pISSN 2671-9940
eISSN 2671-9924
J Korean Soc Fish Ocean Technol, 55(3), 181-189, 2019
http://dx.doi.org/10.3796/KSFOT.2019.55.3.181

KSFOT FISHERIES OCEAN TECHNOLOGY
www.fishtech.or.kr
⟨Original Article⟩

Analysis on the body size selectivity for multi-species of discarding juvenile fishes in the bottom trawl

Yonghae Kim*

Professor, Institute of Marine Industry, Department of Marine Production Technology, Graduate School, Gyeongsang National University, Tongyoung 65035, Korea

Discarding juvenile fishes under girth 16 cm nearly equal to inner perimeter of codend mesh size collected by a cover net method in bottom trawl. The body size of the main five species (mackerel, horse mackerel, sea bream, melon seed and black throat seaperch) was measured for their body length, girth, weight, height and width and analyzed size selectivity. Frequency of penetrating fish as retention in a cover net was less than 40% of total number of juvenile discarding fish. The most of body length or girth of five species were significantly different between in the codend and in the cover net. The 50% selection girth in the cover net ranged 8-11 cm were smaller than those in the codend ranged 9-13 cm by the species respectively. The 50% selection body length was significantly related with the ratio of body height (H) by body width (W) both for in the codend or in the cover net while 50% selection girth was not significantly related with H/W. Furthermore 50% selection fish size by fish species between in the codend and in the cover net was not significantly different both in body length or girth. Therefore, the girth selectivity represented possibly as one unique value regarding fish body shape was considered as more useful method for multi-species catch in trawl.

Keywords : Cover net, Discarding fishes, Multi-species, Body length and girth selectivity

Introduction

The optimum catch as body size selection or bycatch reduction in towed fishing gear was greatly controlled and managed for last several decades by many researches in aspect of fisheries management and resource maintenance (Sea Grant, 2014). The relevant methods for the bycatch reduction or size selection was a grid separating system as BRD (Bycatch Reduction Devices) or the square mesh window system respectively (Sala et al., 2015). Those methods was well known significant effects by fishing gear and fishing ground especially in western area while little effects were also reported by species or season (Cho et al., 2005; Beutel et al., 2008). However until now lawful regulation for bycatch reduction device or the codend size limitation was not fully adapted in Korea although there were several cases of bycatch ratio allowance. One of the main reason or difficulty for fish size selection is considered as multi-species catch in towed fishing gear of commercial fishery. The sizes of caught fish are varied by mainly two aspects of fish and mesh. Fish factor is body shape, swimming ability, penetrating behavior etc. by fish species. Mesh factor is considered as materials, twine diameters, mesh openings, mesh

*Corresponding author: yonghae@gnu.ac.kr, Tel: +82-55-772-9183, Fax: +82-55-772-9180

shape, towing speed etc. More effective modifications of fishing gear and new legislation will required for certain contribution to improved size selection and bycatch reduction for resource management in the future (Chopin and Suuronen, 2009).

The body length selectivity curve is considered as effective powerful method for evaluate to determine 50% caught selection body length according to several software tools developed (Miler and Fryer, 1999; O'Neill and Herrmann, 2007). However body length selectivity can be applied only for one species or similar body shape species under the assumption of normal distribution of body size in caught fishes. Furthermore penetrating factor for mesh opening as mesh circumference in water at towing state is more closely related to fish girth as like most of the other fishing gear. Fish girth was investigated in relation to body length for many species as to represent body shape (Mendes et al., 2006). There was a girth selectivity analysis in a bottom trawl (Özbilgin, 1998; Kim, 2015a) and a shrimp beam trawl (Kim, 2015b).

The purpose of this study is to compare body size of discarding smaller fishes between in the codend and in a cover net and also to find out inter-relationship of girth selectivity between species and body shape. The results of analysis on girth selectivity was also discussed on a representative body size as an unique indicator in case of multi-species catch and also suggest possible application in body size selectivity.

Materials and methods

The fishing gear was a regular six-panel bottom trawl with a total length of 58.7 m and headrope length of 45.2 m used in the training ship “Saebada” (999 G/T, 3000 HP) as previously reported from Kim (2015a). Linear dimensions in the fishing gear were as follows: normal warp length 500 m; otter pendant 13.8 m; hand rope 96 m; and net pendant 47 m. The otter board used was a super-V type that was 3.4 m high, 2.0 m wide, weighed 1,697 kg underwater, and had an attack angle of 24°.

