Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-27

Lobster Trap Escape Vent Selectivity

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Massachusetts Division of Marine Fisheries
Department of Fish and Game
Executive Office of Environmental Affairs
Commonwealth of Massachusetts

August 2006

Massachusetts Division of Marine Fisheries Technical Report Series

Managing Editor: Michael P. Armstrong

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Lobster Trap Escape Vent Selectivity

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August, 2006

Abstract: Management of the American lobster (*Homarus americanus*) fishery by the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Lobster Fishery Management Plan requires the use of escape vents in traps. Adjustments to vent size can maintain fishing efficiency, maximize retention of legal lobsters, and minimize retention of sublegal lobsters and therefore injury to them. The purpose of this study was to generate selectivity curves for escape vents that correspond with potential increases in minimum legal size for American lobster. Evaluations of both rectangular and circular vents were made to maintain options for those lobster fishermen concerned about crab or finfish escapement (minimized with circular vents). The lobster size selectivity of eight experimental lobster trap escape vents (four rectangular and four circular) was investigated in two phases. During Phase I, a laboratory-based study utilizing concrete flow-through sea-water "raceway" tanks was conducted in order to standardize the effects that lobster density in traps, bait, soak time, and size structure had on escapement. Phase II involved sea sampling of experimentally vented and unvented traps. Selectivity curves generated from the Phase I controlled study exhibited parallel slopes compared to inconsistent slopes calculated from at-sea sampling data in Phase II. The Phase II study area was a heavily fished environment where large lobsters were scarce; this produced inconsistent results in the size at 100% retention. In contrast, Phase I samples were selected by sex for both carapace length (CL) and carapace width (CW). Carapace width is an important variable in escapement through rectangular vents and therefore becomes a critical factor with small sample sizes. The sampling of broad ranges of CW for each CL in Phase I helped to provide a representative array of lobster morphometrics for testing in circular vents also. Phase I study results were more reliable than Phase II and are therefore useful for making recommendations to management on appropriate escape vent sizes for proposed minimum CL's. Results allow managers to adjust vent size beyond 2" rectangular or 2 1/2" circular sizes as CL regulations increase.

Introduction

Current management strategy for the American lobster (Homarus americanus) fishery, as defined in Amendment 3 to the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Lobster Fishery Management Plan, includes a requirement for use of escape vents in traps. These vent openings can be either rectangular or circular in shape and have gap dimensions designed to minimize the catch of sublegal lobsters while maximizing retention of the legal catch. Vent size should increase with regulation of minimum legal carapace length (CL) to maintain fishing efficiency and minimize injury to sublegal lobsters.

In the late 1990's, ASMFC Lobster Conservation Management Teams (LCMT's) recommended increases in lobster minimum legal CL in order to meet the egg-production goals of Amendment 3. These proposed increases in minimum CL were approved by the ASMFC Lobster Management Board and were defined in Addenda 2 and 3 to Amendment 3 of the Interstate Lobster Fishery Management Plan in 2001 and 2002. These regulatory changes required a revision to escape vent size recommendations to be compatible with proposed minimum legal CL's.

The size selectivity effects of escape vents have been studied by a number of researchers. Wilder (1943) and Templeman (1958) studied trap selectivity and reported the advantages of catching fewer sublegal lobsters. Other studies have demonstrated the effectiveness of escape vents (Krouse and Thomas 1975; Fair and Estrella 1976; Krouse 1978; Stasko 1975; Fogarty and Borden 1980; Krouse et al 1994). Several of these studies not only documented a significant reduction in sublegal catch, but also demonstrated an increase in trap efficiency in the form of higher catch rates of legal-sized lobsters compared to unvented traps (Krouse and Thomas 1975; Fair and Estrella 1976; Fogarty and Borden 1980). However studies of size selectivity and retention are most useful for CL regulation.

Based on the work done by Krouse and Thomas (1975) and their associated recommendations, all state and federal jurisdictions adopted a $1^{3}/_{4}$" (44mm) high x 6" (152.4mm) long rectangular (2.28", 58mm circular) escape vent rule for lobster traps by the 1980's. In 1992, escape vent size was increased from $1^{3}/_{4}$" (44mm) high rectangular (2.28", 58mm circular) to $1\ ^{7}/_{8}$" (47.6mm) high rectangular ($2\ ^{3}/_{8}$", 60mm circular) to accommodate the increase in minimum legal CL to 3¼ " (83 mm) which had previously occurred in 1989. In 1999, escape vent height was increased to $1^{15}/_{16}$" (49.2mm) high rectangular or $2^{7}/_{16}$" (62 mm) circular. Beginning with the rectangular escape vent height increase to $1^{7}/_{8}$" in 1992 to accommodate the 1989 increase in minimum CL to $3^{1}/_{4}$", managers have demonstrated their support for maximizing sublegal lobster escapement. A $1^{7}/_{8}$"

high vent maximizes escapement of sublegals and provides for >90% legal lobster retention rate (Krouse, unpublished data). It has been shown that this minimal legal lobster escapement has not adversely impacted catches (Krouse et al. 1994). Legal lobster escapees will likely be recaptured and if at large long enough to molt, would become fully vulnerable to the gear thereafter. The ASMFC-mandated vent increase to $1^{15}/_{16}$" (49.2mm) in 1999 maximized escapement of sublegals. According to data collected by Krouse, this escape vent height results in a CL at 100% retention which was approximately 5 mm larger than the minimum legal size at that time ($3^{1}/_{4}$" CL) so some escapement of legals was expected.

Krouse et al. (1988) generated selectivity curves for an array of optional rectangular and circular vent sizes which have been useful in making subsequent management decisions. However, the selectivity curves from which these recommendations were made do not envelop a possible future range of CL increases. Recent attempts to extrapolate circular escape vent recommendations from earlier selectivity studies for minimum CL sizes beyond those that were tested may have produced unreliable results. Consequently additional research on escapement from a wider array of vent sizes is warranted.

The purpose of this study is to generate selectivity curves for escape vents that correspond with the possible increases in minimum legal size for American lobster. Results will allow managers to implement appropriate vent size increases as CL regulations change. Evaluations of both rectangular and circular vents are made to maintain options for those lobster fishermen concerned about crab or finfish escapement (minimized with circular vents).

Methods

Rectangular vents: The critical morphological dimension which limits escapement through rectangular vents is carapace width (CW) (Krouse & Thomas 1975, Nulk 1978, Fogarty & Borden 1980). Theoretical analyses of the carapace length-width relationship can be helpful in estimating optimal vent size and also in calculating theoretical catch size distributions for a particular vent (Nulk 1978). Experimental vent sizes initially tested were approximated according to the dimensions below.

