Net Selectivity for Barramundi (*Lates calcarifer*)

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Summary

Log-linear modelling of two fisheries-independent barramundi catch and effort datasets (2000-2006 research survey data and 1981-1984 research survey data) from the east coast of Queensland provided estimates of selectivity of barramundi for seven mesh sizes from 101.6 mm to 203.2 mm. These estimates provide a basis for assessing the sensitivity of barramundi production model (SHASSAM) to selectivity. The two datasets were best fitted by different selection curves with a gamma selection curve providing the best fit to the 2000-2006 barramundi catch data and a lognormal selection curve for the 1891-1984 dataset. The difference in the optimum length of capture across the range of mesh sizes between these two selection curves ranged from 20 to 40 mm. However, the optimum lengths of capture for are substantially larger than reported previously for gillnet selectivity of barramundi in Fly River (Milton *et al.*1998). A thorough investigation of net selectivity characteristics for barramundi would require rigorous experimental design to account for factors other than mesh size including hanging ratio, filament gauge and fishing intensity and to assess entangling effects. Additional investigation is also required to investigate the relationship between contact selection and population selection to ensure appropriate catch size structure adjustment for stock assessment.

Introduction

The inshore net fishery in Queensland east coast waters is a substantial fishery with more than 500 netting endorsements. Barramundi is a major component of the catch from the inshore net fishery with 300 vessels having reported landing barramundi between 1990 and 2000. The catch of barramundi ranged from 480 t in 1992 to 900 t in 1999. Recently, an age-based model for barramundi production in northern Australia incorporating spatial, age, habitat and sex components was developed cooperatively between Queensland, Northern Territory and Western Australian fisheries management agencies (Gribble pers. com. November 2006). The results of the model for the Queensland barramundi indicate a discrepancy between the observed data and the age structure predicted by the model. The model included a selectivity factor based on an estimate of net selectivity for barramundi in the estuary of the Norman River (south-east Gulf of Carpentaria) reported by Gribble (1999). The current analyses were undertaken to obtain selectivity parameters using research catch data for barramundi from the east coast of Queensland. The highly selective nature of gillnets determines that catch data from gillnets can not be used for stock assessment unless there is an adequate understanding of selectivity parameters.

Studies on net selectivity and the methods of estimation were reviewed by Hamley (1975) who outlined a variety of factors influencing net selectivity (including fish size and shape, mesh size, net filament gauge, net material, net hanging and method of fishing. The most reliable estimates of selectivity are obtained from “direct” methods where the size structure of the population is known. Since this is rarely the case, indirect methods of estimating selectivity are required where catches of different mesh sizes are compared. Hamley (1975) also describes other methods including prediction from girth measurement and the De Lury method.

Most selectivity studies are concerned with the proportion of fish that are retained by a net once it has been encountered (e.g. Kirkwood and Walker 1986) and this has been defined as contact selection by Millar and Fryer (1999). Of more interest, for stock assessment purposes but more difficult to estimate is population selection or the proportion of fish from the total population that are captured and retained in the net (Millar and Fryer 1999). The probability of gillnet encounter by fish has been considered by Rudstam *et al.* (1984) and will not be explored in this investigation. Millar and Fryer (1999) also identified the available selection curve in relation to the relative probability that a fish is captured given that it was available to (but possibly avoided) the gear. Millar and Fryer (1999) also consider the issue of fishing intensity. Millar (2000) note that it is not possible to estimate available selection or population selection curves from indirect studies.

Sparre *et al.* (1989) described a method used by Holt (1965) for estimating the selectivity factor from the optimum length of fish captured in two nets of different mesh size. The method involves using the natural log catch ratios for each size group from both nets for the lengths where the frequencies overlap. The two mesh sizes must be such that their selection ogives overlap. This procedure is based on the assumption that the selection curve is normally distributed. It is also assumed that the optimum length is proportional to the mesh size, the two selection curves have the same standard deviation, and the two gears have the same fishing power so that when set they have the same area.

Hamley (1975) also reviewed the shape and mathematical representation of selectivity curves and noted that most selectivity curves appear to be skewed to the right and subsequently, Kirkwood and Walker (1986) applied gamma distribution since this distribution was considered a convenient and flexible two parameter model able to accommodate a varying amount of right skew. Kirkwood and Walker (1986) developed a method where an assumed selectivity function is fitted directly to catch data for a number of different mesh sizes, and the parameters of the selectivity function are estimated across all mesh sizes and length-classes simultaneously. Millar and Holst (1997) further developed a log linear model to fit various selectivity curves to catch data using log likelihood to estimate parameters. Millar and Holst (1997) noted the requirement for assumptions or inferences about relative fishing power across mesh sizes, population length distribution, and the shape of the selection curve. Net selectivity for barramundi has previously been examined by Gribble (1998) using a catch ratio analysis of barramundi catches from Norman River (Gulf of Carpentaria) and by Milton *et al*. (1998) who fitted a normal section curve to barramundi catch data from the Fly River (New Guinea).

In this report, various selection curves were fitted to barramundi catch data from fisheries-independent netting surveys of inshore habitats of the Great Barrier Reef World Heritage Area using log linear modelling following Millar and Holst (1997). A catch ratio analysis following Sparre *et al.* (1989) was also completed to provide a comparison with selectivity estimates obtained by Gribble (1999).

Methods

Barramundi populations were sampled with gillnets of five different mesh sizes 101.6, 127, 152.4, 177.8, and 203.2 mm stretched mesh and total lengths recorded for all fish. Survey locations were located in Trinity Inlet and Princess Charlotte Bay. A variety of habitats in each location were surveyed including upper estuary, middle estuary, lower estuary, sheltered intertidal and shallow subtidal foreshore, rocky intertidal and shallow foreshore, and tidal creek. Samples were pooled across both locations and all habitats. The number of barramundi in 50mm size classes for each mesh size was standardised by effort and analysed using log linear modelling to fit selection curves. A catch ratio analysis was also performed on the catch data to enable a comparison with the catch ratio analysis of barramundi catch data from Norman River (south east Gulf of Carpentaria). In addition, several selectivity models were fitted to historical barramundi catch data (including total lengths) from research surveys undertaken from 1981 to 1984 in estuaries from Trinity Bay to Hervey Bay. There analyses were also performed on catches in each size class standardised by effort for each mesh size.