The codend was made from double-panels of 90 mm diamond mesh made up from 5.7 mm thick polyethylene (PE); the codend was 140 meshes in length and 160 meshes in circumference. The codend rope was 12.3 m long (Kim, 2015a). The codend cover-net was made from PE (18 ply), and the mesh size was 43 mm as half of he codend mesh size considering not to collect very small fishes. The cover-net was 160 meshes long and 450 meshes in circumference. The total length was 5 m. It was attached at its front end of the codend with four floats (150 mm diameter). The circumference was 2 m wider and 1 m longer than the codend without using a hoop to reduce masking effect (Wileman et al., 1996; O’Neill and Kynoch, 1996; Mituhasi et al., 2000).

Fish data were collected by total 31 fishing trials from previously 28 fishing trials during the period Jun., 2014 to Aug., 2015 (as shown in Table 1 by Kim, 2015a) and additional 3 trials on 17, 18 and 22/08/2017 performed at the south of Gemoondo in South Sea.

Table 1. Number and the ratio of height by width of 5 discarding juvenile fish species in the codend and in a cover net

Item		Mackerel	Horse mackerel	Sea bream	Melon seed	Black throat	Total (%)
Numbers	Codend	225	1,638	332	354	349	2,898 (62.4)
	Cover net	41	1,127	80	138	358	1,744 (37.6)
	Total	266	2,765	412	492	707	4,642 (100)
Height/Width	Mean	1.45	1.80	2.79	3.72	3.01	-
	S.D	0.06	0.17	0.28	0.32	0.30	-

After each haul, the discarding fishes as smaller girth than 16 cm equal to an inner circumference of the codend mesh both in the codend or in the cover-net were sorted by main 5 species of majority caught and the others. The main 5 species were identified as mackerel (*Scombrus japonicus*), horse mackerel (*Trachurus japonicus*), sea bream (*Pagrus major*), melon seed (*Psenopsis anomala*) and black throat seaperch (*Doederleinia berycoides*). Number of measured 5 fish species in the codend and in a cover net was shown in Table 1.

The individual discarding fish were measured as total body lengths (from snout to the end of the caudal fin), body height and width by plastic scale and also maximum girth by fabric scale as the 1.0 mm unit respectively. The body weights were measured using a digital balance (0.01 g accuracy, EB-4000HU; Shimadzu, Otsu, Shiga, Japan). The frequency of fish sizes were tested as T-test for normal distribution by 10 mm interval. The F-test and Kolmo-Smirov non-parametric test were used to compare statistical significant differences between in the codend and in a cover net. 50% selection body length or girth was estimated under assumption of normal distribution in body size (Miler and Fryer, 1999; Carol and García-Berthou, 2007).

Results and Discussion

Frequency of penetrating juvenile fishes under girth 16 cm as retention in a cover net was less than 40% of total number of juvenile discarding fish in the codend and a cover net. The passing rate of juvenile fishes from codend by number of total undersized fish in this study seems to be more exact representation rather than by whole catch including marketable fish as weight unit. Passing rate of lees than half of total discarding might be affected by passive escaping behavior of juvenile fishes (Kim et al., 2008) and masking effect by bigger fishes caught (O'Neill and Kynoch, 1996; Jones et al., 2008). The escaping ratio of juvenile fishes from the codend of a bottom trawl was varied by species, season or fishing region (MacLennan, 1992; Wardle, 1993; Chopin and Suuronen, 2009).

The relationship between total body length (BL, cm) and girth (GR, cm) or between body length and the body weight (W, g) by in the codend and in a cover net were

