) 2250 (F)	3000	VU	LC
	Carcharhinus fitzroyensis	Creek whaler	3	153	450–550	800 (M) 900 (F)	1350	LC	LC
	Carcharhinus tilstoni	Australian blacktip	19.3	841	600	1100 (M) 1150 (F)	2000	LC	LC
	Rhizoprionodon acutus	Milk shark	7.9	330	350–400	650–950	1000	VU	LC
	Rhizoprionodon taylori	Australian sharpnose	4.5	279	220–280	400 (M) 450 (F)	690 (M) 810 (F)	LC	LC
Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead	8.8	324	310–570	~2000	3400 (M) 3460 (F)	CR	EN
Glaucostegidae	*Glaucostegus typus*	Giant shovelnose ray	0.4	44	380–430	1500–1800	2800	CR	LC
Pristidae	*Anoxypristis cuspidata*	Narrow sawfish	1.1	134	430–700	2000 (M) 2250 (F)	3500	EN	VU

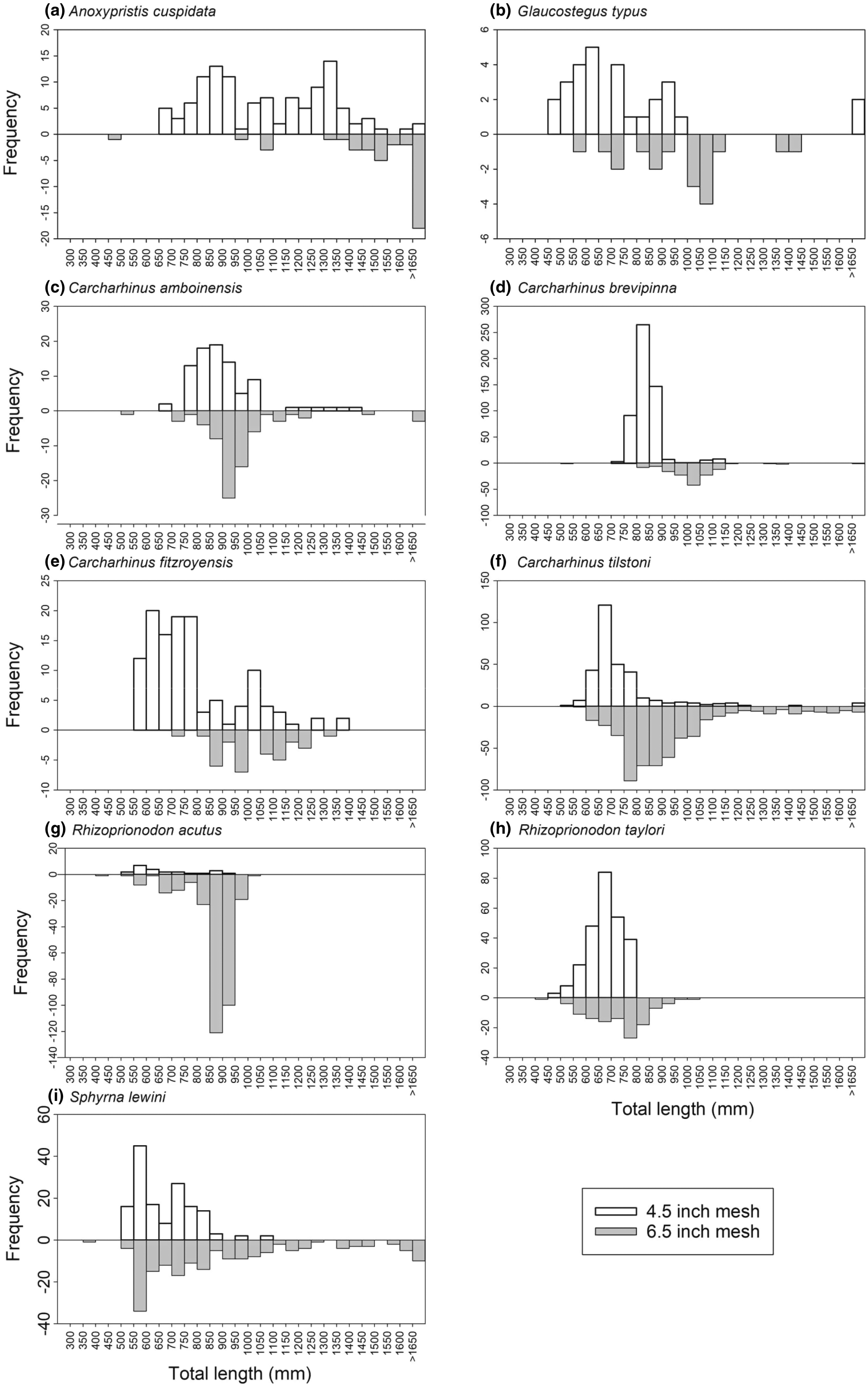

FIGURE 1 Total length–frequency distributions of seven shark and two ray species caught by 4.5-inch (black) and 6.5-inch (gray) gillnets in the Queensland East Coast Inshore Finfish Fishery between June 2006 and July 2009.

TABLE 2 Selectivity parameters θ_1 and θ_2 of seven shark and two ray species (CI = 2.5–97.5 percentiles of 1500 bootstrapped samples) caught by 4.5- and 6.5-inch mesh size gillnets in the Queensland East Coast Inshore Finfish Fishery between June 2006 and July 2009.

Species	θ_1	CI	θ_2	CI
A. cuspidata	247.54	226.64–270.57	186,645	82,565–504,744
C. amboinensis	159.53	154.60–165.21	57,449	32,082–99,027
C. brevipinna	163.83	162.85–165.77	13,387	11,165–16,614
C. fitzroyensis	167.06	159.62–176.23	53,007	35,260–80,378
C. tilstoni	128.71	127.17–130.33	30,719	26,933–35,067
G. typus	142.60	130.76–152.58	52,561	29,859–87,582
R. acutus	120.88	117.88–123.94	13,189	10,106–17,039
R. taylori	127.82	125.73–129.52	28,786	20,026–35,673
S. lewini	119.91	115.35–123.73	64,393	48,020–80,939

