Scup Bycatch Reduction in *Loligo* Squid Fishery

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Final Report

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II. Executive Summary

Gear modifications to reduce scup bycatch in the *Loligo* squid fishery in Nantucket Sound have been the focus of joint research efforts by the Massachusetts Division of Marine Fisheries (DMF) and the Manomet Center for Conservation Sciences (MCCS) since 1996. Effective trawl net modifications have been developed to reduce bycatch of scup except when large schools of scup enter the gear. To combat this problem, two extension modifications were developed and tested on two commercial vessels and show potential for reducing scup bycatch when large schools are encountered. During 14 days of field testing in June-July and October 2001, scup catches averaged 223-475 lb/tow. The vee and ring excluders removed scup at mean rates ranging from 87-100% with no clear difference in performance between the two modifications. However, small (less than10 cm FL) scup were not excluded.

Squid reduction rates ranged from 7-69% with the vee excluder tending to remove more squid. In general, squid reduction rates were higher and more variable than desired, but excluded squid were mostly small and unmarketable, and at low densities.

Underwater footage demonstrated that scup used fisheyes to escape the excluder and appeared unharmed.

Excluders were practical and easy to deploy. Further testing is needed and is planned to determine the effect of excluders on larger squid and on very large schools of scup.

III. Purpose of Project

DMF's Conservation Engineering Program and the Marine Division of MCCS have investigated bycatch of *Stenotomus chrysops* scup in the Northeastern US fisheries (Kennelly 1999) and in the Nantucket Sound *Loligo pealeii* squid fishery (McKiernan and Pierce 1995). Starting in 1996 and following the recommendation of McKiernan and Pierce (1995), scup bycatch was quantified and research was conducted on reduction of scup bycatch through gear modifications. Overall bycatch rates of 26% and scup discard rates of 6% were measured for the Nantucket Sound squid fishery (Glass et al. 1999).

Gear modifications were designed following methods developed by Wardle (1987), who studied the behavior of species reacting to fishing gear and modified gear to exploit differences in reaction between species. Differences between scup and squid were observed using underwater cameras. Squid rose in the mouth of a trawl net as they tired and scup appeared to stay lower (Glass et al. 1999). This difference in behavior was examined with a trawl net with a horizontal separator panel. Initial trials in 1997 with a separator were highly effective in separating squid into the upper codend, away from all other bycatch (Glass et al. 1999).

DMF employed similar separator trawls to study flatfish bycatch in the small-mesh whiting *Merluccius bilinearis* fishery centered on Provincetown, Massachusetts. Following effective sorting of flatfish into the bottom codend and whiting into the upper codend, a raised footrope trawl (RFT) was developed and demonstrated to be highly effective (McKiernan et al. 1998, Pol et al. in prep). The RFT replaces the usual footrope of a trawl net with a chain sweep rigged to be behind the leading edge of the net and to raise the mouth of the net approximately 1-2 feet off the bottom.

Similar success with a separator panel in the squid fishery suggested that the RFT might prove effective at reducing scup bycatch. Independently of DMF and MCCS research efforts, some fishermen who participated in both the whiting and squid fisheries began using the RFT. Sea sampling of these vessels demonstrated that the RFT produced “clean” squid catches.

Research by MCCS and DMF in 1999 and 2000 concentrated on quantifying reduction of scup bycatch using the RFT and other bycatch reduction devices including square-mesh bands in the extension, a square-mesh band followed by a dark tunnel, and a 4.5 in diamond mesh extension top (“Lovgren tunnel”) (Glass et al. 2001, Pol and Carr 2000, Pol 2001). Clear size-selectivity of scup was accomplished using a 5.5 in square mesh band in the extension, with no apparent loss of squid (Glass et al. 2001). Pol (2001) also found no loss of squid with a similar band, but with an anomalous loss of scup when the window was closed.

Nevertheless, large schools (> 5000 lb) appeared to overwhelm these gear modifications (Pol & Carr 2000). Reports by fishermen and observations by DMF seemed to indicate that the frequency and size of these schools was increasing (Pol 2001). These observations were consistent with reported strengths of 1997 and 1999 scup year classes (NEFSC 2000) and the behavior of scup (Bigelow and Schroeder 1953; NEFSC 2000).

The objective of this project was to design and test modifications to a trawl net extension to sharply reduce the bycatch of scup in squid fisheries even when large schools were encountered, with negligible losses of squid.

IV. Methods

Two trawl net modifications were developed following consultation among the principal investigators and with fishermen, including Capt. Luis Ribas (F/V *Blue Skies*) and Capt. Chris Brown (F/V *Grandville Davis*). These modifications were developed to exclude even large schools of scup. Both modifications were based on a grid or grate design, but were built to be flexible enough to wind on a net reel. Each modification consisted of a flexible obstruction in the extension flanked by fisheyes, openings on the sides of the net. Scup that entered the trawl net and encountered the obstruction could then actively or passively exit the net through the fisheyes without entering the codend.

One extension design (“vee excluder”) was built from a panel of 2.5 in[1] diamond (stretch mesh) netting sewn across the extension forming a vee pointed forward, like the prow of a ship (Figure 1). The fisheyes, 100 2.5 in meshes in circumference, were lateral to either side of the vee. The mesh of the panel was oriented horizontally so that the mesh opening was stretched longer on the horizontal axis.

The second extension design tested also used the fisheyes. Instead of a net panel, a flat grid constructed of 2.36 in ID plastic rings was placed in the extension just behind the fisheyes

[1] All mesh sizes are nominal inches.

(Figure 2). The plane of the grid was aligned perpendicular to the flow of water through the net.

Effectiveness of the two devices was determined using "pocket" codends that fit over the fisheyes. An extension with three codends was built (Figure 3) from 2.5 in green single polyethlyene (PE) diamond mesh. The codends were lined with 1.75 in black nylon diamond mesh, following standard commercial practice. No chaffing gear was used.