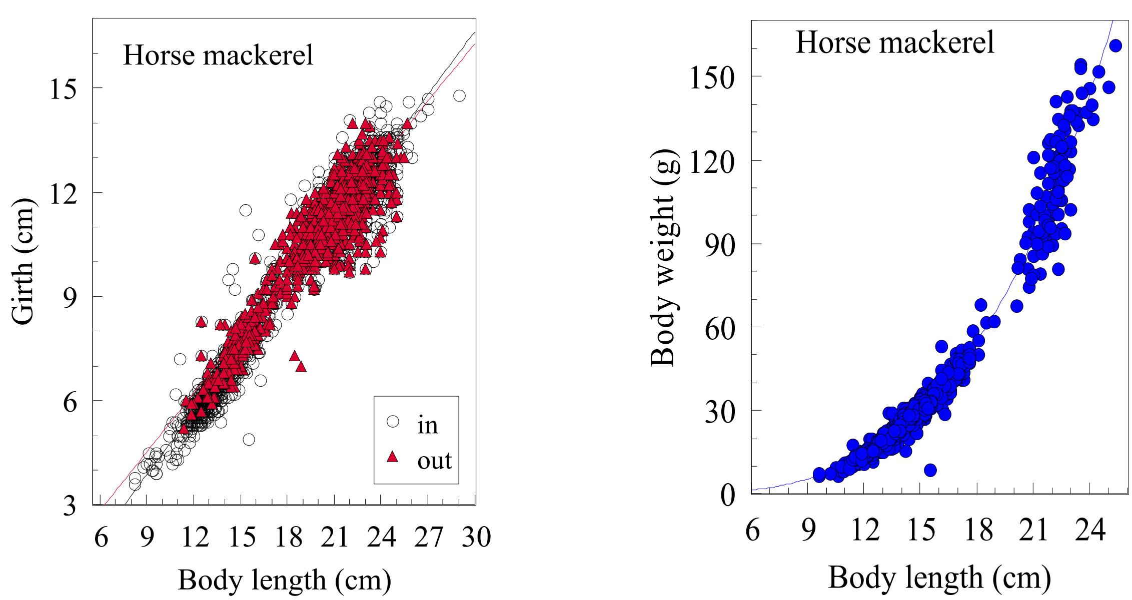


Fig. 1. The relationship between total body length and girth (left), and between body length and the body weight (right) for horse mackerel caught in the codend and out of the codend in a cover net respectively.

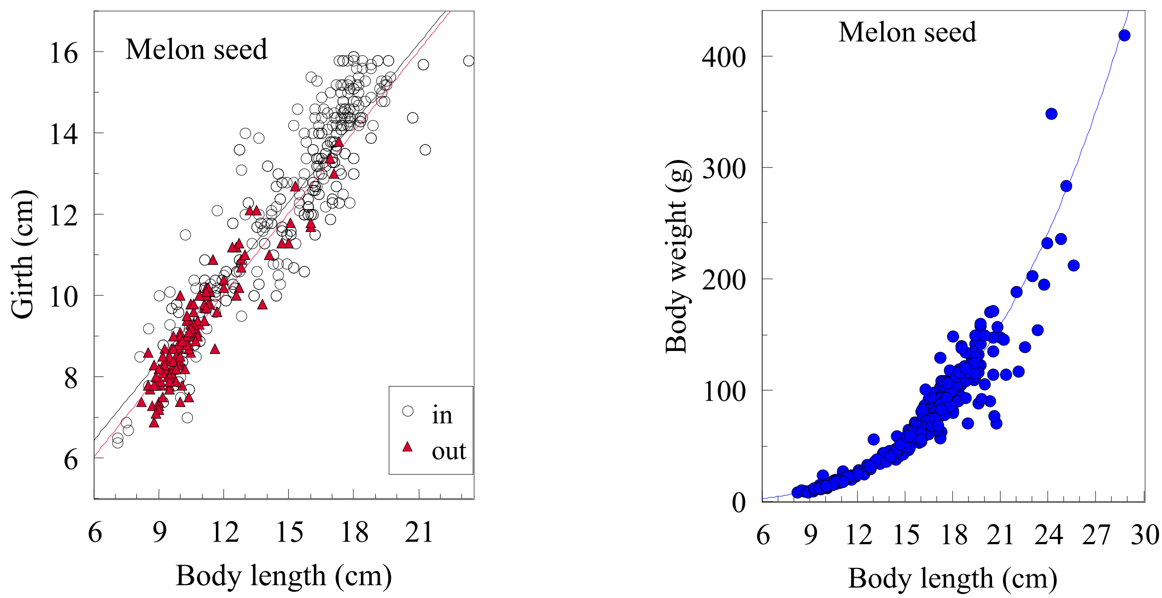


Fig. 2. The relationship between total body length and girth (left), and between body length and the body weight (right) for melon seed caught in the codend and out of the codend in a cover net respectively.

Table 2. Coefficients of fish size in eq. (1) and eq. (2)

Species	Size	Coefficient		n	r^2
		a or c	b or d		
Horse mackerel	GR (in)	0.607	-1.60	1,638	0.942
	GR (out)	0.560	-0.52	1,127	0.858
	W	0.0034	3.45	887	0.975
Mackerel	GR (in)	0.496	-1.12	225	0.846
	GR (out)	0.481	-1.27	41	0.827
	W	0.0063	3.07	267	0.962
Sea bream	GR (in)	0.813	0.85	310	0.757
	GR (out)	1.040	-2.42	80	0.902
	W	0.0111	3.21	201	0.975
Melon seed	GR (in)	0.675	2.29	271	0.832
	GR (out)	0.681	1.87	138	0.847
	W	0.0107	3.15	369	0.966
Black throat	GR (in)	0.622	0.42	168	0.838
	GR (out)	0.506	-1.79	189	0.827
	W	0.0300	2.69	282	0.950

shown in Fig. 1 and 2 for mackerel and melon seed respectively as examples. Linear relationship was expressed as following equations (1 and 2) and their coefficients for 5 fishes were represented in Table 2.