A theoretical schedule of proposed CL increases in $^{1}/_{32}$" increments up to and including 3 ½" CL was defined. These minimum legal sizes and corresponding CW's from previous morphometric studies (>9000 measurements) which we conducted throughout MA coastal waters are:

Minimum CL	Corresponding CW
$3\ ^{9}/_{32}$" (83.34 mm)	2.03" (51.51 mm)
$3\ ^{5}/_{16}$" (84.14 mm)	2.05" (52.05 mm)
$3\ ^{11}/_{32}$" (84.93 mm)	2.07" (52.58 mm)
$3\ ^{3}/_{8}$" (85.73 mm)	2.09" (53.11 mm)
$3\ ^{13}/_{32}$" (86.52 mm)	2.11" (53.64 mm)
$3\ ^{7}/_{16}$" (87.31 mm)	2.13" (54.17 mm)
$3\ ^{15}/_{32}$" (88.11 mm)	2.15" (54.70 mm)
3 ½" (88.90 mm)	2.17" (55.23 mm)

Previous vent selectivity studies have demonstrated that some lobsters with carapace widths up to 5mm greater than escape vent height can escape (Krouse & Thomas 1975, Nulk 1978). Nevertheless, for the purpose of this selectivity study, it was assumed that 100% of lobsters with carapace width equal to or greater than the escape vent height would be retained. Based on this assumption, the following rectangular escape vent heights were chosen for evaluation:

2" (50.8 mm) x 5 ¾" rectangular

$2\ ^{1}/_{16}$" (52.4 mm) x 5 ¾" rectangular

$2\ ^{1}/_{8}$" (54.0 mm) x 5 ¾" rectangular

$2\ ^{3}/_{16}$" (55.6 mm) x 5 ¾" rectangular

Circular Vents: Krouse (1978) identified carapace depth as the critical dimension determining escapement through a circular vent. This relationship is confounded by the additional depth to a lobster's profile created by the walking legs, and the lobster's ability to maneuver through confined spaces. Thus, it is more difficult to predict the circular vent diameter that most closely corresponds to the proposed minimum gauge size. Previous work (Krouse 1994) has shown that a $2\ ^{3}/_{8}$" (60 mm) circular escape vent retained the majority of legal sized (> 83 mm CL) lobsters while allowing significant escapement of sublegal lobsters. In 1999, the ASMFC Lobster Board increased the allowable escape vent size to $2\ ^{7}/_{16}$" circular (corresponding to the $1\ ^{15}/_{16}$" x 5 ¾″ rectangular) as indicated in Addendum I to

Amendment 3 of the ASMFC Interstate Lobster Fishery Management Plan. A subsequent increase in circular vent diameter to 2 $^{1}/_{2}$" (corresponding to a 2" rectangular vent) was proposed for a 3 $^{3}/_{8}$" CL increase in some Lobster Conservation Management Areas (LCMA), but this circular vent size was extrapolated from earlier selectivity work and not directly investigated.

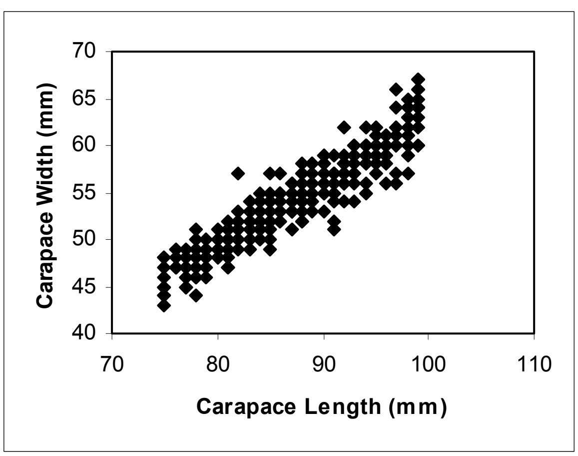
In an attempt to accommodate possible future gauge increases, evaluate vent size proposals made through extrapolation, and use consistent methodology, four vents differing by $^{1}/_{16}$" diameter were chosen for study. The proposed circular escape vents were:

2 ½" (63.5 mm) circular
2 9/$_{16}$" (65.1 mm) circular
2 $^{5}/_{8}$" (66.7 mm) circular
2 $^{11}/_{16}$" (68.3 mm) circular

The manufacturing of rectangular and circular vents needed for this selectivity research was contracted with a local plastic vent manufacturer who supplies the lobster industry. Vent openings were fabricated according to our strict specifications for precise tolerances.

Phase I Methods: Laboratory Trap Vent Selectivity. A laboratory-based selectivity study was conducted to generate selectivity curves based on a finite number of observations in a controlled environment. This approach made it possible to standardize the effects of soak time, lobster density in traps, and bait on escapement.

Figure 1. Scatterplot of carapace length vs. carapace width for American lobsters used in the Phase I selectivity study (one dot represents 1-7 individuals).



An average of twelve lobsters from each 1 mm increment between 75 mm and 99 mm CL (a total of 308 lobsters) was collected during on-going Massachusetts Division of Marine Fisheries (MADMF) sea sampling and spring bottom trawl survey programs and/or purchased from local seafood dealers. An attempt was made to sample sexes equally and incorporate a representative range of CW's for each length (Figure 1). CL, CW, and sex were recorded for each specimen and each lobster was individually tagged with a numbered $^{1}/_{2}$" disc tag on its telson.

Figure 2. Photo of the experimental raceways at the Environmental Systems Laboratory at the Woods Hole Oceanographic Institute.

The study was carried out in five concrete flow-through sea-water "raceway" tanks (dimensions: 40' x 4' x 5') at the Environmental Systems Laboratory (ESL), Woods Hole Oceanographic Institute (WHOI) (Figure 2). The 40 ft. long concrete tanks were scrubbed and flushed and thirty-six 3-ft. long lobster traps were outfitted with the experimental escape vents previously identified and distributed evenly in the raceways. Each trap was identified with an individually numbered plastic tag (1 to 36). Eight traps were placed in each of four raceways (Figure 3). The fifth raceway was evenly divided into two sections with a screened partition. The remaining four experimental traps were placed in one of the two sections and the remaining section was sub-divided into two compartments which were used to store the experimental lobsters between deployments.

Each of eight sets of four traps was outfitted with one of the eight experimental vent sizes (Figure 3). The remaining four traps in the divided raceway were outfitted with the four smallest vent

Figure 3. Schematic of WHOI ESL exterior concrete tank system with deployment design for the thirty-six trap/eight vent combination.

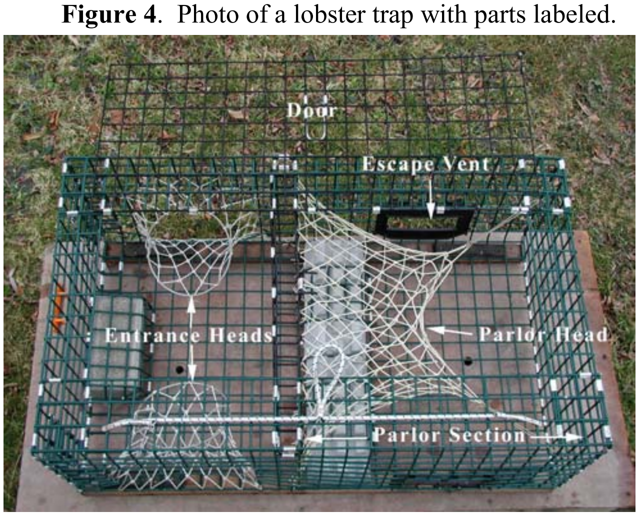
Raceway 1 *(Rect. Vents)*	Raceway 2 *(Rect. / Circ. Vents)*	Raceway 3 *(Rect. Vents)*	Raceway 4 *(Circ. Vents)*	Raceway 5 *(Circ. Vents)*
1*	*General*	13	21	29
2	*Lobster Storage*	14	22	30
3	*"On-Deck"*	15	23	31
4	*Lobster Storage*	16	24	32
5	9	17	25	33
6	10	18	26	34
7	11	19	27	35
8	12	20	28	36

*Trap Number	Vent Size
Traps 1-4 & 11	2" Rect.
Traps 5-8 & 12	2 $^{1}/_{16}$" Rect.
Traps 13-16	2 $^{1}/_{8}$" Rect.
Traps 17-20	2 $^{3}/_{16}$" Rect.
Traps 9 & 21-24	2 $^{1}/_{2}$" Circular
Traps 10 & 25-28	2 $^{9}/_{16}$" Circular
Traps 29-32	2 $^{5}/_{8}$" Circular
Traps 33-36	2 $^{11}/_{16}$" Circular

sizes. Parlor funnel heads on each trap were knitted to close the funnel exit ends such that the experimental vents installed in each trap's parlor, represented the only exit option for test animals placed in this section of each trap (Figure 4).