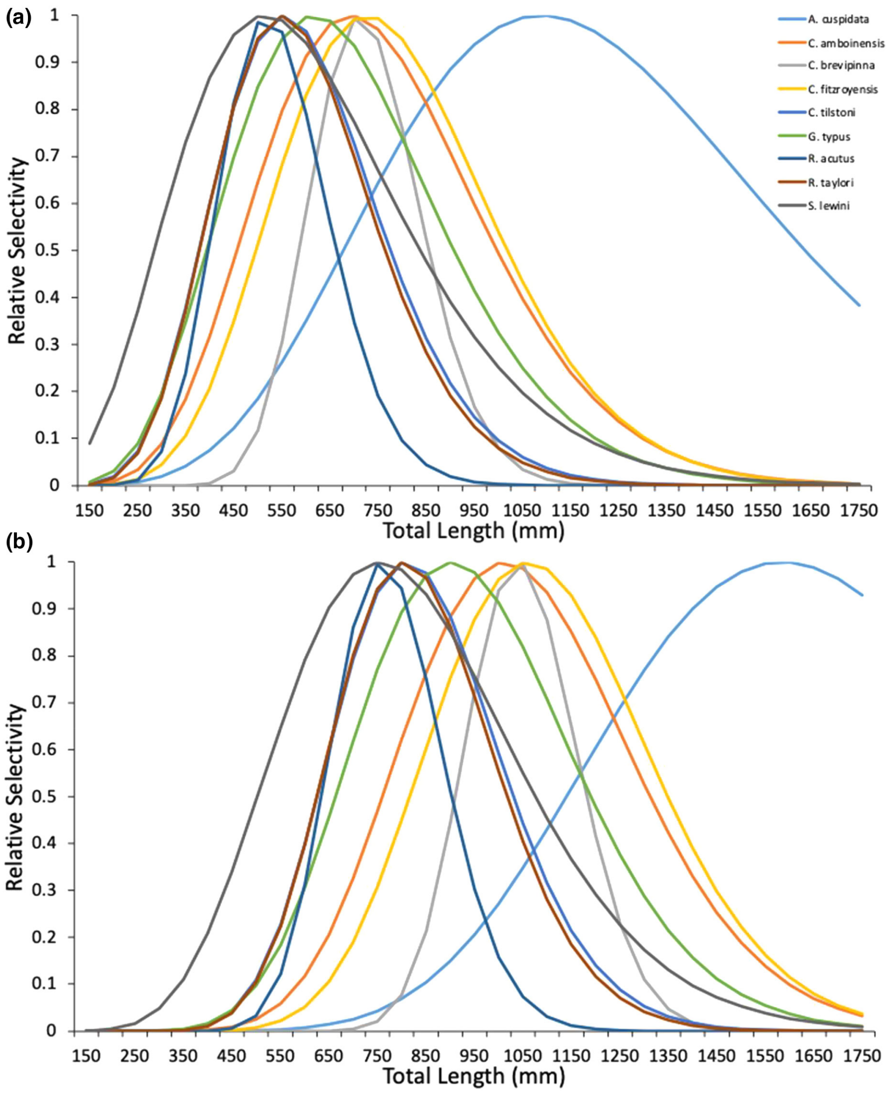

FIGURE 2 Relative selectivity of seven shark and two ray species caught by 4.5-inch (a) and 6.5-inch (b) mesh size gillnets in the Queensland East Coast Inshore Finfish Fishery between June 2006 and July 2009.

carcharhinid species and also *G. typus*. Peak selectivity was slightly higher for larger and broader nosed species (*C. amboinensis* and *C. fitzroyensis*) and often lower for small species (e.g., *Rhizoprionodon* spp.). The selectivity curve was narrowest for *C. brevipinna*, likely because a very narrow size range of mostly very young individuals were caught (Figure 1).

4 | DISCUSSION

Size selection curves of the species we examined, in relation to the range of mesh sizes available to fishers in the ECIFF (≤8 inch), suggest that restricting mesh sizes would have variable effects on the harvest. For example, mesh selection would do little for threatened