$$GR = a\,BL + b \quad (1)$$

$$W = c\,BL^{d} \quad (2)$$

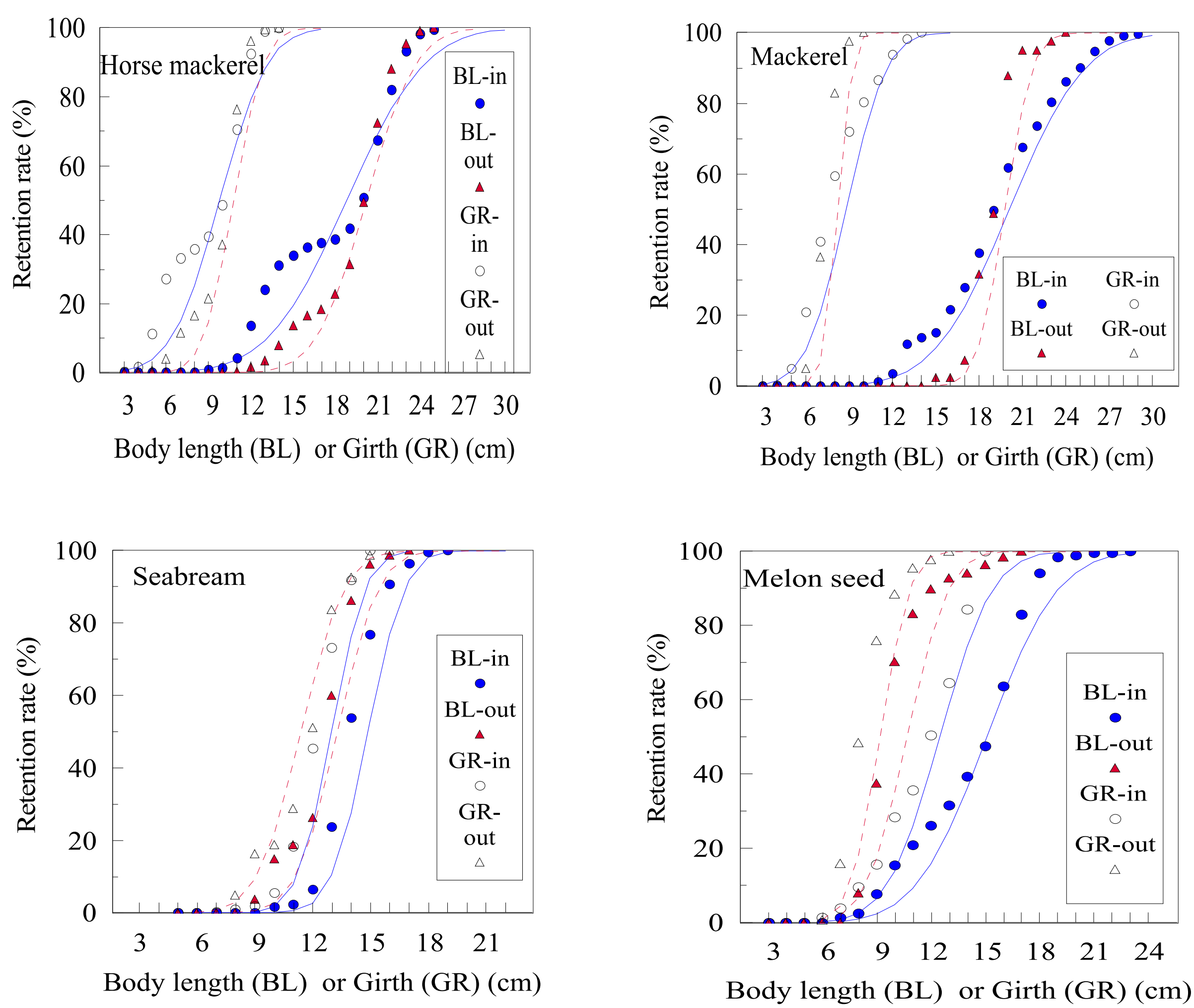
The coefficient a in eq.1 was smaller in fusiform fishes than in compressiform fishes similar with girth comparison (Stergiou and Karpouzi, 2003; Mendes et al., 2006; Jawad et al., 2009). In addition fish girth has strongly related on feeding type or swimming morphology with relative condition factor such as fatness and stomach fullness etc (Santos et al., 2006; Daliri et al., 2012).

The cumulative frequency distribution of body length and girth, and selection curve in the codend or in a cover net were shown in Fig. 3 for 5 species.