The extension and codends were attached to two different nets: an RFT with the chain sweep removed, known as a sweepless net (*Blue Skies*); and a standard squid net with a cookie sweep (*Grandville Davis*). The RFT (*Blue Skies*) consisted of a 60 ft headrope with 15 8 in headrope floats, and an 80 ft footrope with 42 in long dropper chains (2 each of 5/16 in) hung in the center and the corners, and every eight feet thereafter. The net body was constructed from 2.5 in diamond mesh green PE with a fishing circle of 654 meshes. Rectangular v-shaped 660 lb doors were rigged to 15 ft legs as ground gear.

The standard squid net (*Grandville Davis*) was also constructed of a 60 ft headrope (with approx. 30 8 in floats) and 80 ft footrope. The sweep consisted of 4-in rubber cookies. The net body was constructed of 4.75- in diamond twine with 356 meshes in the fishing circle. Doors were 550 lb, with 20 fm of ground cables and 15 fm legs.

The *Blue Skies* is a 65 ft wooden Eastern-rig trawler built in 1957 with a 364 hp Diesel main engine, homeported in Provincetown, MA and fished out of Hyannis, MA for this study. The *Grandville Davis* is a 54 ft wooden Western-rig stern trawler built in 1978 with a 350 hp Diesel main engine, homeported in Point Judith, RI and fished out of Menemesha, MA for this study.

DMF personnel collected set location, duration, and tow contents data for each of the three codends for every tow. Catches in the middle codend (organisms that passed through the excluders) were compared to the collective catch in the two side codends and any organisms trapped on the excluder itself.

Tows with less than 40 lb of scup or less than one pound of squid were not analyzed. Tow by tow exclusion rates were the sum of catches in the side codends and any catch stuck on the excluder, divided by total catch. Each tow was weighted equally when averages were calculated; that is, tows were not weighted by the volume of catch within that tow. Some length-frequencies were subsamples of total catch; these subsamples were extrapolated to full catch for each length category. Total counts represent these extrapolated estimates.

Scup were measured as fork length and squid as mantle lengths, both to the nearest whole centimeter.

Underwater cameras were deployed on several tows during both testing periods to verify that nets were configured properly, fish could enter pocket codends, and fish escaped through fisheyes on tows where pocket codends were removed. Several camera locations were used: inside the extension pointed aft at the excluder; inside the port codend looking aft; inside the extension pointed aft at the port side fisheye without the codend.

V. Results, Evaluation, and Conclusions

Summer 2001: Thirty-five tows were conducted in Nantucket Sound (inside 41° 20' North and 41° 35' N/70° 05' West - 70° 19' W) between 27 June and 7 July 2001 onboard the F/V *Blue Skies* (Table 1). The vee excluder removed an average 100% of the scup encountered during summer testing (Table 2). That is, no scup passed into the main codend when the vee excluder was used; all scup ended up in one of the two pocket codends. Catches of scup ranged from 0 to 1463 lb; 10 tows with < 40 lb of scup were excluded from analysis.

Similarly, the ring excluder removed an average of 99.5% of scup encountered. Catches ranged from 0 to 1430 lb; ten tows with <40 lb of scup were excluded from analysis.

The vee excluder showed an average loss of 53% of *Loligo* squid with a high variability from tow to tow. Catches ranged from 0 to 11 lb of squid; one tow with < 1 lb of squid was removed. The ring excluder averaged a 6.9% loss of squid into the side codends. Catches of squid with the ring excluder ranged from 0 to 7.7 lb of squid; eight tows with < 1 lb of squid were excluded from analysis.

Length-frequencies of scup and squid were analyzed for differences in performance. All scup were excluded using the vee (Figure 4); no scup passed through the vee excluder in these trials. The few scup that passed through the rings were smaller than those that did not. The excluded scup showed modes at 19 and 23-24 cm FL both for the vee excluder and the ring excluder; the scup that passed through the ring separator had a single mode of 18. The scup excluded by both modifications were similar in size, suggesting that the testing involved the same population of scup.

The size of squid that passed through both separators was approximately the same as those that did not (7-9 cm mantle length) (Figure 5). However, these data have little weight because catches of squid were so low (less than 4 lb/tow average) and were not further analyzed.

October 2001: Sixteen tows were completed by the F/V *Grandville Davis* between 10-16 October 2001 south of Cuttyhunk, Massachusetts (approx. 41° 20' N/70° 55' W) (Table 1). Compared to the summer trials, this testing resulted in slightly lower scup removal rates for the vee excluder (avg. = 86%); the ring excluder was approximately the same (avg.= 97%;) (Table 2). However, the effectiveness of the excluders when numbers of scup are considered is different. Nearly 3000 scup (of 9141 scup total) averaging 10.3 cm FL were caught in the main codend using the vee excluder during October testing; the excluded scup averaged 16.3 cm (range = 6-31 cm) and largely consisted of an age-class with a median of 20 cm (Figure 6). The ring excluder results were similar, although fewer scup made it through (1311 out of 7599). These fish averaged 9.5 cm vs. 19.3 cm for escapees. Again, the escapees included an age-class around 20 cm. The 9-10 cm FL scup that made it through the excluders are an apparent year-class that was not present during the summer testing.

Average squid catches in October were 900-1000% higher than in June-July. The vee excluder removed an average of 69% of squid; the ring excluder removed slightly less (avg.=58%) (Table 2).

The mean size of squid that passed through the excluders were slightly smaller than those that were excluded for both the vee (7.7 v. 8.9 cm) and the ring excluder (8.5 v. 9.0 cm), although this size difference is not relevant to markets. Length distributions were found to be different again for both the vee (KS=0.11; p=0.0; N=2653,3013) and ring excluder (KS=0.12; p=0.0; N=1100,1430). Visual analysis indicated that these differences were small (Figure 7).