Log-linear Modelling

The general statistical model for estimating net selection curves described by Millar and Holst (1997) uses a Poisson distribution to model the counts n_{ij} of fish in the length class with a midpoint of *l* caught in mesh size *j*. Millar and Fryer (1999) recognised three processes determining n_{ij} : abundance, relative fishing intensity and contact-selection. The model assumes that the number of length *l* fish contacting the net has a Poisson distribution, with mean λ_l . The relative fishing intensity of length *l* fish in net *j*, $p_j(l)$ is the probability that a fish of length *l* contacts net *j* given that it contacts the combined gear (Millar and Fryer 1999). If it is assumed that the fish will contact only one net and the net relative fishing intensities will sum to unity across nets, ie $\Sigma_j p_j(l)$ = 1. If relative fishing intensity is independent of fish length and proportional to the fishing effort and the nets are fished with equal effort then the $p_j(l)= 1/J$. Millar and Fryer (1999) propose a flexible $p_j(l)$ to model relative avoidance where fish avoid some nets more than others, or conversely, to model fishing power where some gears contact more fish than others. The probability of fish *l* contacting net *j* is therefore $p_j(l)\ \lambda_l$. If the selection curve for net *j* is $r_j(l)$ then the expected number of fish n_{lj} of length *l* retained in net *j* is represented by $p_j(l)\ \lambda_l r_j(l)$. This is expressed as

$$n_{lj} \sim Pois(p_j(l)\lambda_l r_j(l)) \qquad \text{(Millar and Fryer 1999)}$$

Millar and Fryer(1999) note that since the contact selection curves, $r_j(l)$, and the relative fishing intensities , $p_j(l)$, are confounded and cannot be estimated from the data , assumptions must be made about $r_j(l)$ or $p_j(l)$, usually that the relative fishing intensities are constants, p_j, that do not depend on length giving

$$n_{ij} \sim Pois(p_j \lambda_l r_j(l)) \qquad \text{(Millar and Fryer 1999)}$$

In the case of gillnets, the maximum height of the selection curve may vary with the net type, however, it is only possible to model relative selection curves each with unit height. Millar and Fryer (1999) note that the form of p_j, λ_l , and $r_j(l)$ need to be considered. If fishing gears are fished equally then the relative fishing intensity may be assumed equal, proportional to or some function of mesh size or no assumption may be made. A form for the size distribution of fish contacting the net may be postulated. A comparison of residual plots and goodness-of-fit statistics after fitting different models may be used to assess the suitability of each of these.

Millar and Holst (1997) express the selection curve for gillnets in a log-linear form as

$$\log_e(\eta_{lj}) = \log_e(p_j) + \log_e(\lambda_l) + \log_e(r_i(l)).$$

Where $\eta_{lj} = E(n_{lj}) = p_j(l)\,\lambda_l r_j(l)$ denote the expected catch of length l fish in net (mesh size) j.

The log linear form is

$$\log_e(\eta_{lj}) = \sum_i \beta_i \cdot f_i(m_j, l),$$ (Millar and Holst 1997)

where $f_i(m_j,l)$ are known functions of m_j and l, and not dependent on any unknown parameters. (Millar and Holst 1997).

Selectivity curves were fitted to the east coast barramundi catch data using four models, normal with fixed spread, normal with proportional spread, gamma with proportional spread and lognormal with proportional spread following Millar and Holst (1997) as follows:

Model (from Millar and Holst 1997)	Selection Curve	$[\beta_1]\cdot\{f(j,l)\} + [\beta_2]\{f_2(j,l)\}$
Normal: fixed spread	$\exp\left(-\frac{(L - k\cdot m_j)^2}{2\sigma^2}\right)$	$\left[\frac{k}{\sigma^2}\right]\cdot\{L\cdot m_j\} + \left[-\frac{k^2}{2\sigma^2}\right]\cdot\{m_j^2\}$
Normal spread α m_j	$\exp\left(-\frac{(L - k_1\cdot m_j)^2}{2k_2\cdot m_j^2}\right)$	$\left[\frac{k_1}{k_2}\right]\cdot\left\{\frac{L}{m_j}\right\} + \left[-\frac{1}{2k_2}\right]\cdot\left\{\left(\frac{L}{m_j}\right)^2\right\}$
Gamma spread α m_j	$\left(\frac{L}{(\alpha-1)\cdot k\cdot m_j}\right)^{\alpha-1}\exp\left(\alpha - 1 - \frac{L}{k\cdot m_j}\right)$	$[\alpha-1]\cdot\left\{\log\left(\frac{L}{m_j}\right)\right\} + \left[-\frac{1}{k}\right]\cdot\left\{\frac{L}{m_j}\right\}$
Lognormal spread α m_j		

$$\frac{1}{L}\exp\left(\mu_1+\ln\left(\frac{m_j}{m_1}\right)-\frac{\sigma^2}{2}-\frac{\left(\ln(L)-\mu_1-\ln\left(\frac{m_j}{m_1}\right)\right)^2}{2\sigma^2}\right) \qquad \left[\frac{1}{\sigma^2}\right]\cdot\left\{\log(L)\cdot\log\left(\frac{m_j}{m_1}\right)-\frac{1}{2}\log^2\left(\frac{m_j}{m_1}\right)\right\} + \left[1-\frac{\mu_1}{\sigma^2}\right]\cdot\left\{\log\left(\frac{m_j}{m_1}\right)\right\}$$

Maximum likelihood was used to obtain parameter estimates with the statistical software package R: A language and environment for statistical computing 2006.

Catch Ratio Analysis (following Sparre (1989))

The analysis described by Sparre *et al.* (1989) calculates the log ratios for each length group for those lengths where the frequencies overlap.

$$Y=\ln(Cb/Ca)$$

where *Ca* and *Cb* are the catches for the small large and mesh net respectively. Sparre *et al.* (1989) then perform a regression analysis of the log ratio against the interval midpoint.

$$\ln(Cb/Ca)=a+b*L$$

The optimum length for small mesh net is determined by:

$$Lma=-2*\frac{a*ma}{b*(ma+mb))}$$

And the optimum length for the large mesh net is determined by:

$$Lmb=-2*\frac{a*mb}{b*(ma+mb)}$$

where *ma* and *mb* are the mesh sizes of the small and large mesh nets respectively.

The common standard deviation is

$$S=\sqrt{(2*a*(mb-ma)))/(b^2*(ma+mb))}$$

The selection factor is estimated from:

$$S.F.=\frac{-2*a}{b*(ma+mb)}$$

For more than two mesh sizes, Sparre *et al.* (1989) estimate an overall selectivity factor and a common standard deviation from the results of each pair of successive

$$S.F. = -2\sum_{i=1}^{n-1}\left[a(i)/b(i)\right]*\left[m(i)+m((i+1)\right]/\sum_{i=1}^{n-1}\left[m(i)+m(i+1)\right]^2$$

mesh sizes. The overall selection factor is estimated from:

Selection as a function of length is described as

$$S(L) = \exp\left[-(L-Lm)^2 / 2 * s^2\right]$$

Where Lm is the optimal length for being caught and s is the standard deviation.
The above procedures provide an estimate of selection when fish are gilled or wedged and does not account for fish that may be entangled. The selection ogives of the two mesh sizes must overlap. The analyses assume that the optimum length size is proportional to the mesh size, the two selection curves have the same standard deviation, and the two gears have the same fishing power. The analysis is based on the assumption that the selection curve is normally distributed.