The mean±S.D of 50% selection size for discarding 5 fish species caught in the codend and in cover net, and their normal distribution test were shown in Table 3. The most of 15 cases in body length and in girth in the codend or in a cover net were normal distribution except 5 cases as a abnormal distribution. These abnormal cases might be come from uneven population in fishing ground, lack of sampling fish number or cover net effect etc. The most of body length or girth between in the codend and in a cover net by F-test and Kolmo-Smirov non-parametric test were significantly different. The 50% selection girths in a cover net ranged 8-11 cm were smaller than those in the codend ranged 9-13 cm by the species respectively.

The body length or the girth distribution and caught rate by fish size for whole 5 species by in the codend and a cover net were represented in Fig. 4. The peak frequency of body length or girth in a cover net was a little greater than those in the codend although their frequency distributions were similar.

By the selection curves of normal distribution from Fig. 3, 50% selection body length or 50% selection girth for in the codend or in a cover net were plotted by the ratio of height by width in Table 1 as shown in Fig. 5. Linear relationship between the ratio of body height (H; cm) by body width (W; cm) and 50% selection body



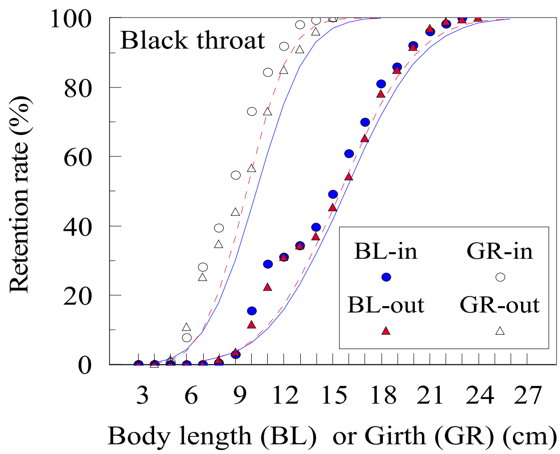


Fig. 3. The cumulative frequency distribution of body length and girth, and selection curve in the codend or out of the codend in a cover net for 5 species.

The mean 50% selection fish size and the coefficients in eq. (3) for 5 species were represented in Table 4. As a result 50% selection body length was significantly related with the ratio of body height by body width (H/W) both for in the codend or in a cover net while 50% selection body length was not significantly related with H/W. Furthermore pair T-test for 50% selection fish size by fish species between in the codend and in a cover net was not significantly different both in body length or girth (n=5, p>0.1).

In ideal fishing for reduction of juvenile catch in trawl a smaller girth of fishes less than inner mesh circumference must be penetrated from the codend mesh.

Table 3. The mean±S.D of body length (BL) and Girth (GR) by fish species and their normal distribution, and statistical comparison between in the codend (in) and in cover net (out) respectively

Species	Size	Mean±S.D (cm)	DistributionT-test	Test value and probability (in:out)	
				F-value (p)	Kolmo-Smirov (p)
Horse mackerel	BL (in) BL (out)	18.8±4.4 20.2±2.8	Normal Abnormal	86.5 (<0.0001)	11.2 (<0.0044)
	GR (in) GR (out)	9.8±2.7 10.8±1.7	Normal Normal	109.8 (<0.0001)	10.9 (<0.0044)
Mackerel	BL (in) BL (out)	20.1±4.1 19.8±1.5	Normal Normal	0.2 (>0.6300)	15.2 (<0.0016)
	GR (in) GR (out)	8.8±2.2 8.2±0.8	Abnormal Normal	3.0 (>0.0860)	19.9 (<0.0015)
Sea bream	BL (in) BL (out)	14.9±1.5 13.3±1.7	Normal Normal	63.5 (<0.0001)	26.3 (<0.0001)
	GR (in) GR (out)	13.0±1.4 11.4±1.8	Abnormal Normal	71.9 (<0.0001)	29.3 (<0.0001)
Melon seed	BL (in) BL (out)	15.1±3.1 10.7±1.8	Normal Normal	230.1 (<0.0001)	81.0 (<0.0001)
	GR (in) GR (out)	12.5±2.3 9.2±1.3	Abnormal Normal	239.0 (<0.0001)	72.4 (<0.0001)
Black throat	BL (in) BL (out)	15.8±3.8 15.5±3.7	Normal Normal	1.1 (>0.2980)	0.9 (>0.6478)
	GR (in) GR (out)	10.3±2.5 9.7±2.1	Abnormal Normal	11.3 (<0.0008)	5.4 (>0.0665)

length (SL; cm) or 50% selection girth (SG; cm) can be expressed as following equation.