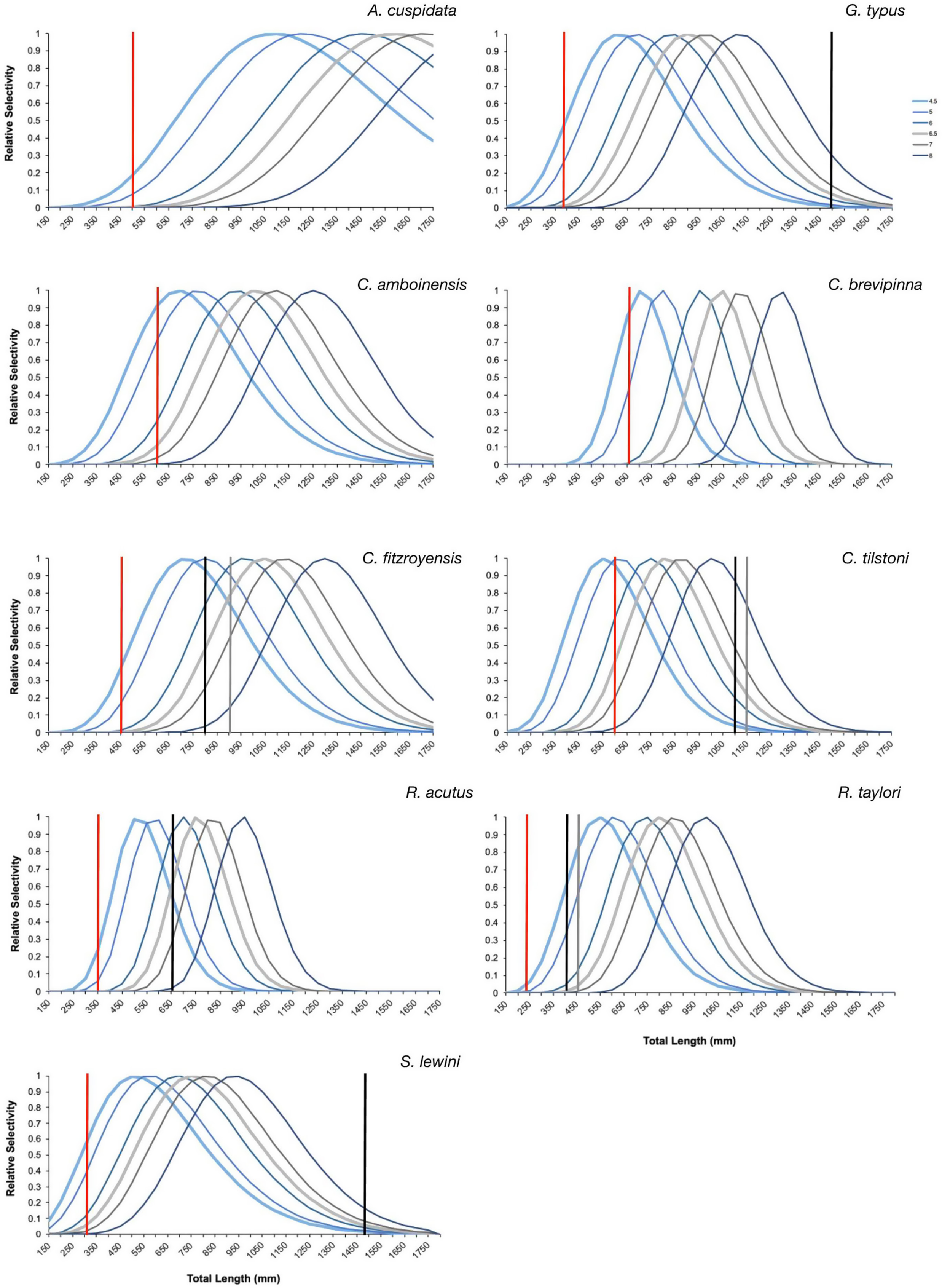

FIGURE 3 Relative selectivity of 4.5–8.0 inch mesh sizes, length at birth (red), and maturity (black = male, or both male and female; gray = female) for seven shark and two ray species caught by 4.5-inch (a) and 6.5-inch (b) mesh size gillnets in the Queensland East Coast Inshore Finfish Fishery between June 2006 and July 2009.

A. cuspidata, given its broad selectivity, although using mesh sizes >5 inches would eliminate the capture of small individuals. Similarly, the other species threatened in Australian waters, *S. lewini*, would benefit little from smaller mesh sizes because all mesh sizes between 4.5 and 8 inches are highly selective for juvenile size classes, the main sizes caught by the fishery (Harry et al., 2011). In contrast, using smaller mesh sizes (e.g., 4.5–6 inch) would potentially provide a gauntlet fishery for several carcharhinid species, and *S. lewini* and *G. typus*, with selection focused on small juveniles, except for *R. taylori*, which would be caught as adults in even the smallest mesh sizes. Mesh selectivity parameters (θ_1 and θ_2) we estimated were weakly related ($R^2 = 0.32$, $p = 0.01$) to those from other studies (Carlson & Cortés, 2003; Márquez-Farias, 2005; McAuley et al., 2007; McLoughlin & Stevens, 1994; Simpfendorfer & Unsworth, 1998). Most species in the genus *Carcharhinus* were grouped together with similar θ_1 and θ_2 values (Figure 4). The remaining three species within the genus *Carcharhinus*, although varying in θ_2 