Approximately 19 hours of underwater video were collected during all field testing. Scup were capable of holding station in front of the net for lengthy periods, although identifying individuals was not possible (Figure 8). Scup were seen swimming out of the fisheyes (and out of the net) with the pocket codends removed (Figure 9). Scup were seen swimming in, alongside, and out of the net for extended periods, ultimately escaping with little or no apparent physical impact. Squid were rarely observed to hold station, although some did (Figure 10). Squid appeared to be passive when entering camera view and mostly did not engage in directed behavior, appearing to flow along with currents. Other species such as smooth dogfish, black sea bass, and bluefish actively swam in and out of view (fore and aft in the extension). Skates and weakfish were also seen. Schools of small butterfish passed through the excluders into the codend.

Both excluders appeared to function well, excluding nearly all scup harmlessly. The ideal excluder would remove 100% of scup and no squid. Both excluders in the summer met or approached this ideal. The scup that passed into the main codend for the most part were very small as might be suggested by the designs. The catches of very small scup while excluding large scup suggests that the excluders will not be appropriate for use when very small scup are present. While using a smaller mesh might exclude these fish, our results indicate that squid are being excluded, too. We presume that use of smaller mesh or smaller rings will increase loss of squid by preventing their entry to the codend.

It is interesting to note that mean catches of scup in summer trials and in October were strikingly similar (vee: 223 lb v. 230 lb; ring: 472 lb v. 435 lb) suggesting that the nets were performing similarly, despite their differences in design.

Some of the scup that passed by excluders were surprisingly large (23-24 cm FL) with no apparent large openings in excluders. This length corresponds to heights of 3.1-3.5 in, much larger than the ID of the rings (2.38 in) or the mesh size of the vee (2.5 in) (Glass et al. 2001). To pass through the vee excluder requires a scup of this size to roll onto its side. Pacific cod approaching a grid have been observed to turn sideways and compress their heads through rigid bars during crowding (Rose 2001). No similar behavior has been recorded for scup, but clearly may be possible. Also, the relationship between scup height and length is not well documented and is under further study (Y. Doganyilmaz, MCCS, pers. comm.). It may be that some scup at 23 cm FL were less than the height of the openings in excluders.

The effect of the excluders on squid catches is inconclusive. While the losses of squid in general are not minimal, most of the squid encountered were at best marginally marketable, and the level of loss may be acceptable. Catch weights of squid were also at all times low, and often very low. Testing should occur when squid are of larger size (>12 cm) and at higher densities. One note of concern is that losses of squid are similar between excluders, and excluded squid are the same size or larger than squid that are retained. These data, coupled with the passivity of squid during filming, suggest that the losses are due to squid being carried along with water flow, and not due to direct action by squid. If true, these losses may not be easily preventable. It may be that larger squid will exhibit greater stamina and resist passing out of the fisheyes, and indeed a few individual squid were observed holding station during filming.

Excluders were demonstrated to be practical to construct and handle. Materials involved (webbing and plastic rings) were inexpensive and readily available. Crewmen were able to construct both excluders and test codends without difficulty. The flexibility of excluders allowed them to be easily rolled onto a net drum. Rigid grids and grates used in other fisheries have been criticized due to their impracticality, their expense, and the difficulty of handling during fishing.

Summary

Both excluders are practical and very efficient at excluding scup > 10 cm FL. Escaping scup appeared to be completely unharmed. When small scup are present, the excluders have little or no effect on their removal. The effect on squid has been unclear.

The inefficiencies of the designs at excluding scup < 10 cm could eliminate the need for further testing in areas where scup this size are present. In Nantucket Sound, further testing may be justified because small scup are not usually seen during squid season and the squid densities are higher, with larger squid (at least at the beginning of the season.) Also, scup densities in the Sound are growing, and the effectiveness of the excluders on schools with large numbers of scup, a primary motivation for their development, remains untested.

Further testing of these designs or modifications was planned for the spring and summer 2002, using funding provided by a quota set-aside from the Mid-Atlantic Fishery Management Council. Concerns over the uncertainty of this funding source have delayed implementation of this research.

Discarding of scup has the largest impact on stock rebuilding (NEFSC 2000). Attempts to limit this discarding with trip limits have resulted in unquantified regulatory discards that further impact stock rebuilding (Pierce 2001). These excluders can reduce regulatory discards by allowing larger scup to escape before being landed on deck.

The authors acknowledge contributions of Capt. Chris Brown and the crew of the *Grandville Davis* and Capt. Luis Ribas and the crew of the *Blue Skies*. Sea sampling was conducted by Mark Szymanski and Vincent Manfredi of DMF and Gregg Morris and Jean Nguyen of MCCS. Funding was provided by the National Marine Fisheries Service, through a Northeast Marine Fisheries Initiative (MARFIN) grant, number NA16FL1215. We are grateful for that support.

VI. Products

This report is Contribution #10 of the Mass. Division of Marine Fisheries technical report series. A redacted version is planned for publication in the DMF newsletter, distributed to thousands of households by mail and Internet. The raw video footage collected during this study is archived at DMF offices.