$$SL \text{ or } SG = p\,(H/W) + q \qquad (3)$$

The penetrating ratio of juvenile fishes from the codend in this study was less than half of whole juvenile fishes. This ratio of escaping ratio could be varied by species, season, region etc. (MacLennan, 1992; Mituhasi et al., 2000; Pol et al., 2016) The several trials for increasing

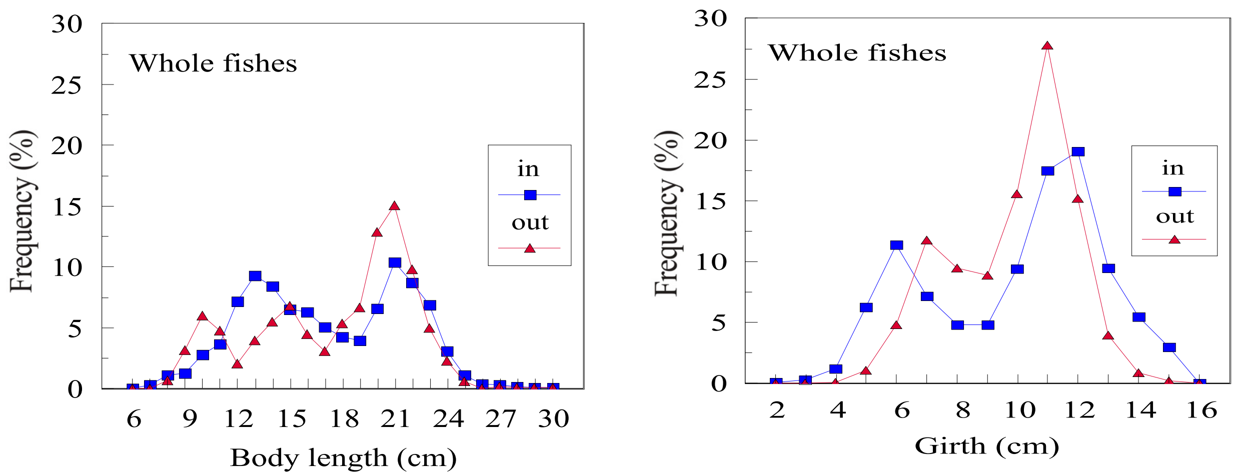


Fig. 4. The body length (left) and the girth distribution (right) for whole 5 species by in the codend and in a cover net respectively.

Table 4. The mean 50% selection fish size and the coefficients in eq. (3) for n=5 species from Fig. 5

Size	Mean±S.D (cm)	Regression coefficient				p
		p	q	n	r^2	
SL50 (in)	16.9±2.4	-2.36	23.0	5	0.858	<0.01
SL50 (out)	15.9±4.1	4.24	26.7	5	0.903	<0.01
SG50 (in)	10.9±1.8	1.54	6.9	5	0.628	>0.05
SG50 (out)	9.9±1.3	0.19	9.4	5	0.020	>0.10

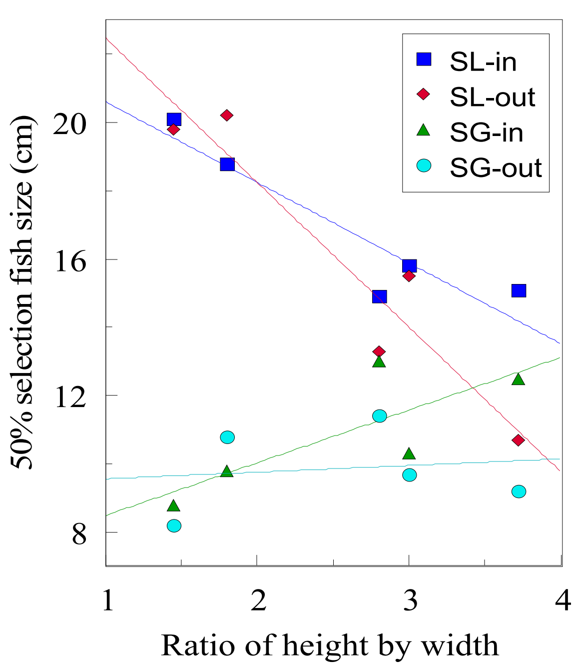


Fig. 5. The 50% selection body length (SL) or the 50% selection girth (SG) for in the codend or in a cover net plotted by the ratio of height (H) by width (W).

the penetrating ratio of juvenile fish from the codend were carried out by square mesh codend or the stimulating method as black tunnel (Glass and Wardle, 1995) or the shaking codend (Kim, 2015a).