values, still share similar θ_1 values. The two *Rhizoprionodon* spp. from this study were grouped close together, but the third from the Gulf of Mexico had a significantly larger θ_1 and θ_2. *Sphyrna* spp. had similar θ_1 values and varied slightly in θ_2. *Anoxypristis cuspidata* had the largest θ_1 and θ_2 values.

Similarities in θ_1 among species in our study were likely caused by similar morphology, with closely related (within genus or family) species being the most similar. Within large families (e.g., Carcharhinidae), θ_1 were most similar for species of similar morphology (e.g., *C. amboinensis* and *C. fitzroyensis*). Similarities in θ_1 among morphologically similar species, including species from the family Carcharhinidae, have been observed by previous studies and is supported by results from this study (Simpfendorfer & Unsworth, 1998, Carlson & Cortés, 2003, McAuley et al., 2007, Baremore et al. 2012, Braccini et al., 2022). Furthermore, morphology also likely explained a high θ_1 for *A. cuspidata*, with a large toothed rostrum, and *S. lewini*, with a large cephalofoil, which leads to capture of even large individuals in relatively small mesh nets. The relationship between morphology and θ_1 suggests that this parameter can be estimated for species with similar morphology. Therefore, our findings may be useful for estimating mesh selection for developing fisheries management options in the absence of fishery-specific mesh selectivity data, if the uncertainty of such use is taken into account.