Results

Log-linear Analyses of Barramundi Research Catch Data from 2000-2006

The barramundi catch data (by 50mm size class for each mesh size) from research netting surveys from 2000-2006 with total effort, minimum and maximum total lengths, mean total lengths, and standard deviations for five mesh sizes are presented in Table1. The barramundi size distributions standardised by effort for five mesh sizes are shown in Figure 1.

The selectivity function parameters and residual deviances from log linear modelling to fit normal (fixed spread and proportional spread), lognormal (proportional spread) and gamma (proportional spread) distributions to barramundi catch data for fishing power equal across mesh sizes and for fishing power proportional to mesh size are presented in Table 2 for catch data from five mesh sizes and in Table 3 for catch data from three mesh sizes. The analyses of catch data from three mesh sizes provided a better fit than the five mesh analyses, however, the results of the five mesh analyses are presented to provide an estimate of net selectivity characteristics for the larger (177.8 mm and 203.2 mm) mesh sizes in use in the commercial inshore net fishery.

The gamma selection curve provided the best fit to the catch data from three mesh sizes although the normal (proportional spread) selection curve best fitted the catch data from five mesh sizes. Results of the five mesh size analyses must be considered tentative since the sample sizes for the 177.8 mm and 203.2 mm mesh sizes are considerably smaller than for the other mesh sizes. There was no difference in fit between modelling for equal fishing power across mesh sizes to modelling fixed fishing power across mesh sizes for the gamma or lognormal functions in either the three mesh or five mesh analyses.

The optimum lengths of capture (S(L)), S50% and L50% sizes are presented in Tables 4, 5 and 6 for the gamma selection curves from three and five mesh analyses and the normal selection curve for the five mesh analysis. The difference in the optimum lengths between the normal selectivity curve from the five mesh analysis and the gamma selectivity curve from the three mesh net analysis is 15 mm for the 152.4 mm mesh size. The difference in optimum lengths between the gamma selection curves for three mesh and five mesh analyses is considerably lower at 4 mm. The gamma selection curves for three mesh sizes and the normal selection curves for five mesh sizes are presented in Figure 2 and Figure 3.

Log-linear Analyses of Barramundi Research Catch Data from 1981-1984

The barramundi catch data (by 50 mm size classes for each mesh size) from research netting surveys from 1981-1984 with total effort, minimum and maximum total lengths, mean total lengths, and standard deviations for seven mesh sizes are presented in Table 7. The barramundi size distributions standardised by effort for seven mesh sizes are shown in Figure 4. This dataset includes two additional mesh sizes (114.3 mm and 165.1 mm) and included larger sample sizes for the 177.2 mm and 203.2 mm mesh sizes compared to the 2000-2006 dataset.

The selectivity function parameters and residual deviances from log-linear modelling to fit normal (fixed spread and proportional spread), lognormal (proportional spread) and gamma (proportional spread) distributions to barramundi catch data for fishing power equal across mesh sizes and for fishing power proportional to mesh size are presented in Table 8 for seven mesh sizes.

The lognormal selection curve provided the best fit to the catch data from seven mesh sizes. As with the analyses of the 2000-2006 catch data, there was no difference in fit between modelling for equal fishing power across mesh sizes to modelling fixed fishing power across mesh sizes for the gamma or lognormal functions.

The optimum lengths of capture (S(L)), S50% and L50% sizes are presented in Table 9 for the lognormal selection curves for each of the seven mesh sizes. The optimum lengths of capture, S(50%) and L(50%) associated with the lognormal selection curve fitted to the 2000-2006 barramundi research catch data are presented in Table 10 for comparison. The difference in the optimum lengths between the 1981-1984 data set and the 2000-2006 dataset ranges between 20 to 40 mm.

The lognormal selection curves for seven mesh sizes are presented in Figure 5 for the 1981-1984 dataset and the lognormal selection curves for five mesh sizes are presented in Figure 6 for the 2000-2006 data set. The observed and estimated barramundi size distributions by mesh size for the 1981-1984 barramundi catch data are presented in Figure 7. The estimated size distribution for three mesh sizes (101, 127 and 165mm) contained six outlying values and the length classes in which these occurred are shown in Figure 7 a, c, and e and occurred possibly as a result of higher then expected estimated catch of larger fish in these three mesh sizes. The estimated catches for these length class mesh size categories may indicate an entangling effect for some of the larger fish.

Catch Ratio Analysis

The optimal sizes of capture obtained from catch ratio analyses of the 2000-2006 barramundi catch data were 541 mm and 440 mm for 152.4 mm and 127 mm mesh nets respectively. The optimal length of barramundi in the 101.6 mm mesh net was 352 mm from the ratio analysis of catches from the 101.6 mm and 127 mm mesh and 360 mm from the analysis of catches from 101.6 mm and 152.4 mm mesh nets. The selection factors, intercepts and slopes derived from the analyses based on Sparre *et al.* (1989) are presented in Table 11.

Table 1 Barramundi size distribution by mesh size from fisheries-independent surveys 2000-2006.

Mesh Size (mm)	101.6	127	152.4	177.8	203.2
Sample Size	94	87	193	46	10
Size Class (mm)					
301: 350		1	1		
351: 400	6	2			
401: 450	33	5	2		
451: 500	31	5	3		
501: 550	13	19	4	1	1
551: 600	8	20	29	10	
601: 650	2	18	45	12	
651: 700	1	14	33	5	2
701: 750		1	25	6	
751: 800			24	3	1
801: 850		1	13	4	1
851: 900		1	10	3	
901: 950			1		1
951:1000			2	1	2
1001:1050			1	1	2
Effort (m hours)	11319	8621	45104	14900	11284
Mean Length (mm)	476	582	688	694	849
Max Length (mm)	700	890	1010	1045	1030
Min Length (mm)	360	315	325	550	550
Std Dev	62.40	90.43	105.68	118.45	166.15

Figure 1 Barramundi size distribution from research netting surveys on the east coast of Queensland (2000-2006) standardised by effort for five mesh sizes.