VII. References

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VIII. Key words: Scup; squid; excluder; fisheye; bycatch reduction; cooperative research

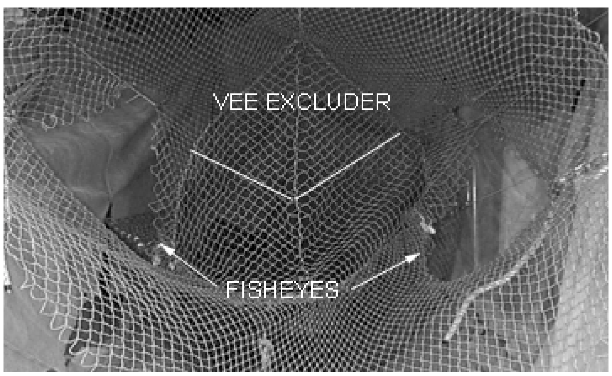


Figure 1: Looking aft at the vee excluder

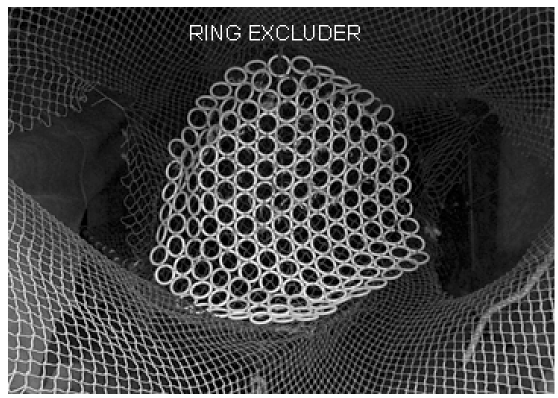


Figure 2: Looking aft at the ring excluder

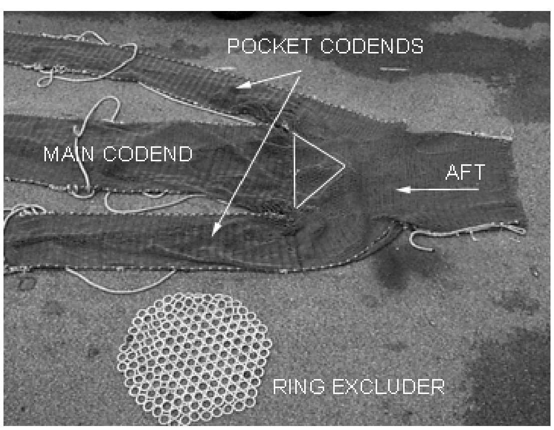


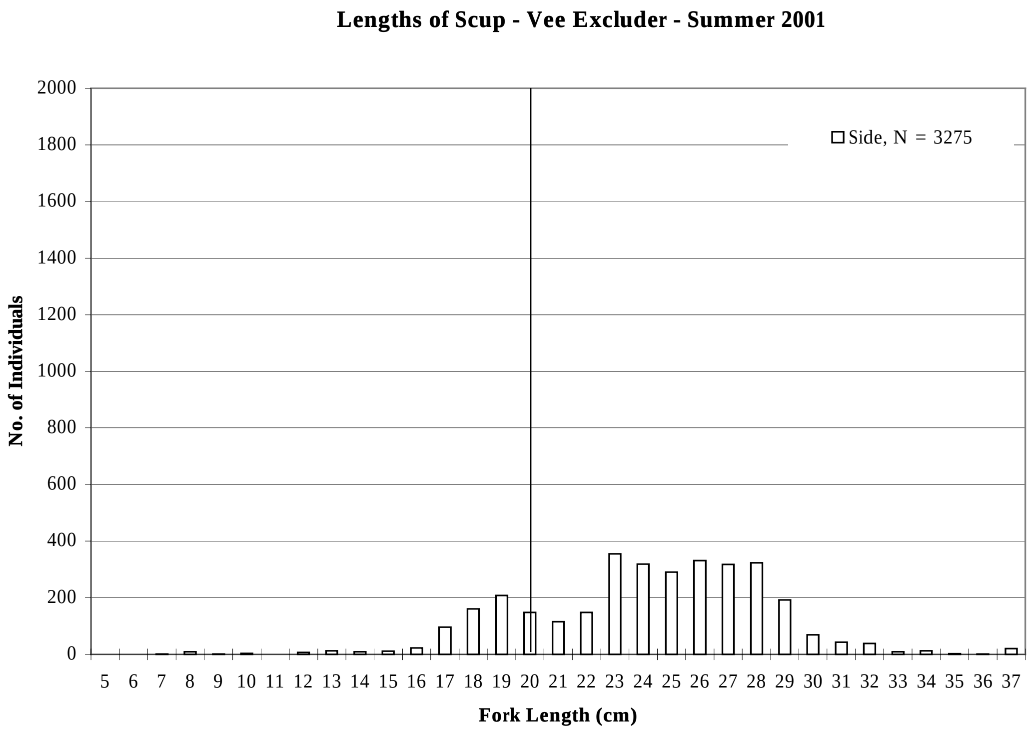
Figure 3: This piece replaces the codend on a squid net. The triangle marks the shape and location of the vee excluder. The ring excluder hangs vertically where the left side of the triangle is.

Table 1: Summary of field testing of scup excluders. Trip ID is a unique identifier for each sampling trip. Tow durations were not fixed because underwater cameras allowed towing until scup were seen in the net.

Vessel	Trip ID	Date	No. of Hauls	Device	Avg. Tow Dur. (h)	Avg. Depth (fm)
Blue Skies	SCX01	6/27/01	3	Vee	1:16	7
	SCX02	6/28/01	4	Vee	1:34	7
	SCX03	6/29/01	4	Vee	1:08	7
	SCX04	7/2/01	1	Vee	3:20	8
	SCX05	7/3/01	4	Ring	1:08	8
	SCX06	7/5/01	4	Ring	1:25	7
	SCX07	7/6/01	4	Ring	1:40	7
	SCX08	7/9/01	4	Ring	1:31	7
	SCX09	7/10/01	4	Vee	1:32	7
	SCX10	7/11/01	3	Vee	1:11	7
Grandville Davis	SCX11	10/10/01	2	Ring	0:48	15
	SCX12	10/11/01	4	Ring	0:35	16
	SCX13	10/12/01	6	Vee	0:24	17
	SCX14	10/16/01	5	Vee	0:44	17

Table 2: Mean catches and lengths for scup excluder trials. Results are separated into Summer and October 2001 testing, and by species. Lengths are fork for scup and mantle for squid. N for lengths are estimates of total numbers caught.