We found that θ_2 estimates were more variable than θ_1 estimates, likely because of variations in species morphology, size range sampled, mesh breakage, mesh sizes analyzed, and fish behavior. First, fish morphology, particularly morphology that negates gilling in gillnets, can result in very large estimates of θ_2. For example, the sawfish *A. cuspidata* has a long-toothed rostrum that is easily entangled in a wide range of mesh sizes, irrespective of fish size that produces a broad selection curve (Seitz & Poulakis, 2006). Similarly, the hammer-shaped head of *S. lewini* leads to broad selectivity (Carlson & Cortés, 2003). Both these species had higher θ_2 estimates than species in our study. Second, θ_2 values can be constrained by a small size range of fish available to capture, as when sizes segregate spatially in a population and sampling is only in one area. This was the case for *C. brevipinna* in our study, which were primarily caught as newborn animals in a small number of gillnet sets, which caused θ_2 to be underestimated because all sizes were not equally available to capture (Kirkwood & Walker, 1986). Size segregation is common in shark and ray populations, with juveniles and adults inhabiting different areas, sometimes separated by large distances (Braccini & Taylor, 2016; Heupel et al., 2007; Springer, 1967). Third, when a mesh breaks during capture, an individual fish can be gilled in a larger-sized mesh, thereby resulting in a higher estimate of θ_2. We lacked data to study this possibility, but θ_2 (and θ_1) estimates for dusky sharks (*Carcharhinus obscurus*) were substantially smaller when only individuals caught in single meshes were analyzed (Simpfendorfer & Unsworth, 1998). Fourth, behavior when encountering nets affects how individuals are caught, such as *Carcharhinus isodon* thrashing when encountering nets, which increases the likelihood of entangling rather than gilling, and ultimately causes θ_2 to be

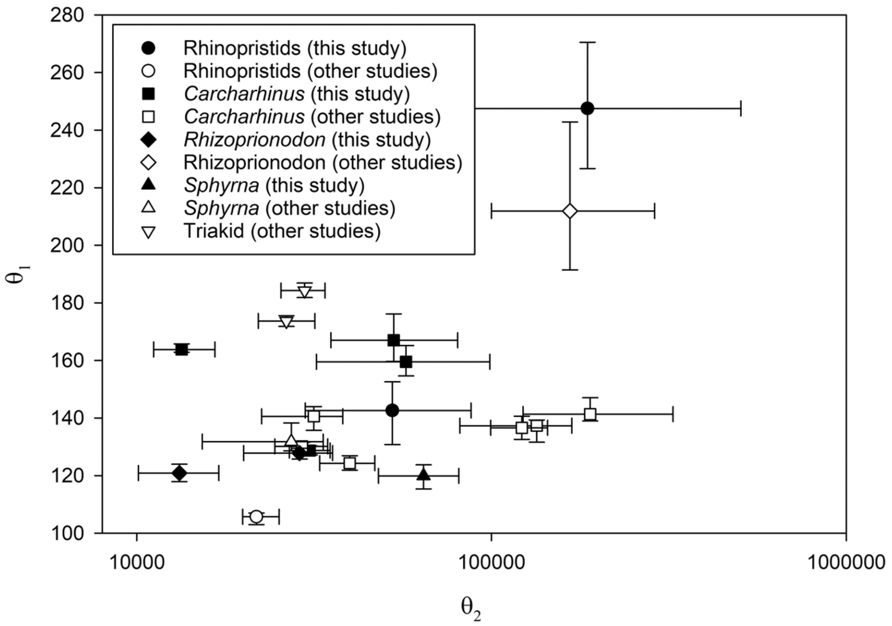

FIGURE 4 Relationship between gillnet mesh selectivity parameters, θ_1 and θ_2 (±SE), for all species within five genera of sharks and rays caught by 4.5-inch (a) and 6.5-inch (b) mesh size gillnets in the Queensland East Coast Inshore Finfish Fishery between June 2006 and July 2009 (this study) and other studies that used the same (Kirkwood & Walker, 1986) method for estimating gillnet mesh selectivity parameters.

overestimated (Carlson & Cortés, 2003). Last, when gillnet characteristics increase the likelihood that individuals will become entangled rather than gilled, the size range caught in a particular mesh size is wider than when fish are just gilled. Net characteristics that affect this outcome include the breaking strength of the mesh (i.e., lighter nets are more likely to entangle), the tension of the net (Thorpe & Frierson, 2009), hanging ratio (Hamley, 1975), and netting material (i.e., monofilament is less likely to entangle than multifilament mesh) (Hamley, 1975). When available, these net characteristics can better inform outcomes of size selectivity studies. However, these characteristics were not recorded in the current study due to fishers not providing the data. Despite this, equal fishing power can be assumed since all size ranges were caught within the fishery nets and results were comparable to previous studies (Baremore et al., 2012; Carlson & Cortés, 2003; Kirkwood & Walker, 1986; McAuley et al., 2007; Simpfendorfer & Unsworth, 1998).