The tanks were filled to a depth of approximately 26 inches which was maintained with elevated drain holes in a PVC standpipe inserted into the drainage hole at the end of each tank. The tanks were allowed to flush for several days prior to inserting experimental animals. Bait bags were filled with herring and assorted fish racks and were suspended at the water in-flow end of each tank such that amino acids from bait breakdown would flow downstream and across all traps to promote escapement. Bait was changed weekly. An Onset Stowaway temperature logger was attached to one of the ESL raceway tanks to monitor water temperature during the study. A 1" cold-water PVC line with five shut-off valves was constructed and connected to the main line which exits from a chiller unit at ESL. This was intended to temper the warm ambient (Nantucket Sound) water entering the flow-through system during summer months.

Figure 4. Photo of a lobster trap with parts labeled.



In-tank experiments were conducted from 9 May, 2002 to 21 July, 2002. On each day, one of the 308 tagged lobsters was placed in the parlor section of each of the 36 numbered experimentally vented traps (one lobster per trap) and the door was secured. These thirty-six (36) deployed lobsters were then given a standard one-day (24 hour) maximum soak time to escape. The following day the disposition of each deployed lobster (i.e., retained or escaped) was logged and each animal was re-deployed in a new numbered trap with a different vent size. The numbering of experimentally vented traps and tagging of each lobster facilitated the accounting of each lobster's deployment history. Lobsters were rotated daily from one trap to another until each was exposed once to all eight experimental vents. The exception was that if a lobster escaped from the smallest size of a vent type (rectangular or circular) it was assumed that it was capable of escaping from all larger sizes of that vent type and it was given credit for them. All data log sheets were edited and keypunched daily.

Selectivity curves were generated by calculating the proportion retained at length and fitting it with a logistic regression model.

<u>Phase II Methods: In Situ Commercial Trap Vent Selectivity</u>. In June, 2002, a total of eighty (80) 3-foot long experimental wire traps (enough for eight 10-pot trawls) were purchased and distributed equally to two contracted commercial lobstermen such that each fisherman would be allowed to fish four 10-trap trawls with alternating vented and unvented traps. Four different experimental vent sizes (two rectangular, two circular) were distributed to each fisherman and installed in traps so that escape vent size remained constant within a trawl (Table 1).

Phase II data collection began in July, 2002 with sea sampling of experimental vented traps conducted aboard the two vessels in the Cape Cod Bay area and was completed in December, 2002.

Two lobstermen were involved in this Phase to help ensure adequate observations through concurrent trap hauling during the contract period. MADMF sea sampling personnel recorded the catches of all experimental traps a minimum of once each week. However, research sampling aboard the contracted vessels during November and December was less consistent due to weather-related problems. CL, CW, sex, vent presence, and vent size were recorded for each lobster captured by experimental traps.

Table 1. Vent sizes distributed to contracted fishermen.

	Lobsterman #1		Lobsterman #2	
Trawl 1	2"	Rectangular	2 $^{1}/_{8}$"	Rectangular
Trawl 2	2 $^{1}/_{16}$"	Rectangular	2 $^{3}/_{16}$"	Rectangular
Trawl 3	2 $^{5}/_{8}$"	Circular	2 $^{1}/_{2}$"	Circular
Trawl 4	2 $^{11}/_{16}$"	Circular	2 $^{9}/_{16}$"	Circular

Selectivity curves were generated to determine vent retention rates at length using the methodology of Beverton and Holt (1957). For each CL mm increment within each 10-trap experimental trawl, the retention rates equaled the ratio of the number of lobsters retained by vented traps to that from unvented traps. If there were no observations at a CL mm interval for vented traps or for unvented traps then that mm increment was eliminated from the analysis of that trawl's data. This procedure provided an estimate of the proportion retained at length for each vent size. The selectivity curves were then generated by fitting the proportion retained at length with a logistic regression model.

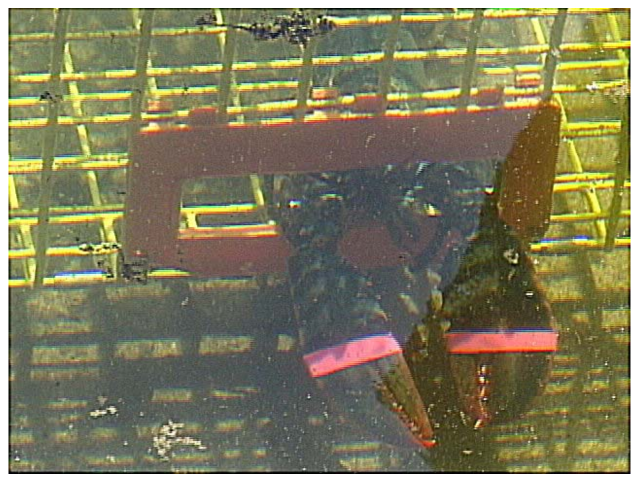
Results

Phase I Results: Laboratory Trap Vent Selectivity. Lobster escapement through circular vents appeared to be more challenging than through rectangular vents. Observations revealed that lobsters did not exit backwards, i.e. tail first, through either vent shape. Egress was limited to a forward approach wherein the insertion of both major claws through the vent was a necessary precursor to insertion of the walking legs (Figures 5 and 6) and thorax. This was more difficult with circular vents because of the narrower diameter of the hole size compared to the standard 5 $^{3}/_{4}$" width of rectangular vents. Escapement through circular vents required a crossing of the major claws to fit them through the hole simultaneously (Figure 6 A). If this could not be achieved then a lobster was not successful in escaping. Escapement through a rectangular vent often required turning sidewise to present the narrowest anatomical profile, viz. carapace/tail width (Figure 5 B).

Lobster mortality in the tanks peaked during June due to ecdysis and warm ambient Nantucket Sound water in the flow-through system. By late June, water temperature in the tanks approached 23C. In July, the 1" chilled-water PVC line was turned on in active raceways in order to temper the rising water temperature. Even though the cold water flow rate was minimal, i.e., several gallons/ minute (gpm) when shunted to five tanks (10 gpm for one), it helped to slow the rising ambient water temperature (Figure 7).

Figure 5. Escapement through a rectangular vent showing claws-first approach (5A) and sidewise profile (5B).

5A



5B

Selectivity curves were generated for each experimental vent size tested in Phase I by fitting the proportion retained at length with a logistic regression model. The predicted proportions retained for both rectangular and circular vents are depicted in Figures 8 and 9. Retention curves for both vent types are overlaid in Figure 10. A comparison of predicted and observed proportion retained shows a relatively "tight" relationship with minimal scatter for all vent sizes and types tested (Figures 11A and 11B).

Phase II Results: In Situ Commercial Trap Vent Selectivity. Phase II sea sampling of experimental vented traps aboard two contracted lobster vessels in the Cape Cod Bay area generated a significant amount of data from unvented traps. However, experimental vented traps were not as productive. The intense fishing effort in this area truncates the size distribution consequently the abundance of lobster greater than minimum legal size and in particular in the upper end of the legal size range is lacking.