Fish selection size could depend on the relationship between fish girth and mesh circumference as inner mesh size basically in gill net using thin flexible twine (Özbilgin, 1998; Özekinci, 2005; Sala et al, 2007) although outer appendage such as fin or spine could affect mesh penetrating. In contrast mesh selection in the codend of towed fishing gear was affected by passive escaping behavior and masking effect by amount of fish catch in exhaust state. Furthermore the thick twine and double panel of the codend in this study may have affected girth selection (Özbilgin and Tosunoğlu, 2003; Sala et al., 2007; Hermann et al., 2013).

Traditionally fish size for mesh selection in towed fishing gear was used by total body length as representative body size as defined in Korean fisheries law. However in case of many species caught by trawl, body length selection is very difficult to find out inter-relationship between species because body length is not directly related to mesh size rather than fish girth. Therefore this study was analyzed and compared fish size selection between body length and girth for 5 species with body form as height ratio by width. As a result 50% selection body length of 5 species was decreased with height ratio by width while 50% selection girth was nearly constant without linear relationship. Consequently girth selection method could be useful for multi-species catch like as gillnet selectivity (Carol and García-Berthou, 2007; Jawad et al., 2009).

The fish body shape used in this paper as 5 species was nearly fusiform and compressiform as the ratio of height by width length ranged from 1.5 to 3.7 in Table 1. The mean 50% selection girth of whole 5 species as 9.9±1.3 cm in a cover net was a little smaller than that in the cod end 10.9±1.8 cm similar to the results obtained in the bottom trawl (Kim, 2015a). It indicated also relatively low S.D ratio to mean girth as ranged 13 or 17% respectively. Therefore the girth selection method could be useful for multi-species trawl as analyzed in this study of 5 species for fusiform and compressiform as height ratio by width ranged from 1.5 to 3.7 as a whole.

50% body length was decreased with the ratio of height by width from Fig. 5 of in this study for discarding juvenile fishes in bottom trawl. In gill nets selection parameter as modal length was also decreased with the ratio of height by body length or the ratio of girth by body length (Mendes et al., 2006; Carol and García-Berthou, 2007). Selection body length by mesh size seems to be decreased from fusiform fishes to compressiform fishes. However direct comparison was difficult due to different of collecting fishes as limited under size of codend mesh perimeter in this study.

In conclusion about half of juvenile fish were caught in the codend of bottom trawl although there was a little difference of fish size distribution in body length or girth between codend and cover net. This methods of juvenile fish bycatch could be applied for another bycatch study to evaluate juvenile catch reduction. Furthermore the girth selection methods for multi-species can be also very useful for regulation of catchable size as a representative value for the other fishing gear caught many species.

Acknowledgements

Author thanks a skipper Mr. Lee N.W and crews of the training stern trawler “Saebada” of Gyeongsang National University for fishing experiments.

References

Beutel D, Skrobea L, Castroa K, Ruhle Sr P, Ruhle Jr. P, O’Gradyd J and Knight J. 2008. Bycatch reduction in the Northeast USA directed haddock bottom trawl fishery. Fish Res 94, 190-198. (DOI:10.1016/j.fishres.2008.08.008).

Carol J and García-Berthou E. 2007. Gillnet selectivity and its relationship with body shape for eight freshwater fish species. J Appl Ichthyol 23, 654-660. (DOI:10.1111/j.1439-0426.2007.00871.x).

Chopin F and Suuronen P. 2009. The development of international guidelines on bycatch management and reduction of discards. ICES CM 2009/M:01.

Cho SK, An HC, Shin JK, Yang YS and Park CD. 2005. Study on the development of trawl escapement device. J Korean Soc Fish Technol 41, 241-247. (DOI:10.3796/KSFT.2005.41.4.241).

Daliri M. Paighambari, SY. Shabani MJ, Pouladi M and Davoodi R. 2012. Length-weight and length-girth relationships, relative weight and relative condition factor of four Commercial fish species of northern Persian Gulf. Ann Rev & Res Biol 2, 15-26.

Glass CW and Wardle CS. 1995. Studies on the use of visual stimuli to control fish escape from codend. Ⅱ. The effect of a black tunnel on the reaction behaviour of fish in otter trawl codends. Fish Res 23, 165-174.

Herrmann B, Wienbeck H, Moderhak W, Stepputtis D and AhmKrag L. 2013. The influence of twine thickness, twine number and netting orientation on codend selectivity. Fish Res 145, 22-36. (DOI:10.1016/j.fishres.

2013.03.002).

Jawad LA, McKenzie A and Al-Noor SS. 2009. Relationship between opercular girth, maximum girth and total length of fishes caught in gillnets in the estuarine and lower river sections of Shatt al-Arab River (Basrah Province, Iraq). J Appl Ichthyol 25, 470-473. (DOI:10.1111/j.1439-0426.2009.01254.x).