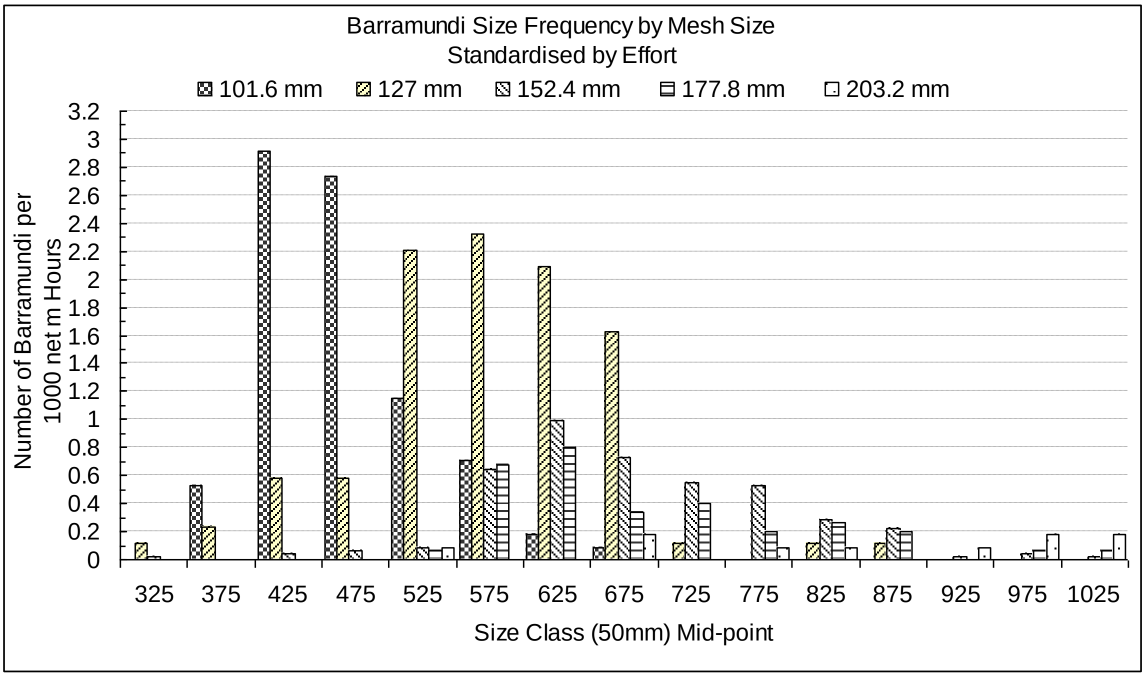


Table 2 Selectivity model parameters for east coast barramundi catch (2000-2006) from five mesh sizes.

	Equal Fishing Power		Fishing power α mesh-size	
Model (32DF 5 mesh sizes)	Parameters	Residual Deviance (AIC)	Parameters	Residual Deviance (AIC)
Normal				
Fixed Spread	k = 4.663 σ =119.54	696.7 (978.2)	k = 4.823 σ =121.54	698 (979.5)
Spread α m_j	k_1 = 4.81 k_2 =0.593	453.5 (735)	k_1 = 4.93 k_2 =0.576	453.6 (735.1)
Log Normal				
Spread α m_j	σ =0.18 μ_1=6.13	502.8 (784.2)	σ=0.18 μ_1=6.16	502.8 (784.2)
Gamma				
Spread α m_j	α=34.252 k=0.142	473.3 (754.8)	α=35.252 k=0.142	473.3 (754.8)

Table 3 Selectivity model parameters for east coast barramundi catch (2000-2006) from three mesh sizes.

	Equal Fishing Power		Fishing power α mesh-size	
Model (15DF)	Parameters	Model Deviance	Parameters	Model Deviance
Normal				
Fixed Spread	k = 4.689 σ =90.78	301.8 (503.4)	k = 4.826 σ =92.27	286.4 (488)
Spread α m_j	k_1 = 4.806 k_2 =0.495	283.2 (484.8)	k_1 = 4.907 k_2 =0.483	283.8 (485.4)
Log Normal				
Spread α m_j	σ =0.176 μ_1=6.25	295.2 (496.8)	σ=0.176 μ_1=6.281	295.2 (496.8)
Gamma				
Spread α m_j	α=42.599 k=0.113	278.3 (479.9)	α=43.599 k=0.113	278.3 (479.9)

Table 4 Gamma selection curve characteristics for east coast barramundi research catch data (2000-2006) from three mesh sizes.

Mesh Size mm	Max(S(L)) mm	S 50% mm	D 50% Mm
101.6	491	408	585
127	615	510	731
152.4	736	611	877

Table 5 Gamma selection curve characteristics for east coast barramundi research catch data (2000-2006) from five mesh sizes.

Mesh Size mm	Max(S(L)) mm	S 50% mm	D50% mm
101.6	493	401	599
127	616	501	749
152.4	740	601	899
177.8	863	701	1048
203.2	986	801	1198

Table 6 Normal selection curve characteristics for east coast barramundi data (2000-2006) from five mesh sizes.

Mesh Size mm	Max(S(L)) mm	S 50% mm	D50% mm
101.6	501	410	591
127	626	512	739
152.4	751	615	887
177.8	876	717	1035
203.2	1002	820	1183

Figure 2 Gamma (proportional spread and fishing power proportional to mesh size) selection curve fitted to east coast barramundi research catch data (2000-2006) from three mesh sizes.

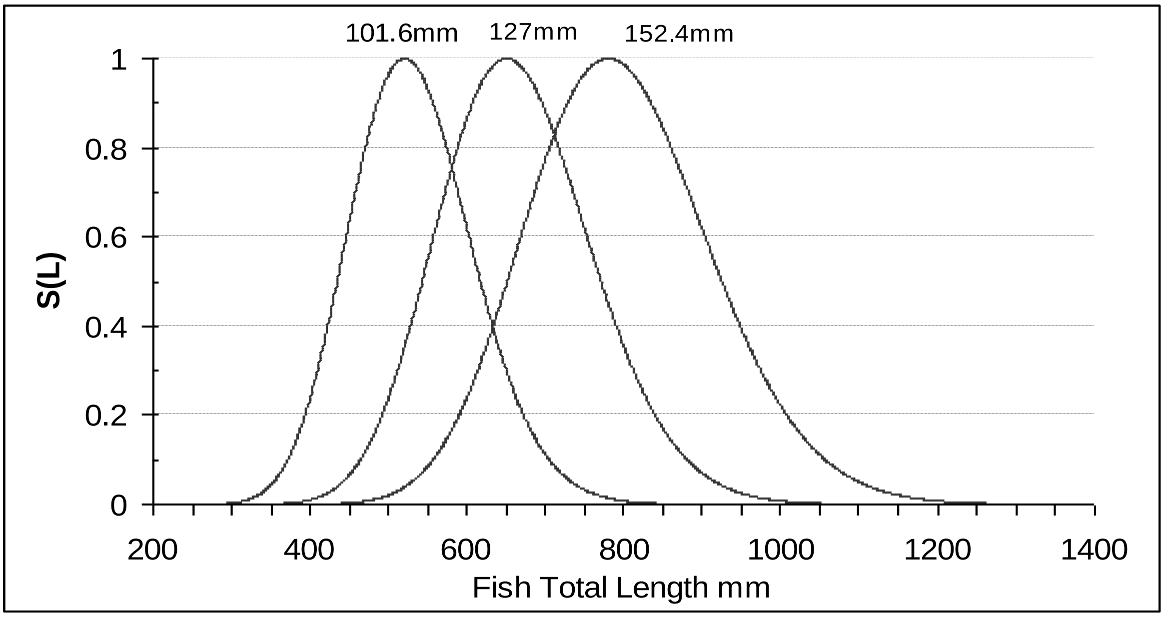


Figure 3 Normal (proportional spread and fishing power proportional to mesh size) selection curve fitted to east coat barramundi research catch data (2000-2006) from five mesh sizes