A total 10,807 lobsters (635 from vented and 10,172 from non-vented traps) were sampled from eighty experimental traps during forty-four (44) trips aboard commercial lobster vessels (1760 trap hauls). Due to the distribution of vents between the two contracted lobstermen, each experimentally vented trawl was sampled 22 times (220 trap hauls). Table 2 describes the sample size breakdown observed in sea sampling during Phase II of the study. Figures 12, 13, and 14 show the selectivity curves generated from at-sea sampling to have inconsistent slopes. Compared to Phase I during which over 300 lobsters were tested in each experimental vent size, Phase II sample sizes were inadequate (Table 2). This is evident in a comparison of predicted and observed proportion retained at size for the eight experimental vents (Figures 15A and 15B). Desired observed data were reduced by the exclusion of mm increments with missing vented or unvented counterparts.

Figure 16 displays overlays of Phase I with Phase II selectivity curves. Despite similarities in the respective curves for the three smallest rectangular vents, in nearly all cases, inadequate Phase II sample sizes, particularly the lack of lobsters at the higher end of the size range, contributed to inconsistent results in the size at 100% retention. As a result, attempts to compare size structure observed from Phase II experimental vents with that from commercial sea sampling of $1^{15}/_{16}$" rectangular vented traps (the legal vent size at the time of the experiment) produced spurious results.

Figure 6. Escapement through a circular vent showing crossing of major claws (6A) and exiting without turning sidewise (6B).

6A

6B

Conclusions

Phase I selectivity experiments were conducted in a controlled environment, with standardized soak time, bait, sex, and size structure. Samples were selected by sex for both CL and CW. CW is an important variable in escapement through rectangular vents and therefore can be a critical factor if sample sizes are inadequate. The sampling of broad ranges of CW for each CL in Phase I also helped to provide a representative array of lobster morphometrics for testing in circular vents.

Figure 7. Water temperature of flow-through system during lobster trap escape vent selectivity trials, WHOI Environmental Systems Laboratory, May-July, 2002.

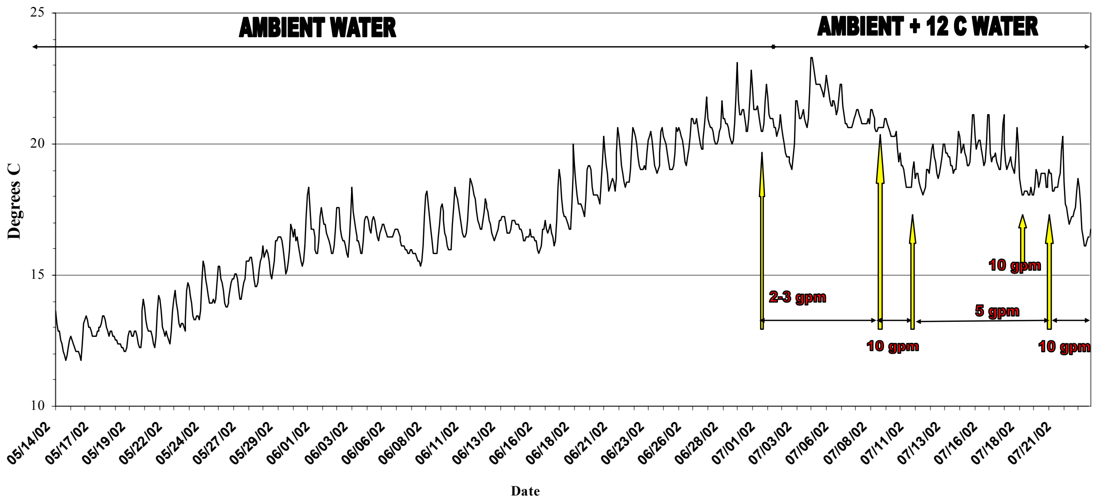


Figure 8. Phase I selectivity curves for experimental rectangular escape vents.

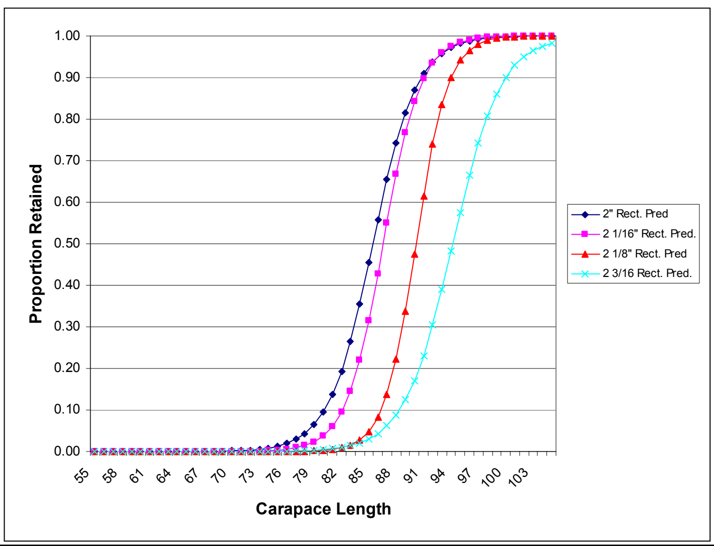


Figure 9. Phase I selectivity curves for experimental circular escape vents.

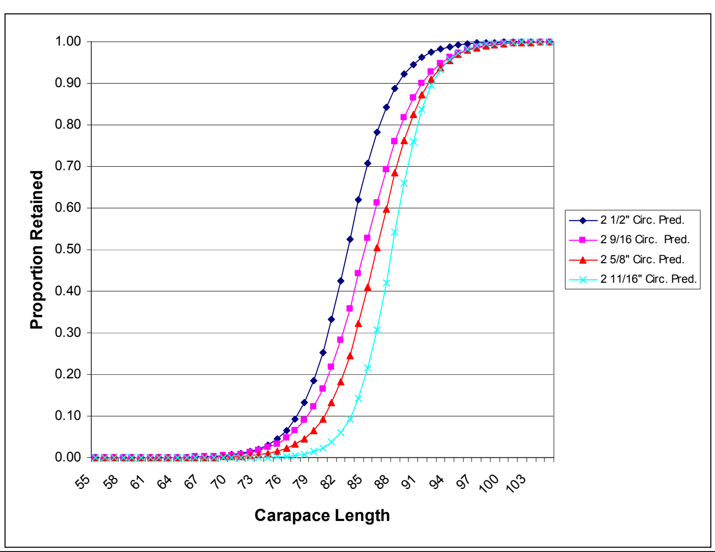


Figure 10. Phase I selectivity curves for both rectangular and circular escape vents.

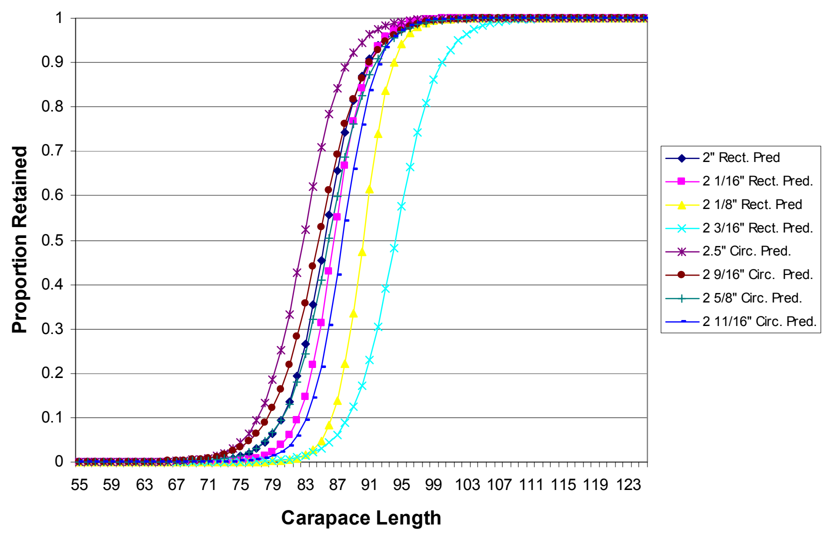


Figure 11A. Comparison of predicted and observed proportion retained for four experimental rectangular vents from raceway studies.