Jones EG, Summerbell K and O'Neill F. 2008. The influence of towing speed and fish density on the behaviour of haddock in a trawl cod-end. Fish Res 94, 166-174. (DOI:10.1016/j.fishres.2008.06.010).

Kim YH. 2015a. Bycatch reduction by experimental shaking codend attached with canvas in a bottom trawl. Fish Aquat Sci 18, 325-332. (DOI:10.5657/FAS.2015.0325).

Kim YH. 2015b. Analysis of body size selectivity of bycatch using the cover net method for a shrimp beam trawl. J Korean Soc Fsh Technol 51, 171-178. (DOI:10.3796/FSFT.2015.51.2.171).

Kim YH, Wardle CS and An YS. 2008. Herding and escaping responses of juvenile roundfish to square mesh window in a trawl cod end. Fish Sci 74, 1-7. (DOI:10.1111/j.1444-2906.2007.01490.x).

MacLennan D.N. 1992. Fishing gear selectivity: an overview. Fish Res 13, 201-204.

Mendes B, Fonseca P and Campos A. 2006. Relationships between opercula girth, maximum girth and total length of fish species caught in gillnet and trammel net selectivity surveys off the Portuguese coast. J Appl Icthyol 22, 209-213.

Miler RB and Fryer RJ. 1999. Estimating the size-selection curves of towed gears, traps, nets and hooks. Rev Fish Biol Fish 9, 89-116.

Mituhasi T, Tokai T, Ercoli R, Garcia JC, Salvini L, Bartozzetti J and Roth R. 2000. Estimating codend selectivity and fish escapement from a cover net of an insufficiently small mesh size. Fish Sci 66, 327-333.

O'Neill FG and Herrmann B. 2007. PRESEMO-a predictive model of codend selectivity - a tool for fishery managers. ICES J Mar Sci 64, 1558-1568. (DOI:10.1093/icesjms/fsm101).

O'Neill FG and Kynoch RJ. 1996. The effect of cover mesh size and cod-end catch size on cod-end selectivity. Fish Res 28, 291-303.

Özekinci U. 2005. Determination of the Selectivity of Monofilament Gillnets Used for Catching the Annular Sea Bream (*Diplodus annularis* L., 1758) by Length-Girth Relationships in İzmir Bay (Aegean Sea). Turk J Vet Anim Sci 29, 375-380.

Özbilgin H. 1998. The seasonal variation of trawl cod-end selectivity and the role of learning in mesh penetration behaviour of fish. PhD thesis, University of Aberdeen, Scotland, UK. 206.

Özbilgin H and Tosunoğlu Z. 2003. Comparison of the selectivities of double and single codends. Fish Res 63, 143-147. (DOI:10.1016/S0165-7836(03)00005-5).

Pol MV, Herrmann B, Rillahan C and He P. 2016. Selectivity and retention of pollock *Pollachius virens* in a Gulf of Maine trawl fishery. Fish Res 184, 47-53. (DOI:10.1016/j.fishres.2015.07.029).

Sala A, Lucchettia A, Perdichizzi A, Herrmann B and Rinelli P. 2015. Is square-mesh better selective than larger mesh? A perspective on the management for Mediterranean trawl fisheries Fisheries Research 161, 182-190. (DOI:10.1016/j.fishres.2014.07.011).

Sala A, Lucchetti A and Buglioni G. 2007. The influence of twine thickness on the ize selectivity of polyamide codends in a Mediterranean bottom trawl. Fish Res 83, 192-203. (DOI:10.1016/j.fishres.2006.09.013).

Santos MN, Canas A, Lino PG, Monteiro CC. 2006. Length-girth relationships for 30 marine fish species. Fish Res 78, 368-373. (DOI:10.1016/j.fishres.2006.01.008).

Sea Grant. 2014. Fisheries Bycatch- Global issues and creative solutions. 29th Lowell Program and Abstracts, pp.106.

Stergiou KI and Karpouzi VS. 2003. Length-girth relationships for several marine fishes. Fish Res 60, 161−168. (DOI:10.1016/S0165-7836(02)00077-2).

Wardle CS. 1993. Fish behaviour and fishing gear. In: Behaviour of Teleost Fishes. 2nd Ed., Pitcher T.J. ed. Chapman & Hall, London, UK, 609-644.

Wileman DA, Ferro RST, Fonteyne R and Millar RB. 1996. Manual of methods of measuring the selectivity of towed fishing gears. Copenhagen, ICES Coop Res Rep 215, 126.

2019. 07. 05 Received
2019. 08. 09 Revised
2019. 08. 13 Accepted