	Mean Catches (lb)								Lengths (cm)											
	Vee Excluder				Ring Excluder				Vee Excluder						Ring Excluder					
	N	**Avg**	**Range**		**N**	**Avg**	**Range**		**N**	**Avg**	**Range**		**Modes**		**N**	**Avg**	**Range**		**Modes**	
Summer 2001			Min	Max			Min	Max			Min	Max					Min	Max		
Scup																				
Main codend	15	0.00	0	0	6	2.42	0	7.7	0						65	17.4	5	20	18	
Side codends	15	222.93	30.8	1452	6	472.21	35.2	1427.8	3275	24.2	7	37	19	23	3719	24	11	36	19	24
% Removed	15	100%	100%	100%	6	99%	98%	100%												
Squid																				
Main codend	18	2.65	0.01	8.8	8	3.93	1.1	6.6	1025	6.53	2	15	6		426	9.04	2	21	9	
Side codends	18	2.76	0	6.6	8	0.37	0	2.21	575	8.45	2	18	7		70	8.79	4	16	6	14
% Removed	18	53%	0%	100%	8	7%	0%	29%												
October-2001																				
Scup																				
Main codend	10	25.08	4.4	70.4	6	9.09	3.3	18.7	2998	10.3	6	24	9	20	1311	9.49	6	23	9	
Side codends	8	229.75	63.8	1098.9	6	435.08	245.3	714	6143	16.3	6	31	9	20	6288	19.3	6	32	9	20
% Removed	8	86%	82%	96%	6	97%	93%	100%												
Squid																				
Main codend	10	13.88	7.7	28.6	6	11.47	9.84	17.2	2653	7.66	2	22	7		1100	8.45	4	17	9	
Side codends	8	29.82	9.9	45.1	6	17.55	5.52	28.6	3013	8.86	2	18	10		1430	8.96	4	18	9	
% Removed	8	69%	59%	77%	6	58%	36%	70%												



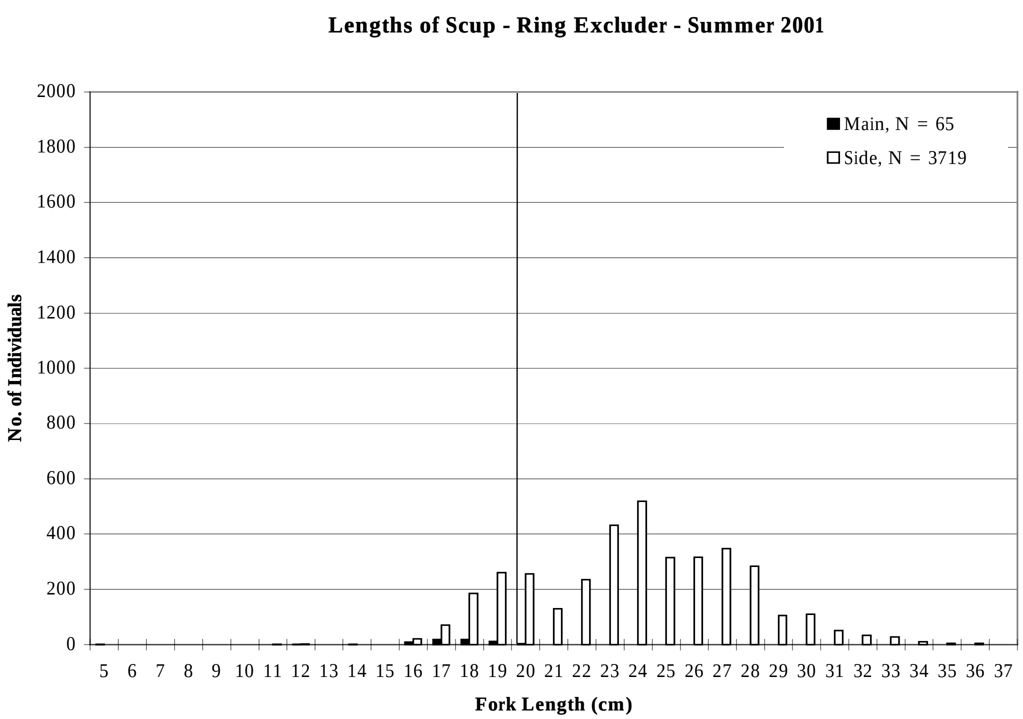
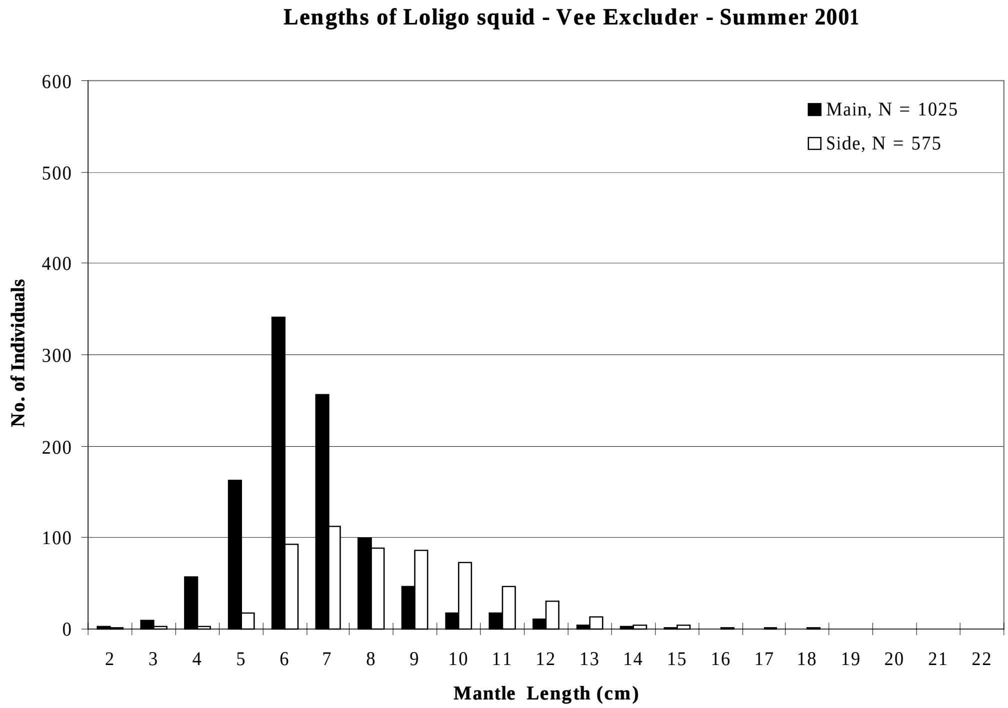