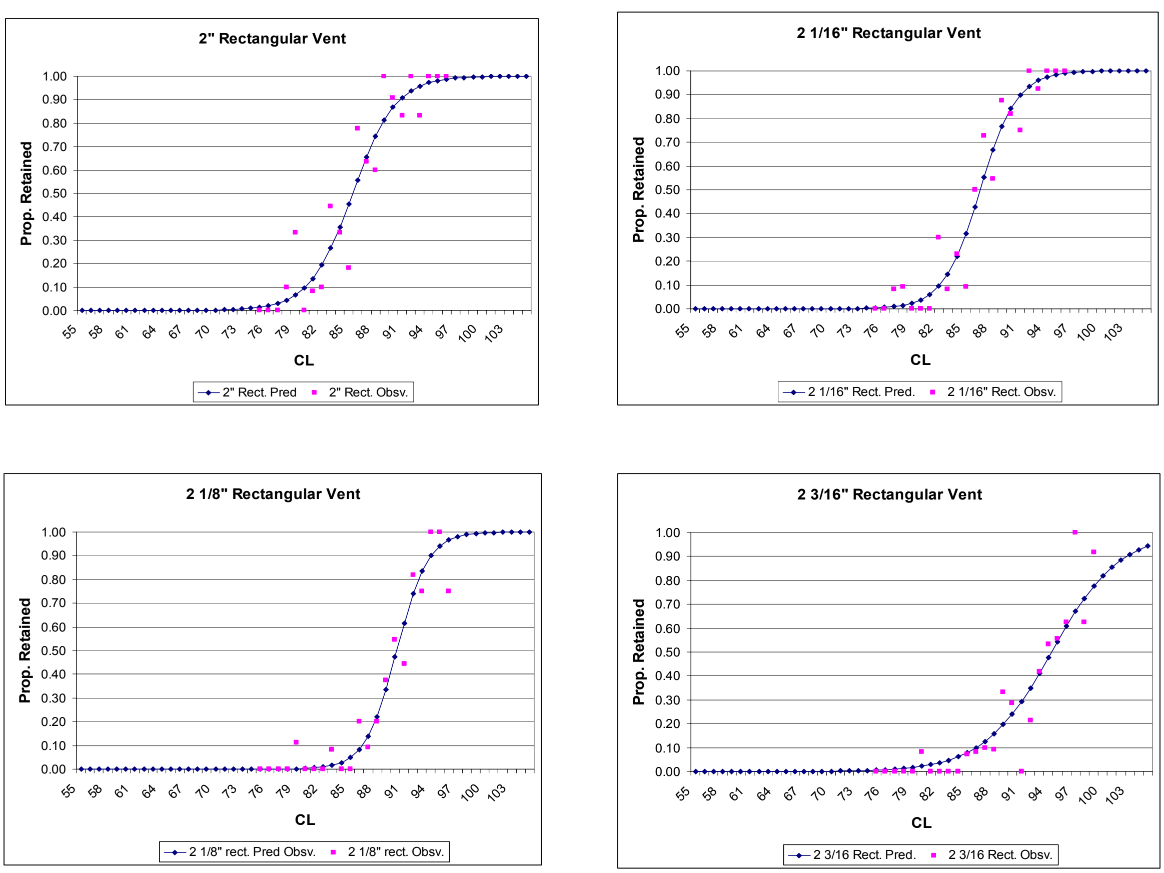
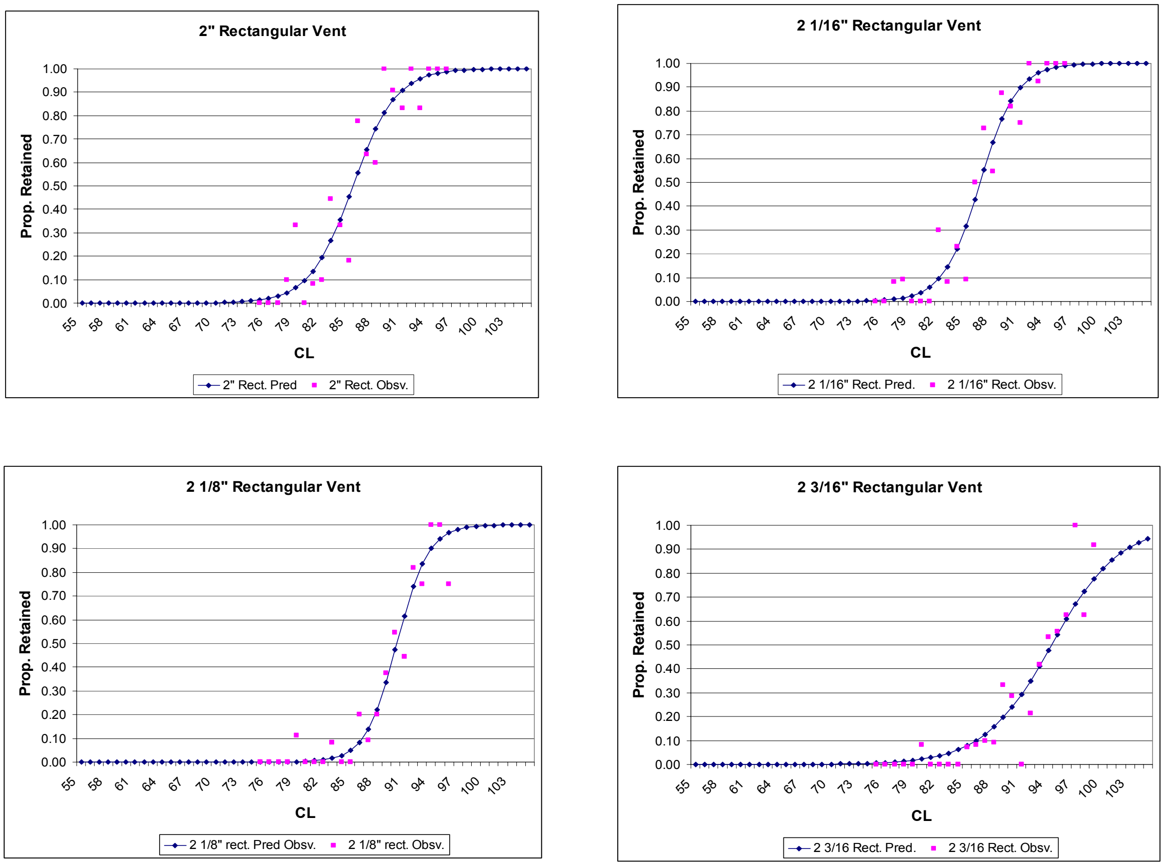


Figure 11B. Comparison of predicted and observed proportion retained for four experimental circular vents from raceway studies.



High fishing mortality rates (F) and the resulting recruitment-dependency of the MA coastal lobster fishery limited the abundance and subsequent catches of legal-sized lobsters during Phase II of the study. Due to this problem and the scarcity of large lobsters in a heavily fished LCMA-1 environment, 220 trap hauls per 10-trap trawl was insufficient to provide adequate data for Phase II analyses. In contrast to Phase II results, Phase I retention data were less variable and yielded regression curves with parallel slopes. Phase I study results are thus more reliable and therefore useful for making recommendations to management on appropriate escape vent sizes for proposed minimum CL's.