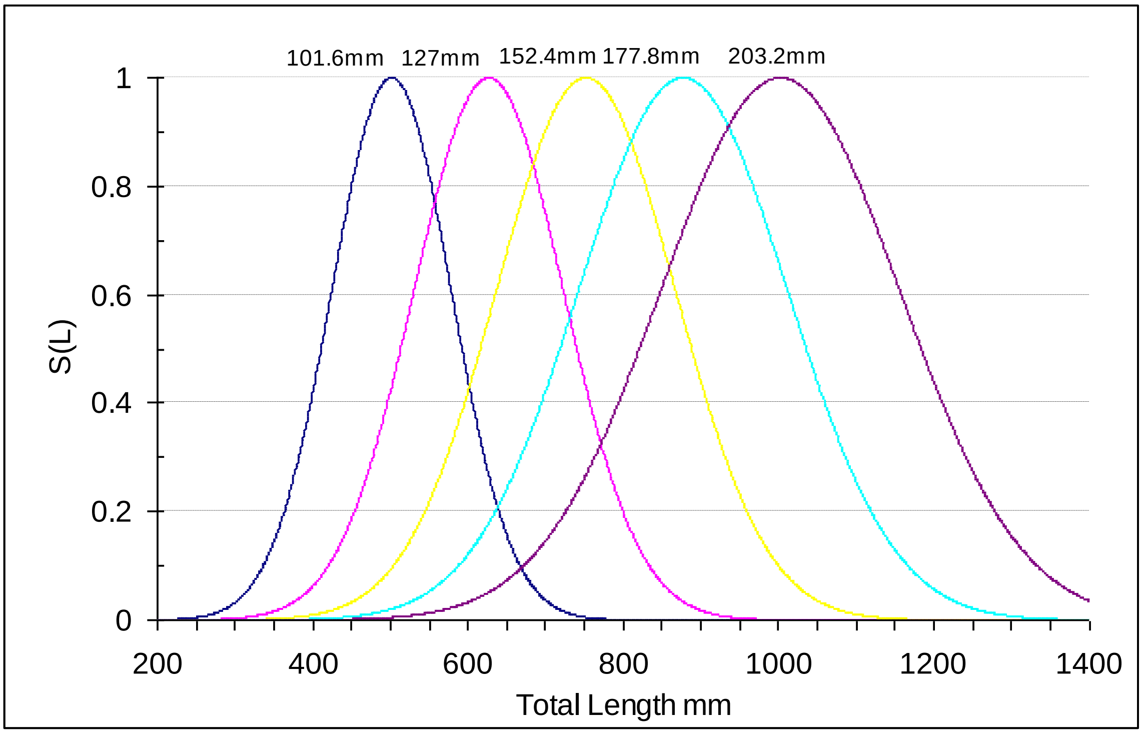


Table 7 Barramundi catch data by size class and mesh size from research netting surveys east coast of Queensland,1981-1984.

	Mesh Size (mm)							Total
	101.6	114.3	127	152.4	165.1	177.8	203.2	
No. of Sample	41	28	46	87	11	152	16	381
Size Class (mm)								
350	1							1
400	19	9	1			1		30
450	27	33	5	3				68
500	19	32	14	2				67
550	9	12	17	5				43
600	3	4	15	17	2	2		43
650	3	4	6	35	2	6		56
700	3	1	4	33	7	17		65
750	1	1	3	30	4	31	1	71
800	2	1	1	15	7	39	4	69
850			1	18	2	51	3	75
900	2			15	5	63	9	94
950	1		2	5		47	18	73
1000				1		36	10	47
1050			1			11	9	21
1100					2	8	2	12
1150						5	3	8
1200						3		3
1250						1		1
Total	90	97	70	179	31	321	59	847
Effort (m hours)	109270	57064	120848	136974	27661	217538	33212	702567
Mean Length (mm)	485.9	476.8	573.6	703.9	769.8	859.1	944.2	721.9
Max Length (mm)	950	780	1020	970	1070	1220	1150	1220
Min Length (mm)	350	390	400	410	595	100	740	100
Std Dev	120.5	71.8	119.2	107.8	115.8	123.4	88.9	194.6

Figure 4 Barramundi size distribution from research netting surveys on the east coast of Queensland (1981-1984), standardised by effort for seven mesh sizes.

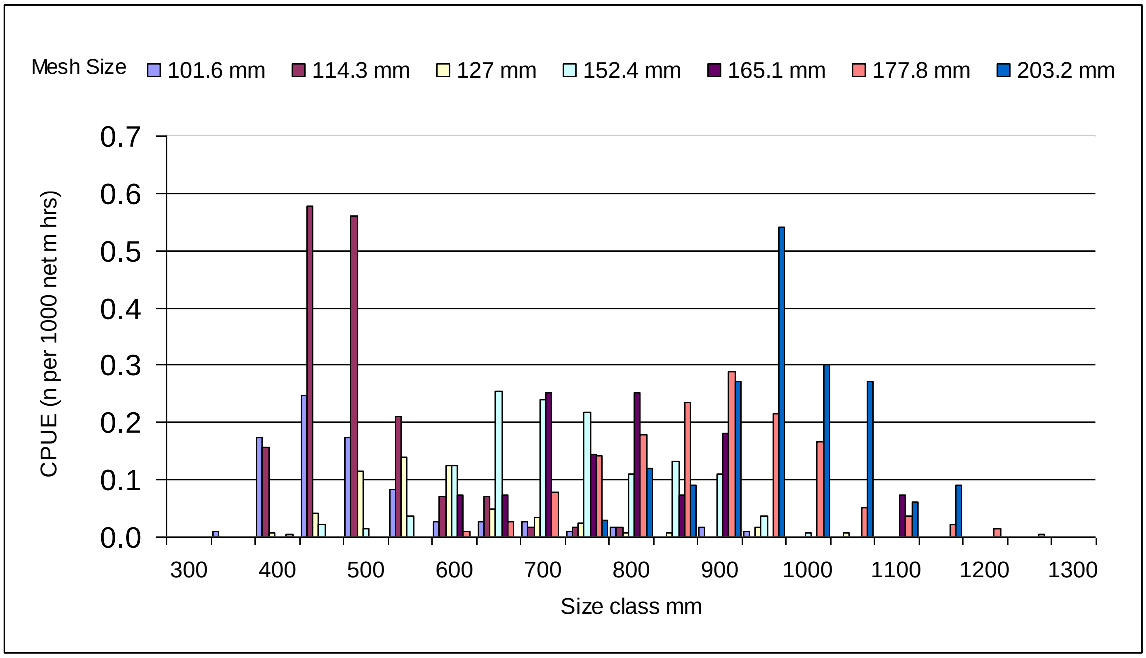


Table 8 Selectivity model parameters for east coast barramundi research catch data (1980-1984) from seven mesh sizes.