Figure 4: Fork length-frequencies of scup for vee (top) and ring excluders during Summer 2001 testing. Open bars represent scup caught in side codends; solid bars were caught in the main codend. Vertical line at 20 cm represents estimated minimum landing size, in fork length. Numbers are extrapolated from subsamples.



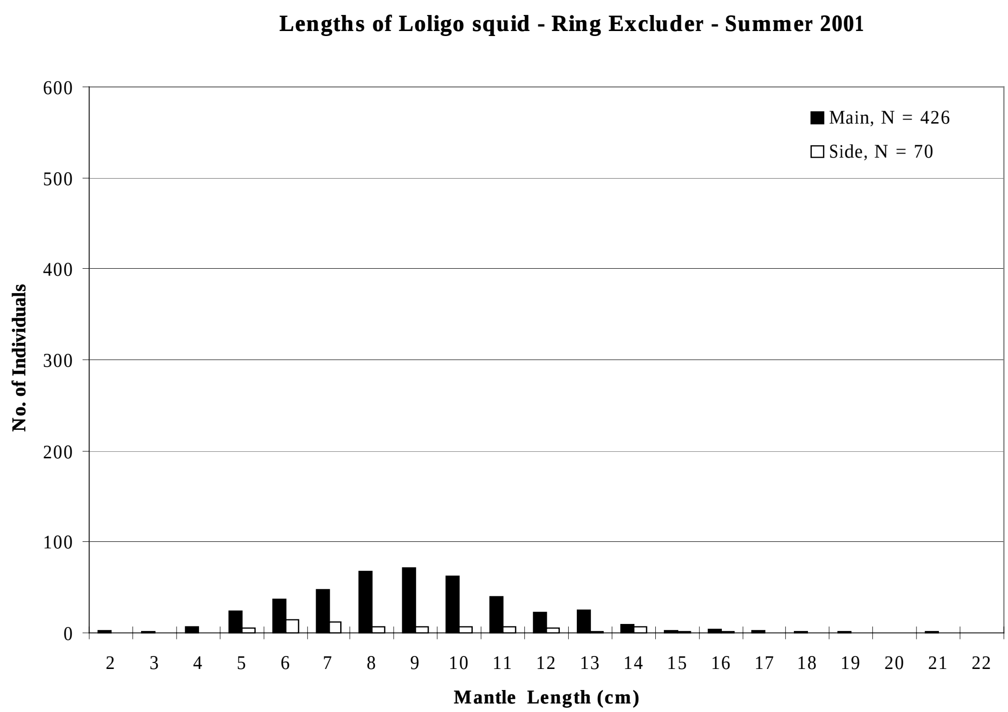
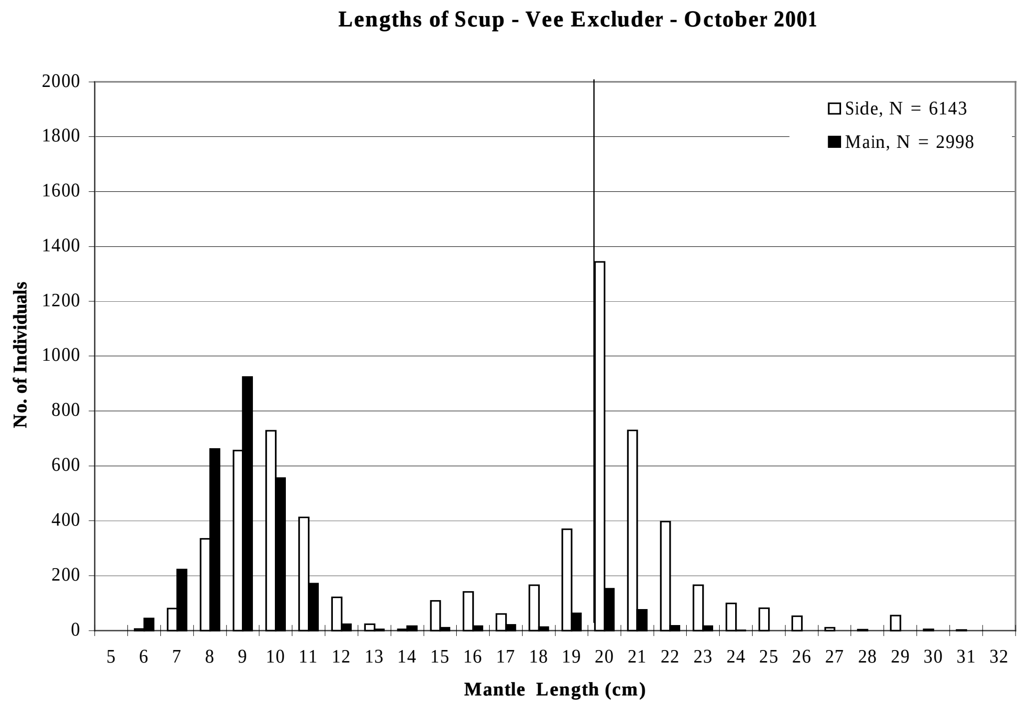


Figure 5: Mantle length-frequencies of *Loligo* squid for vee (top) and ring excluders during Summer 2001 testing. Open bars represent squid caught in side codends; solid bars were caught in the main codend. Numbers are extrapolated from subsamples.