Following its implementation in 1999, the 2 $^{7}/_{16}$" circular vent (paired with a 1 $^{15}/_{16}$" rectangular vent for a minimum legal 3 $^{1}/_{4}$" CL) received criticism from some fishermen for retaining more lobsters than its corresponding rectangular vent. This circular vent size had been previously recommended by the ASMFC Lobster Technical Committee based on extrapolation from a regression analysis of smaller vent sizes studied by Krouse (1988). This issue had raised questions in recent years regarding the suitability of the 2 $^{1}/_{2}$" circular vent proposed for a minimum legal CL increase to 3 $^{3}/_{8}$", since it was also similarly extrapolated. It may be that with each molt, the increase in lobster morphometrics critical to escapement through circular vents is proportionally greater than that for rectangular vents.

Our evaluation of selectivity of eight experimental vent sizes supports the 2" rectangular vent currently proposed for a minimum legal CL of 3 $^{3}/_{8}$", but the retention data do not support its proposed companion circular vent size of 2 $^{1}/_{2}$" which retains considerably more lobsters than a 2" rectangular vent. The retention rate for a 2 $^{5}/_{8}$" circular vent, however, is compatible with a 2" rectangular vent. Based on this study, we recommend altering the previously recommended alternative circular vent size from 2 $^{1}/_{2}$" to 2 $^{5}/_{8}$". In addition, we recommend vent sizes of 2 $^{1}/_{16}$" rectangular and 2 $^{11}/_{16}$" circular for a 3 $^{1}/_{2}$" minimum legal CL in order to maintain a similar conservation buffer which maximizes escapement of sublegal lobsters while minimizing escapement of legal lobsters.

Table 2. Sample sizes observed during at-sea testing of eight experimental vents during Phase II.

Vent Size Sampled in 10-Trap Trawl	Number of Lobsters	Number of Lobsters Sampled	Row Total
2" Rect.	55	1199	1254
2 1/16" Rect.	48	1233	1281
2 1/8" Rect.	52	1527	1579
2 3/16" Rect.	57	1149	1206
2 1/2" Circ.	161	1313	1474
2 9/16" Circ.	109	1298	1407
2 5/8" Circ.	95	1241	1336
2 11/16" Circ.	58	1212	1270
Grand Total # lobster Sampled:	**635**	**10,172**	**10,807**

Figure 12. Phase II selectivity curves for rectangular vents from field study.

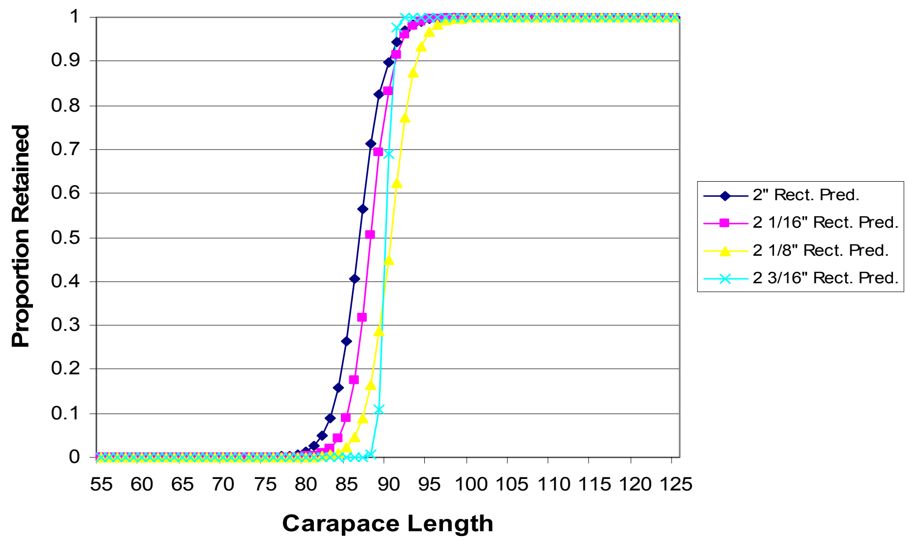


Figure 13. Phase II selectivity curves for circular vents from field study.

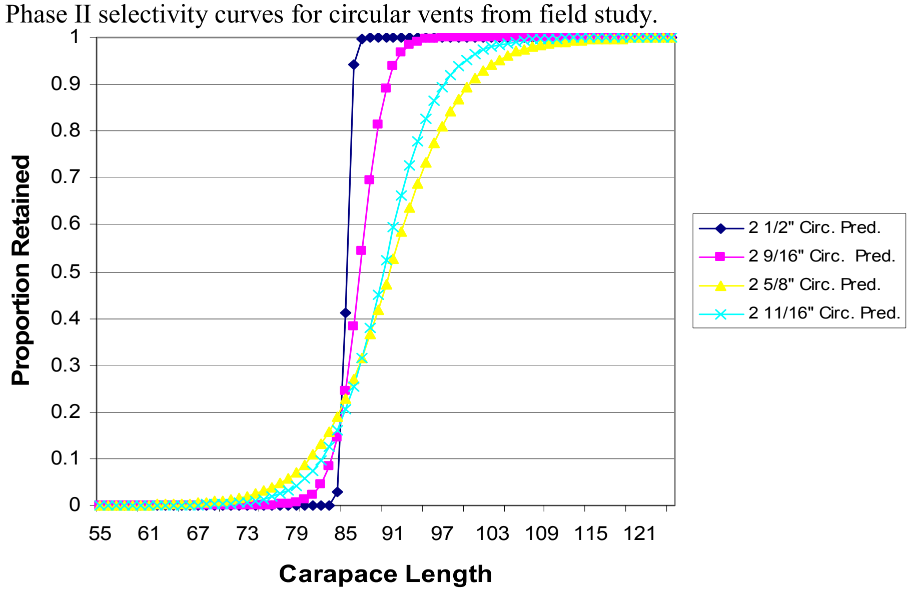


Figure 14. All Phase II selectivity curves generated from field study.

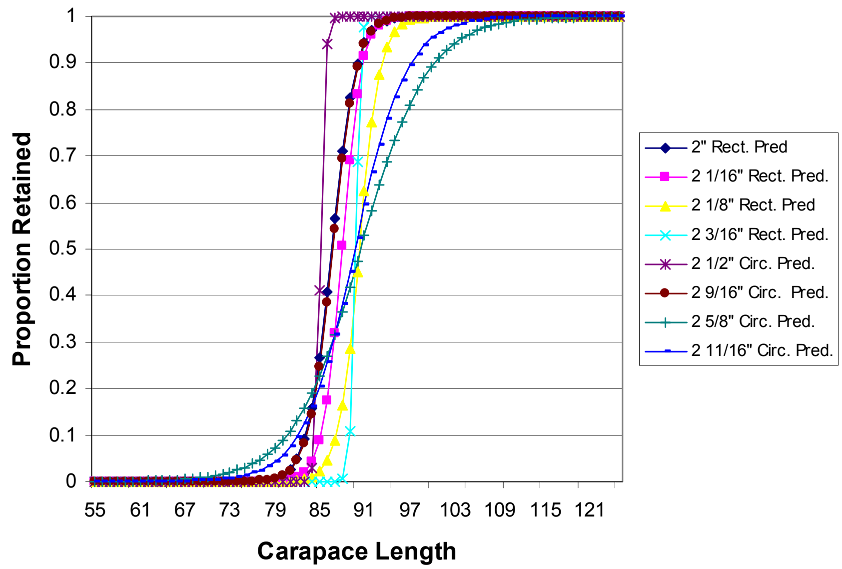


Figure 15A. Comparison of predicted and observed proportion retained for four experimental rectangular vents from field studies.