	Equal Fishing Power		Fishing power α mesh-size	
Model (56 DF 7 mesh sizes)	Parameters	Residual Deviance (AIC)	Parameters	Residual Deviance (AIC)
Normal				
Fixed Spread	k = 4.606 σ =125.7	939 (1334)	k = 4.755 σ =126.15	895.4 (1326)
Spread α m_j	k_1 = 4.73 k_2 =0.979	1177 (1607)	k_1 = 4.94 k_2 =0.935	1189 (1619)
Log Normal				
Spread α m_j	σ =0.19 μ_1=6.17	817.1 (1248)	σ=0.19 μ_1=6.21	817.1 (1248)
Gamma				
Spread α m_j	α=27.074 k=0.177	917.3 (1348)	α=28.074 k=0.177	917.3 (1348)

Table 9 Lognormal selection curve characteristics for east coast barramundi research catch data from 1981-1984 using seven mesh sizes

Mesh Size mm	Max(S(L)) mm	S 50% mm	D 50% mm
101.6	479	383	599
114.3	539	431	674
127	599	478	749
152.4	718	574	898
165.1	778	622	973
177.8	838	670	1048
203.2	958	766	1198

Table 10 Lognormal selection curve characteristics for east coast barramundi research catch data from 2000-2006 using five mesh sizes

Mesh Size mm	Max(S(L)) mm	S 50% mm	D50% mm
101.6	459	371	568
127	574	464	710
152.4	689	557	852
177.8	804	649	994
203.2	918	743	1136

Figure 5 Lognormal (spread proportional and fishing power proportional to mesh size) selection curve for barramundi research catch data (1981-1984).

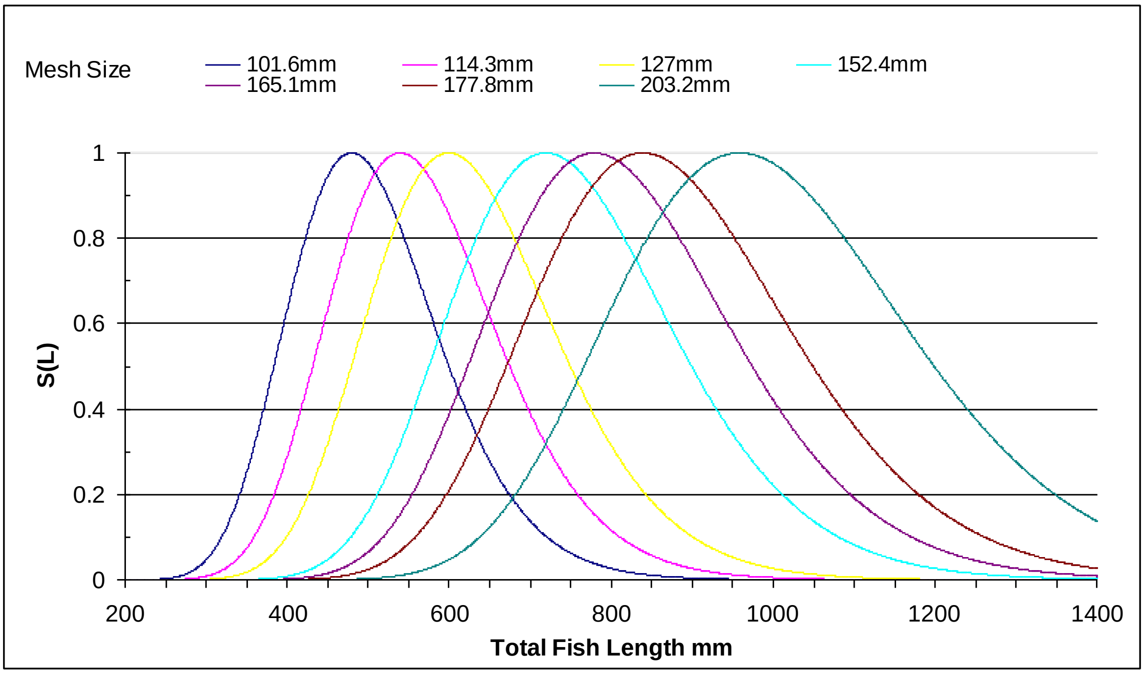


Figure 6 Lognormal (proportional spread and fishing power proportional to mesh size) selection curve for east coast barramundi research catch data (2000-2006).