Our mesh selectivity parameters may improve management outcomes for sharks and rays in Queensland's ECIFF, although mesh sizes beneficial to some species may be harmful to others, such as smaller mesh sizes for gauntlet fisheries (Prince, 2002; Simpfendorfer, 1999) that target large carcharhinid species (e.g., *C. amboinensis*) or larger mesh sizes to avoid capturing newborn *A. cuspidata*. For example, such considerations were suggested to improve sustainability and reduce the mortality of threatened species for the complex, multispecies, and multi-life stage shark fisheries within the Great Barrier Reef World Heritage Area (Harry et al., 2011). Our mesh selectivity findings can be used to operationalize such an approach, by incorporating into stock assessments to better understand population dynamics, and how mesh size affects sustainable harvest levels. However, other factors related to mesh size choices must be taken into account when considering the ideal mesh size for multispecies fisheries, including mesh selection for nonshark target species, such as barramundi (*Lates calcarifer*) and gray mackerel (*Scomberomorus semifasciatus*), that underpin profitability of many fishers in the ECIFF (Harry et al., 2011), size of sharks caught and their market acceptability (Simpfendorfer, 1999), and the probability that particular mesh sizes capture species of conservation concern, such as dugongs and dolphins (Berg Soto, 2012). Fisheries management decisions about ideal mesh sizes must consider trade-offs among these factors in making decisions about appropriate mesh size(s) for use in the fishery.

For species with broad size selectivity curves (e.g., *A. cuspidata*, *S. lewini*), mesh size regulations will not likely benefit sustainability, so other management approaches will be required for these species. One such approach is to close areas to net fishing as refuges, as along the Queensland east coast where multiuse marine parks include net-free zones (e.g., Great Barrier Reef Marine Park, Great Sandy Marine Park, Moreton Bay Marine Park). More nuanced regulation about mesh size regulations could be used to manage fishing where juveniles or adults are the dominant part of the gillnet catch, such as selecting a mesh size that either avoids or targets specific size or maturity classes to optimize sustainability, albeit at relatively small spatial scales that depend on species ecology. This situation would require knowledge of gillnet mesh selection parameters, and also the spatial ecology of focal species, to ensure that regulations are implemented correctly. With increasing knowledge of gillnet mesh selection parameters, and the potential to infer parameters for species based on morphology and gear characteristics, such approaches are becoming more viable.

The similarity between mesh selection parameters in this study, which did not use a multi-panel experimental gillnet with different-sized meshes, and those from other studies that did (Carlson & Cortés, 2003; Kirkwood & Walker, 1986; McAuley et al., 2007; McLoughlin & Stevens, 1994; Simpfendorfer & Unsworth, 1998), suggests that our approach can generate representative data and realistic estimates of mesh selectivity parameters. Widespread use of the two mesh sizes used in our study (4.5 and 6.5 inch) ensured that sampling was across a wide range of habitats and thereby provided a reasonable opportunity to meet the assumption that all size classes were equally vulnerable to sampling. However, for some species, parameter estimates, especially θ_2, were not close to the expected values. For example, the θ_2 for *C. brevipinna* was much smaller than for other species with similar morphology because sampling was biased toward newborn individuals. Under-estimation of this parameter was therefore not caused by the modeling approach, but rather, because of size segregation in the population. Multi-panel gillnet studies can suffer from similar limitations (e.g., *C. isodon*, *Rhizoprionodon terraenovae*; Carlson & Cortés, 2003). While results are likely to be best when based on catches in multi-mesh gillnets, our results suggest that fisheries data from different-sized meshes can be used to accurately estimate mesh selection parameters. The approach we used can therefore be used to estimate gillnet selectivity parameters where researchers only have access to size frequency data from multiple mesh sizes.

A growing number of studies have estimated mesh selection parameters for sharks and rays using the Kirkwood and Walker (1986) method to increase understanding of gillnet selectivity. Our results suggest that selectivity parameters can be estimated based on taxonomic and morphological similarity, although further research will be required to confirm the usefulness of such an approach. As a key tool for managing sustainable gillnet fisheries (Walker, 1998), this growing body of knowledge can be used to improve the sustainability of shark and ray populations (Simpfendorfer & Dulvy, 2017) and help to address the growing extinction crisis the group faces (Dulvy et al., 2021).

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CONFLICT OF INTEREST STATEMENT

There is no competing interest.

DATA AVAILABILITY STATEMENT

Data will be available upon request.

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