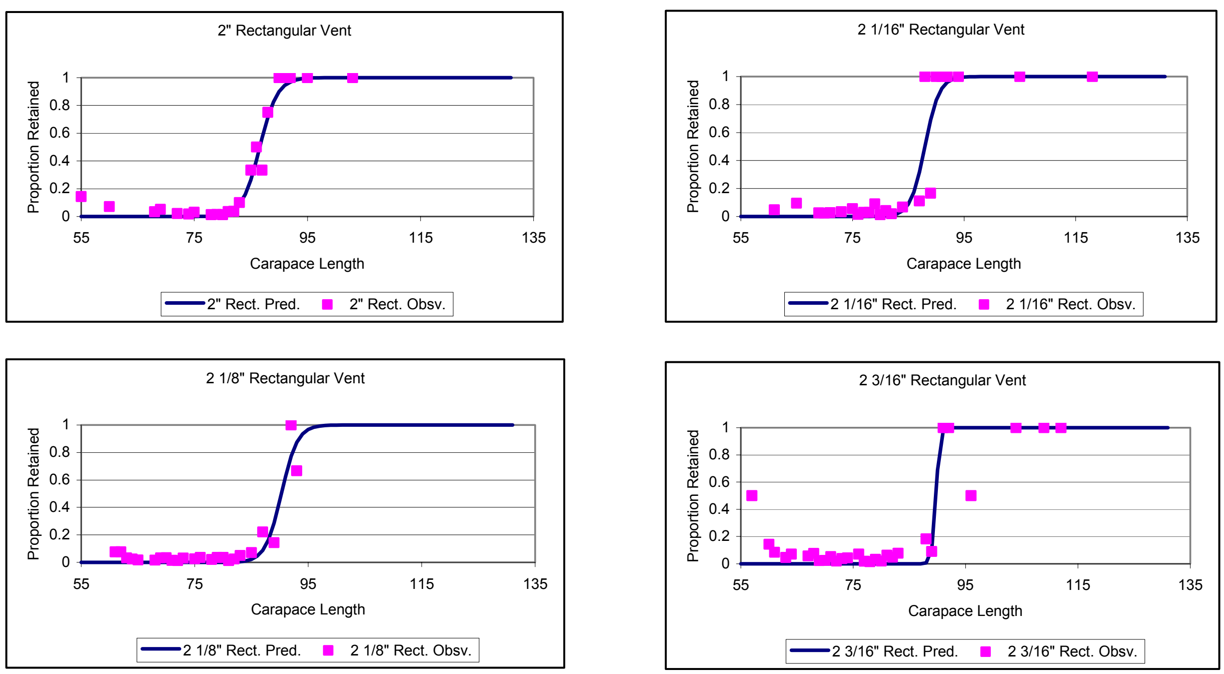


Figure 15B. Comparison of predicted and observed proportion retained for four experimental circular vents from field studies

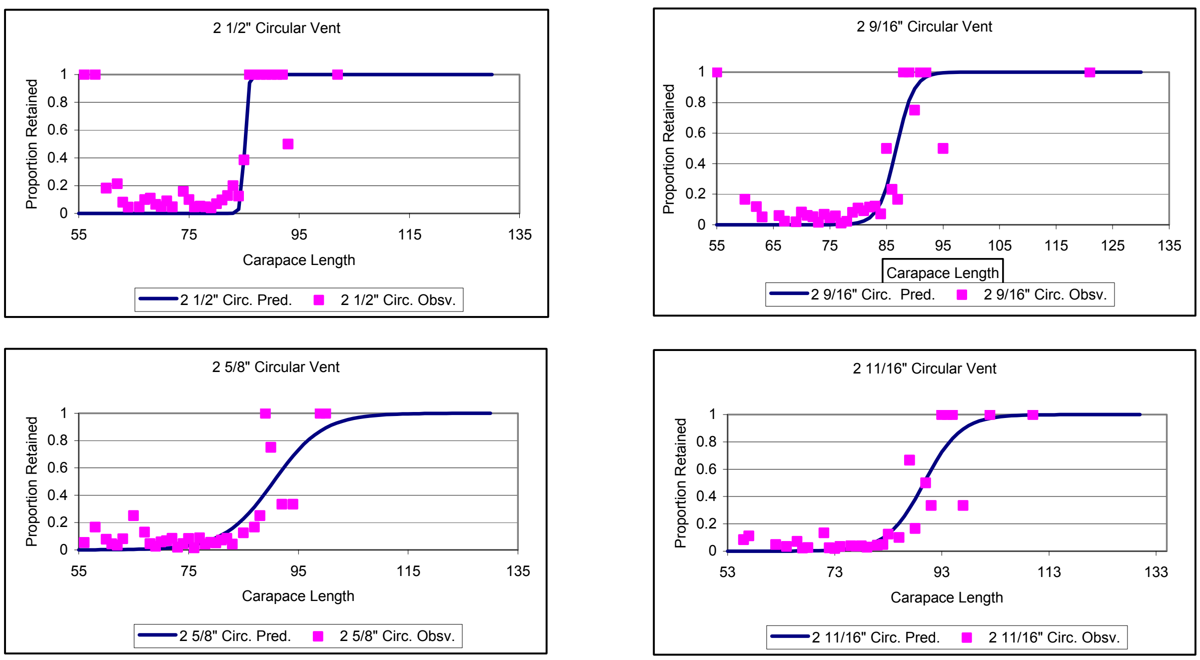


Figure 16. Comparison of Phase I (raceway) and Phase II (field) selectivity curves.