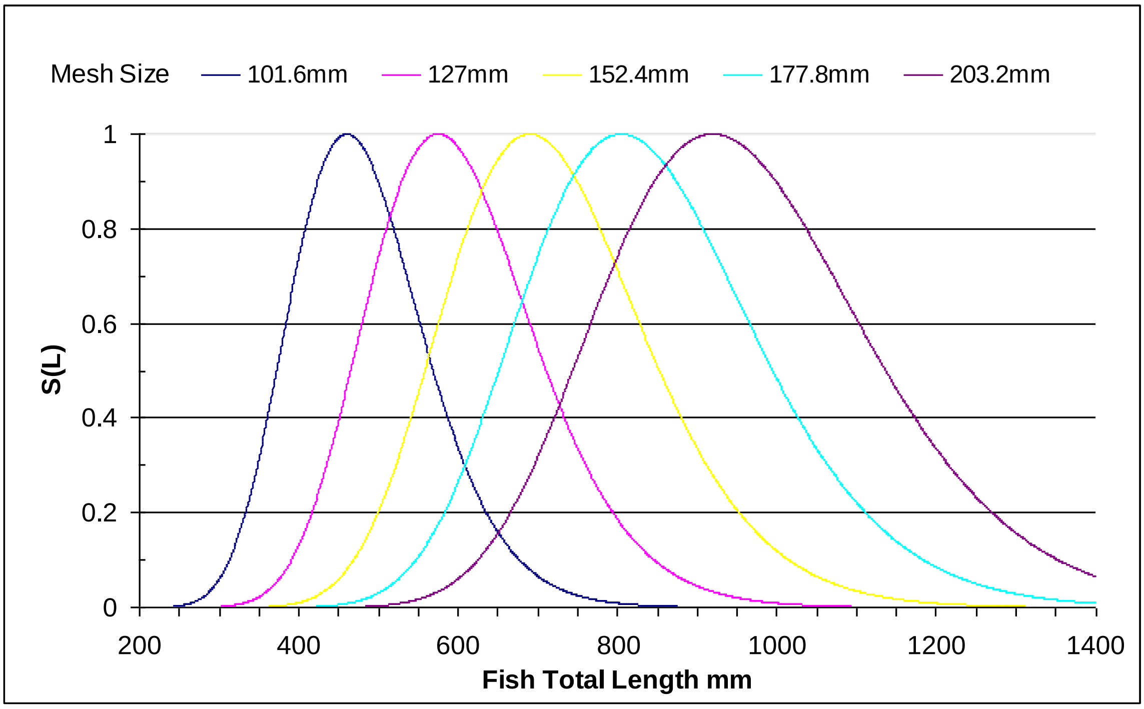
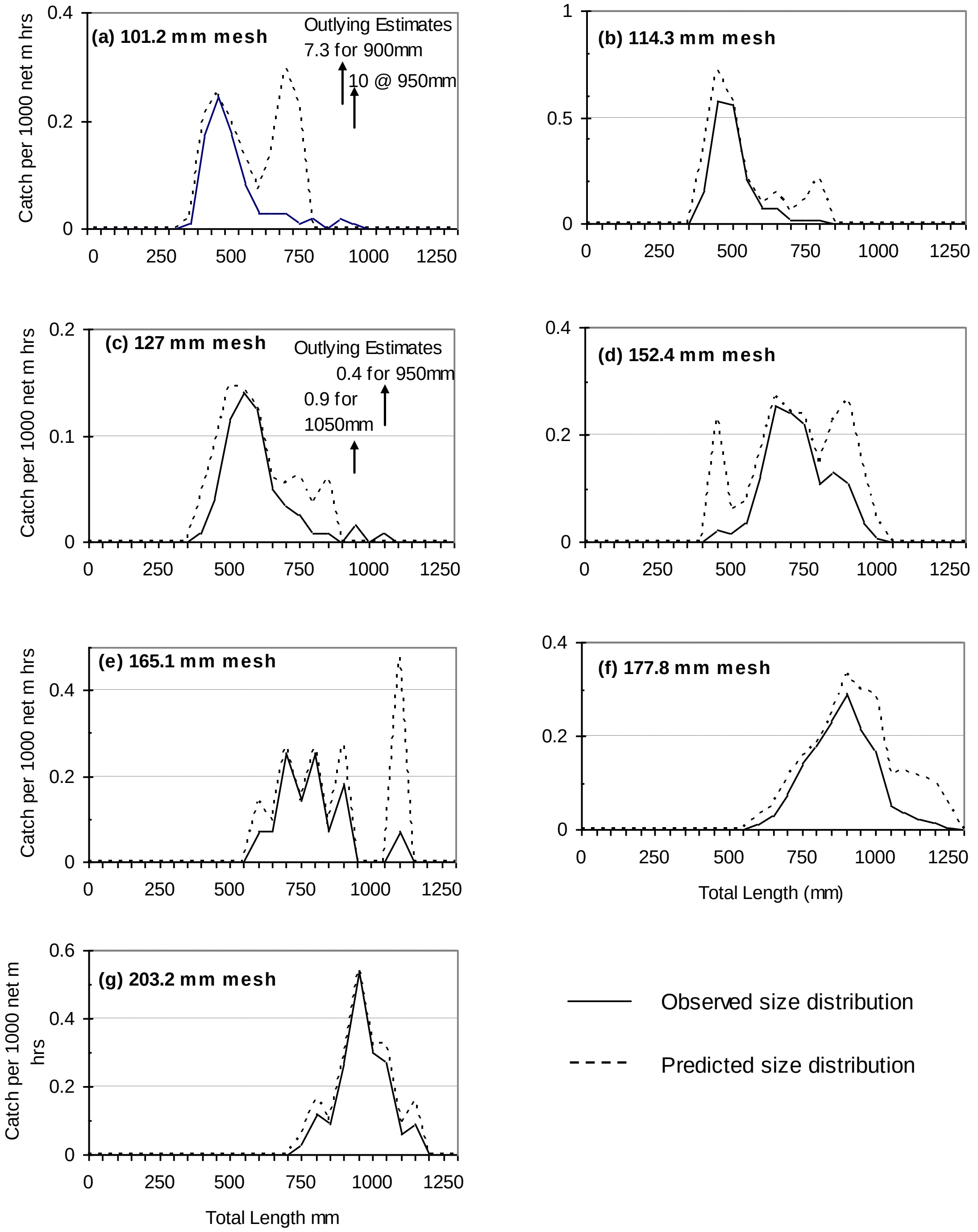


Table 11 Log catch ratio analysis results.

Selection Factors derived from natural log catch ratios following Sparre *et al.* (1989) for Barramundi from estuaries of North Queensland		
Ratio	Cb/Ca	Cc/Ca
Size Range (mm)	425-575	425-625
ma (mm) Small Mesh	101.6	101.6
mb (mm) Large Mesh	127	152.4
Intercept = a	-5.42	-2.23
X Variable =b	0.0013	0.0049
Lma	352	360
Lmb	440	541
S	80.2	54.12
Selection Factor	3.46	4.46

Figure 7 Observed and predicted barramundi length distributions for seven mesh sizes



Discussion

Reliable estimates of net selectivity are required for interpreting gillnet catch and effort data. The results presented in this report provide estimates of net selectivity for barramundi in the coastal waters of the Great Barrier Reef World Heritage Area (GBR WHA) on the east coast of Queensland for mesh sizes from 101 to 203 mm. These estimates represent the probability of retention once a fish has contacted the net or contact-selection as defined by Millar and Fryer (1999). Net contact-selection curves were previously estimated by Milton *et al.* (1998) for barramundi in the Fly River (Papua New Guinea) for mesh sizes from 67 to 101 mm. The contact-selection curve is useful for assessing the effect of mesh changes on yield, discard levels or fish escapement. However, a population selection curve (representing the probability a fish of a given length in the population is captured) is needed to be able to correctly adjust the catch length frequency for stock assessment particularly where there is partial recruitment to the fishery (Millar and Fryer 1999). Further investigation of the relationship between population selection curves and contact selection curves is required to ensure appropriate adjustment of catch length frequency distributions for stock assessment purposes.

Catch Ratio Analysis

The catch ratio analysis developed by Holt (1965) and described by Sparre *et al.* (1989) for calculating selectivity has been included in this report to enable a comparison with selectivity estimates reported by Gribble *et al.* (1999) who applied this method to obtain a selection curve for barramundi in the estuary of the Norman River (Gulf of Carpentaria). The optimal lengths at capture obtained from catch ratio analysis for east coast barramundi was substantially lower than reported by Gribble *et al.* (1999) for barramundi from the Norman River. For the 152.4 mm mesh size, the optimal length of capture for barramundi from east coast was 540 mm and this compared with an optimal length of 670 mm for barramundi from Norman River. For the 101.6 mm mesh size, the optimal length was 360 mm for barramundi from the east coast and 450 mm for barramundi from the Norman River. Possible explanations for different optimal capture lengths for the same mesh size include spatial variation in girth-length relationship, lack of smaller size classes in samples from the Norman River location due to limited range of habitats included in the surveys (i.e. juvenile habitats not included in the surveys), or higher than expected proportion of smaller size classes in the east coast samples due to entanglement (for example from bunching of net in shallow sites). However, Millar and Holst (1997) point out that the statistical properties of the selectivity estimates obtained from catch ratio analyses are largely unknown and do not provide an appropriate statistical model for gillnet catch data. The catch ratio analysis uses the selection ogives for two mesh sizes where these overlap and therefore includes a limited number of size classes. It has limited application in comparison to more rigorous selectivity analyses such as Kirkwood and Walker (1986) and Millar and Holst (1997) and was presented here to provide a comparison with the catch ratio analysis of barramundi catch data from the Norman River by Gribble *et al.* (1999).