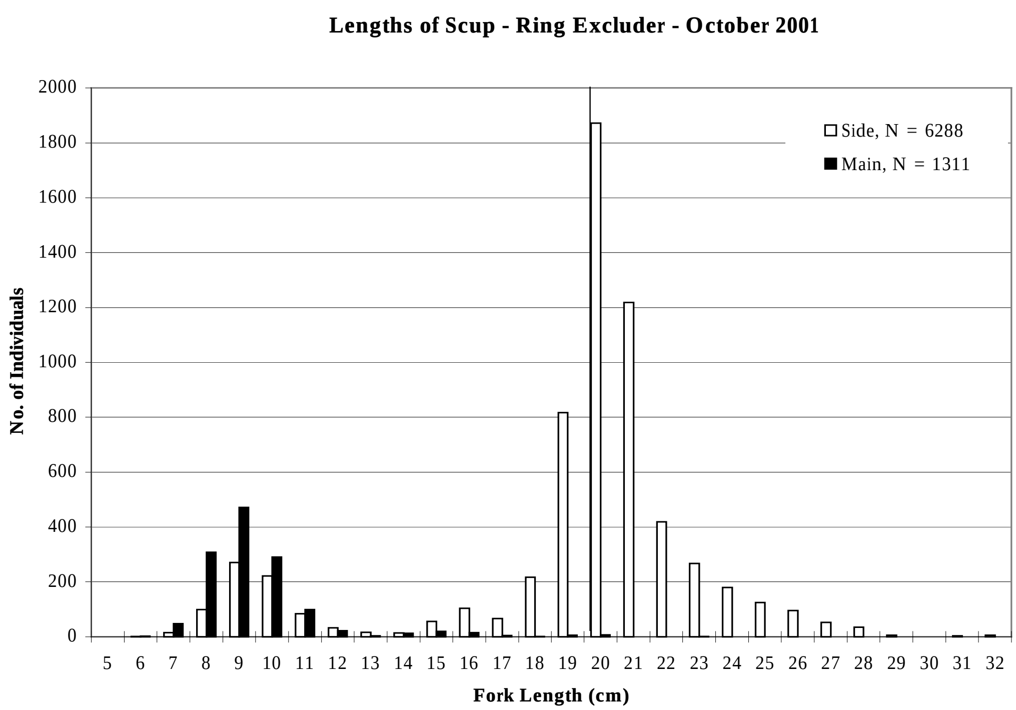
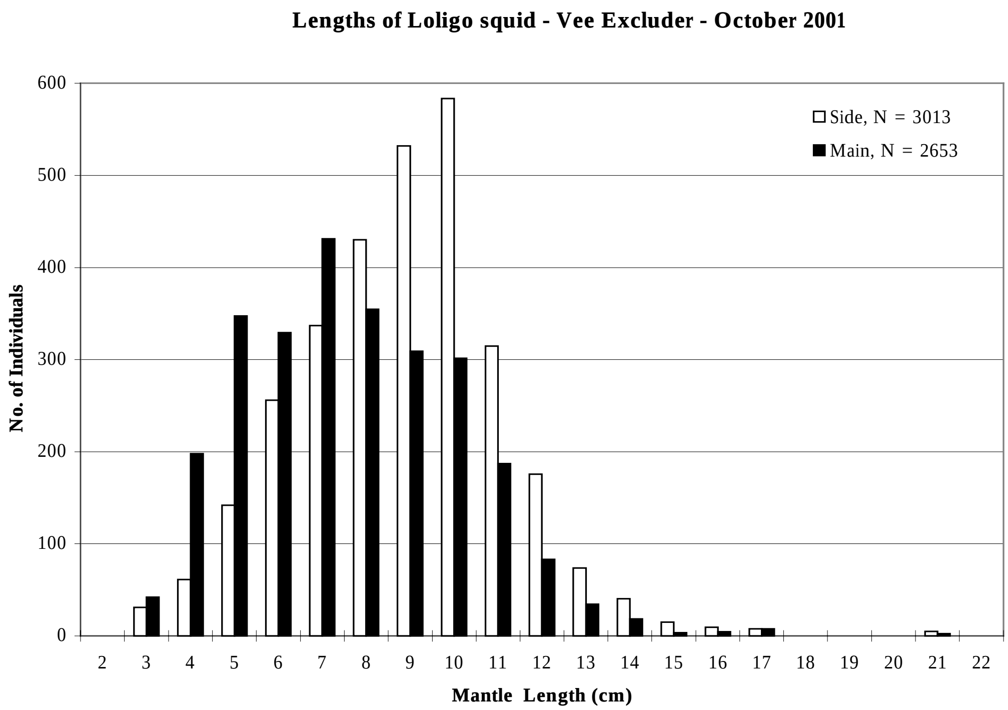


Figure 6: Fork length-frequencies of scup for vee (top) and ring excluders during October 2001 testing. Open bars represent scup caught in side codends; solid bars were caught in the main codend. Vertical line at 20 cm represents estimated minimum landing size, in fork length. Numbers are extrapolated from subsamples.