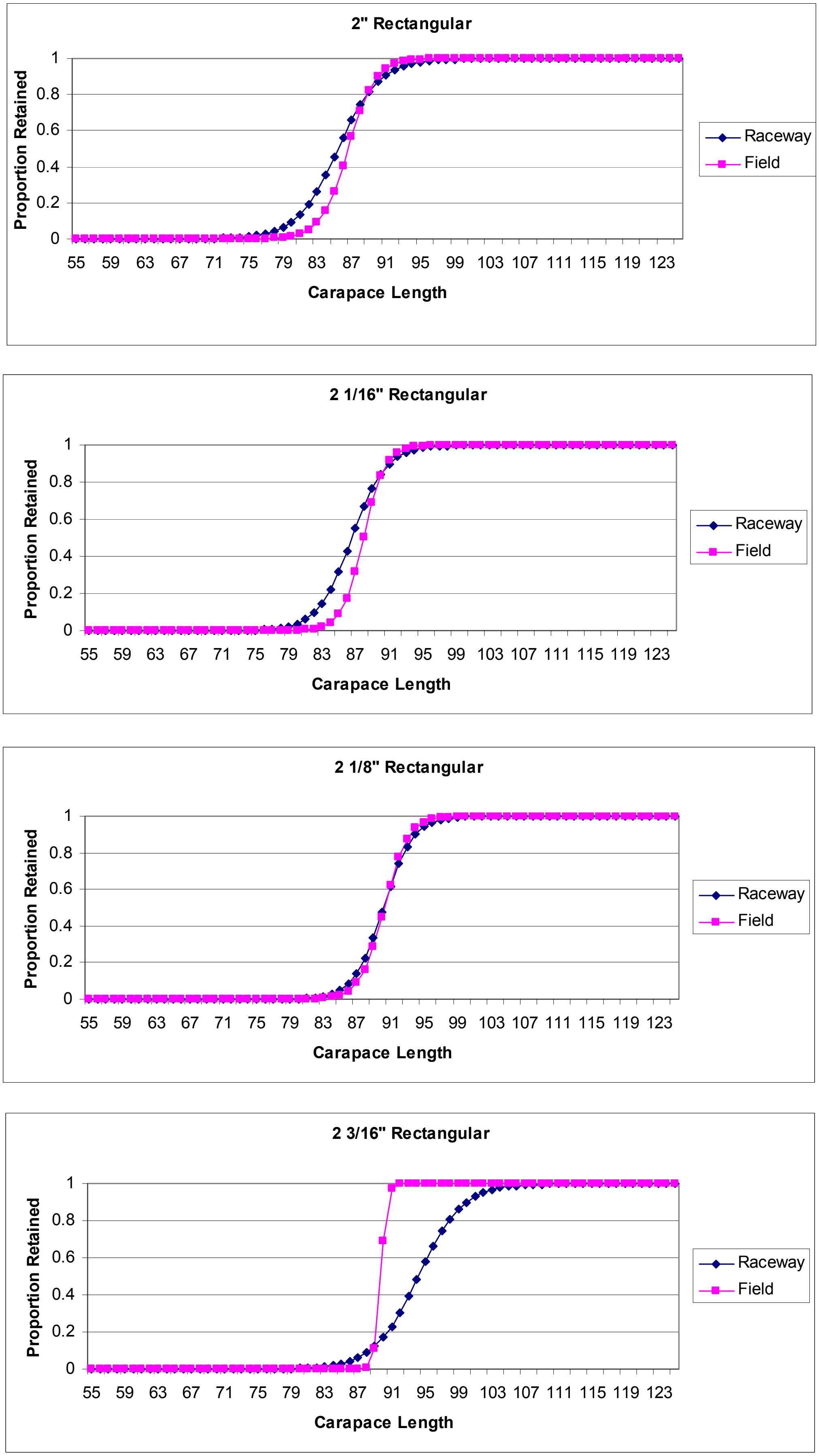
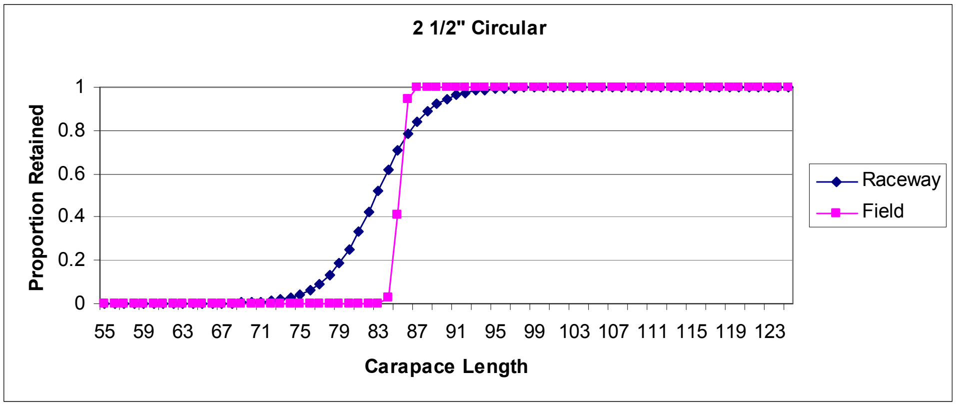
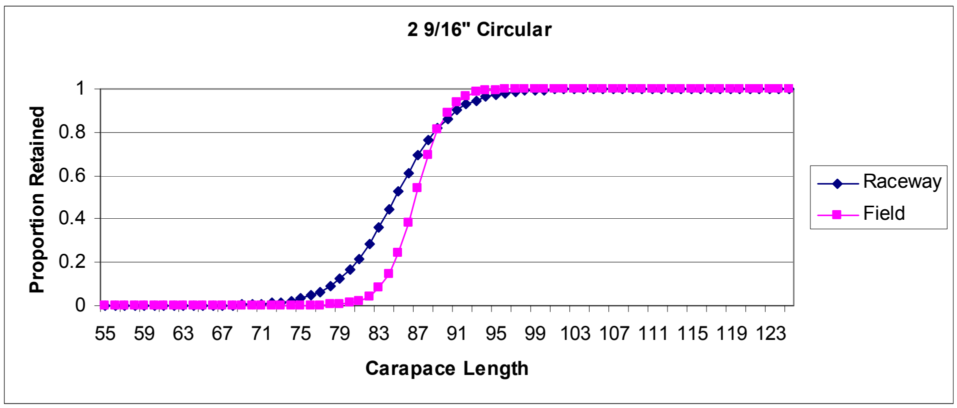
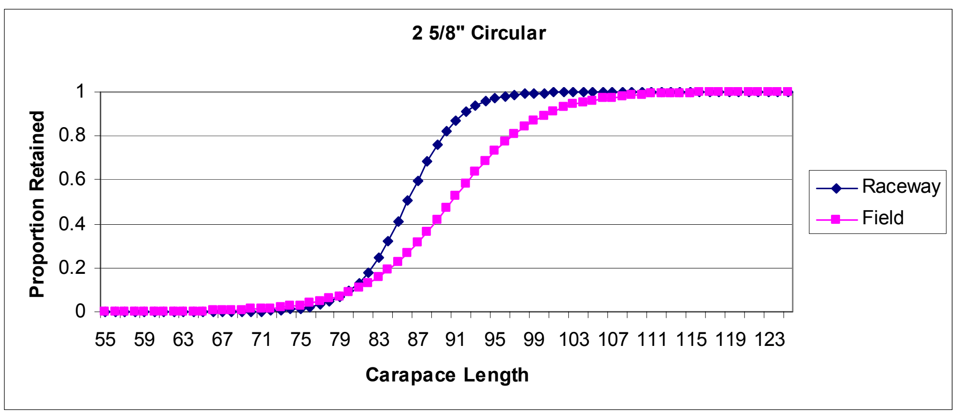
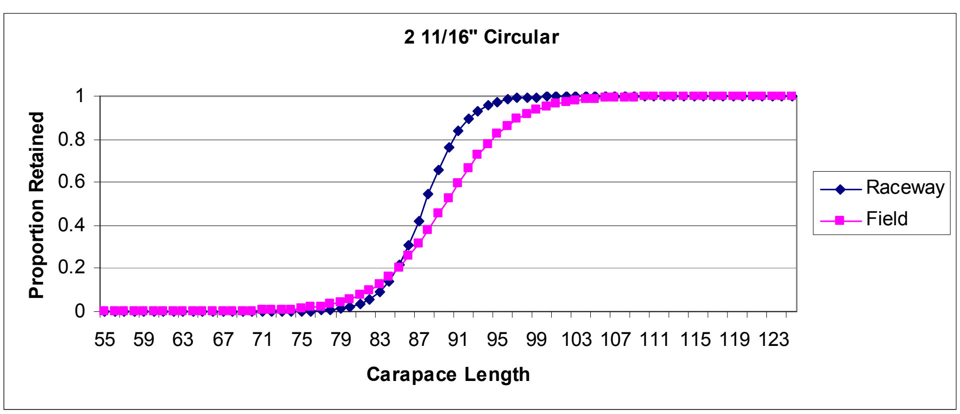


Figure 16 (continued). Comparison of Phase I (raceway) and Phase II (field) selectivity curves.









Acknowledgements

We wish to thank Dr. John Stegeman, WHOI, for permission to use the WHOI Environmental Systems Laboratory flow through seawater system for Phase I of this proposal. Bruce Lancaster, WHOI, was very helpful with technical aspects of the sea water system and in maintaining system operations. Personnel on the MADMF Coastwide Fishery Resource Assessment Program kindly provided a portion of the experimental animals. Tracy Pugh and Elisabeth Jablonski were invaluable in laboratory and field sampling, data entry and quality control. Mary M. Estrella, Brandon C. Estrella, and Christopher Best contributed voluntary assistance in Phase I experiments. Kenneth Weeks and Michael O'Connor supported the sea sampling segment of this project. Daniel McKiernan provided a helpful review of the manuscript.

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