Selection Curve Fitting

The results of the log linear modelling suggest that different selection curves provided the best fit for each of the three barramundi datasets (catch data from three mesh sizes from 2000-2006, catch data from five mesh sizes from 2000-2006, and catch data from seven mesh sizes from 1981-1984). A gamma selection curve provide the best fit to the east coast barramundi catch data from three mesh sizes from the 2000-2006 surveys. Analyses of 2000-2006 catch data from five mesh sizes indicated the normal selection curve provided the best fit. However, a lognormal selection curve provided the best fit to the barramundi catch data from 1981-1984.There was a large residual deviance in all analyses indicating either overdispersion or poor fit of the data. There was no difference in fit for modelling proportional fishing power to modelling equal fishing power across nets for both the gamma and lognormal curves. Milton *et al* (1998) analysed barramundi catch data from the Fly River (New Guinea) with samples from ten mesh sizes from 25 mm to 152 mm and reported that selectivity "approximated" a normal distribution for most mesh sizes although other distributions were not fitted to the data. Milton *et al.* (1998) reported that larger fish were over-represented in the catches from the 152 mm mesh and attributed this to an entanglement or rolling effect of larger fish in the 152mm mesh net. Milton *et al.* (1998) also reported the selectivity curve for the 127 mm mesh size underestimated the number of barramundi captured for this mesh size although the predicted and observed size frequencies were similar. The fit of different models to the same gillnet catch data has been identified by Millar (1995) and Millar and Holst (1997) as a limitation of indirect estimates of selectivity which otherwise provides a method to investigate net selectivity including issues of relative fishing powers, population length distributions and shape of selection curves. However, Kirkwood and Walker (1986) suggest that estimates of selectivities and fishing power should not be performed together without considerable confidence in the adopted selectivity function.

Optimal Size at Capture

There was only minor (< 5 mm) difference in the optimal lengths for capture obtained from gamma selection curves fitted to 2000-2006 catch data from three mesh sizes and from five mesh sizes (Table 4 and 5). The optimal length of capture was more strongly influenced by the choice of selection curve. The difference in optimum lengths at capture between the gamma selection curve and the normal selection curve ranged from 8 to 16 mm (Table 5 and 6). However, the difference in optimal length at capture between normal selection curve (2000-2006 catch data) and the lognormal selection curve (1981-1984 catch data) ranged between 22 mm and 42 mm over all mesh sizes (see Table 9 and 10) and potentially represents an important consideration for stock assessment. The results of this study provide a range of estimates for selectivity of commercial mesh sizes and these estimates are now available for use in barramundi production modelling. The sensitivity of production models to selectivity estimates remains to be tested. The optimal lengths of capture reported by Milton *et* *al.* (1998) (Table 2 in Milton *et al.* 1998) for barramundi in the Fly River (New Guinea) are considerably less (by between 120 and 160mm) than the optimal lengths of capture calculated for Queensland east coast barramundi catch data from 101, 127, and 152 mm mesh nets.

Patterns of Fishing Effort

Since not all the population will be available to all nets at any particular moment, investigation of selectivity should be based on surveys designed to sampling a large an area as possible over all habitats and depths where netting occurs. The data from 2000-2006 surveys used in this study was appropriately from a comparatively large area and a variety of barramundi habitats. However, in many locations commercial landings of barramundi are often highest and fishing effort most concentrated around the river mouths and adjacent foreshores at the start of the fishing season. For the remainder of the season, a reduced level of fishing effort is spread over a range of habitats including upper estuarine, middle estuarine, and lower estuarine reaches as well as foreshores and rocky headlands. Consequently, the fishery may be considered two phase:- firstly a high level of effort concentrated in a comparatively small area and secondly a phase where a reduced level of effort is spread over a large area and wide range of habitats. The variability of selectivity of the same net between seasons or habitats due to differences in distribution, behaviour or condition of fish has been suggested by Hamley (1975) and requires further investigation particularly in relation to net selection characteristics for barramundi at the time and location of peak fishing effort at the commencement of the barramundi netting season and during the remainder of the fishing season when lower levels of fishing effort are more widely applied.

Mesh Size

The mesh sizes used in the surveys were selected to sample as wide a range of barramundi size classes as practicably possible. The range of mesh sizes employed in the surveys overlapped with the range of mesh sizes employed in the east coast inshore net fishery. At the time of writing, minimum and maximum mesh sizes allowed for set mesh nets used to capture barramundi varied with location. On the east coast inshore set net fishery minimum mesh size were mostly 150mm while maximum mesh sizes were mainly 215 mm but with provision for a maximum mesh size of 245 mm in some offshore locations. Most operators in the east coast inshore net fishery use between 150 mm and 203 mm mesh nets when targeting barramundi. Mesh sizes between 162.5 mm and 245 mm are allowed in the inshore net fishery in the Gulf of Carpentaria. The normal selectivity curves obtained for the 152 mm mesh from the east coast catch data (2000-2006) indicate that at the minimum legal size of 580 mm 33% of fish (at this size) are retained (Figure 3). This increased to 53% for the lognormal selection curve obtained for the same mesh size from east coast barramundi catch data from 1981-1984 (Figure 5).

Net Construction

Hamley (1975) noted that various factors of net design in addition to mesh size may affect selectivity and these include visibility, filament gauge, and hanging ratio. A variety of hanging ratios are used in gillnets and Sparre *et al.* (1989) reports that fish are less likely to be entangled in nets with larger hanging ratios. The selection pattern for tangling as well as gilling and wedging is likely to differ from the selection pattern for gilling or wedging alone. A thorough assessment of selectivity would require an assessment of the selectivity patterns of the range of net construction types deployed in the barramundi fishery including the common filament sizes, hanging ratios, and mesh sizes as well as method of fishing.

Further Direction

The log-linear analyses provide estimates of selectivity for barramundi on the east coast of Queensland and these are available for use in the barramundi production model. The substitution of selectivity estimates in the barramundi model SHASSAM (Gribble pers. com. 2007) needs to be undertaken to assess the sensitivity of the model to selectivity estimates. The estimated optimal size for capture of barramundi in the 152 mm mesh net was higher than that used in the barramundi model and this may resolve some of the discrepancy between the observed and predicted age structure for the Queensland component of the barramundi production model.

Further investigations are required to fully assess the selectivity of the range of net construction types utilised in the Queensland barramundi net fishery. Reliable selectivity analyses requires catch data from carefully designed surveys to account for the variety of factors (in addition to mesh size) known to influence selectivity including hanging ratio, filament gauge and filament visibility (colour). Additional investigations would also be required to fully assess the fishing power as well as selectivity.

An understanding of the relationship between population selectivity and contact selectivity is required to allow appropriate adjustment of catch length distributions for stock assessment. This will require a better understanding of fish behaviour (Millar and Fryer 1999) in relation to gillnets.

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