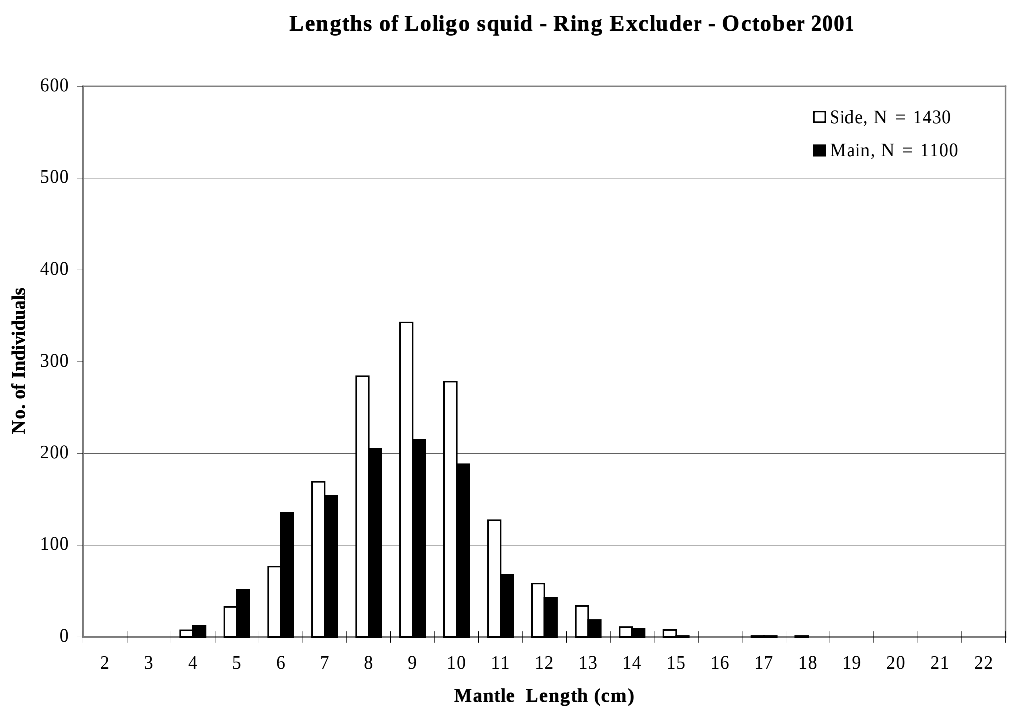


Figure 7: Mantle length-frequencies of *Loligo* squid for vee (top) and ring excluders during October 2001 testing. Open bars represent squid caught in side codends; solid bars were caught in the main codend. Numbers are extrapolated from subsamples.

Figure 8 : School of scup swimming in front of the ring excluder (obscured).

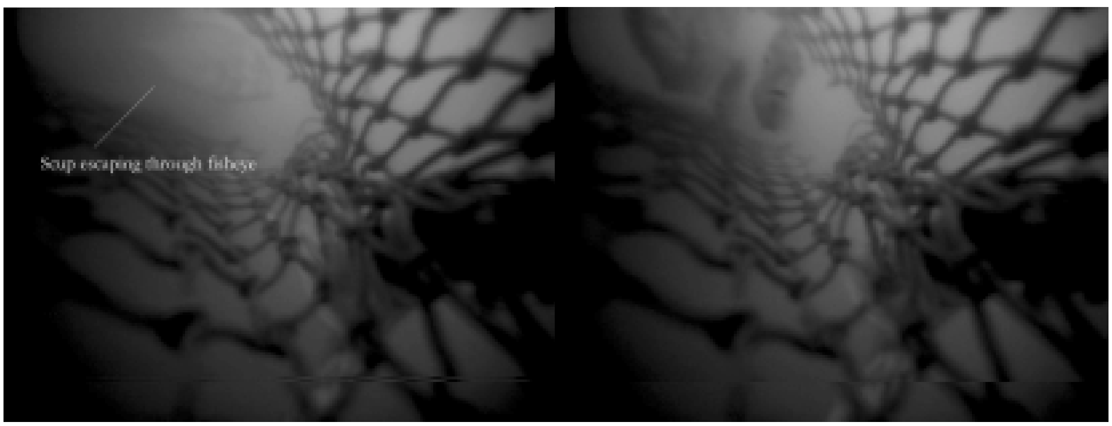


Figure 9: Two views of scup escaping through the portside fisheye, pocket codends removed. A single scup turns and exits (left, labelled); several scup slowly exit by tiring while swimming forward (right).

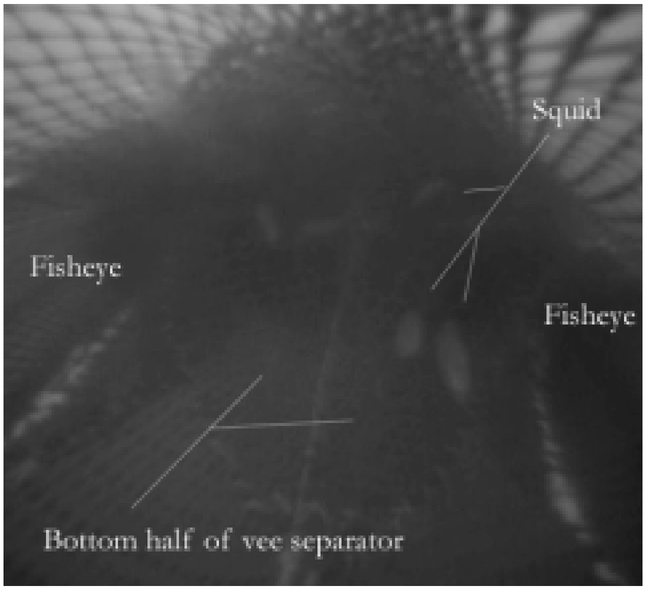


Figure 10: Two large squid holding station in front of vee excluder (labelled, bottom right). Seams and midrib of excluder can be seen; seams of pocket codends over fisheye can also be seen.