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COMPARATIVE EFFICIENCY AND SELECTIVITY OF

3.25" AND 3.50" RING SCALLOP DREDGES

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New England Fishery Management Council
Sea Scallop Oversight Committee
June 25, 1995

Virginia Marine Resource Report No. 95-6

June 1995

COMPARATIVE EFFICIENCY AND SELECTIVITY OF 3.25" AND 3.50" RING SCALLOP DREDGES

Under the provisions of Amendment #4 to the Sea Scallop Fishery Management Plan (FMP) the 3.25 inch dredge rings will be replaced by the use of 3.50 inch rings in 1996. The use of 3.25 inch rings replaced 3.00 inch rings in March 1994. As part of a comprehensive research program to evaluate the efficiency and selectivity of scallop dredge rings, initial studies focused on the use of 3.00 and 3.25 inch rings. A preliminary report on this research was prepared and results presented to the New England Fishery Management Council (NEFMC) Sea Scallop Oversight Committee (DuPaul and Kirkley, 1994). Since mid-1994, subsequent studies focused on the comparison of the 3.25 inch and 3.50 inch ring dredges. Although much of this information is still being analyzed, this preliminary report is offered in conjunction with the presentation of the data to the NEFMC Sea Scallop Oversight Committee in East Boston on June 26, 1995.

Virginia Marine Resource Report No. 95-6
June 1995

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Authors: Dr. William DuPaul and Dr. James Kirkley are faculty of the Virginia Institute of Marine Science, College of William and Mary. Jeffrey Brust is a student conducting his graduate thesis research on scallop gear selectivity.

A total of five trips were made on commercial sea scallop vessels from June 1994 to April 1995. One trip was made aboard the New Bedford based F/V Tradition on Georges Bank. Four trips were made on two vessels from Seaford, Virginia, the F/V Carolina Breeze and the F/V Stephanie B. All fishing operations were conducted in the Delmarva resource area in the mid-Atlantic and lasted from seven to 14 fishing days. The Georges Bank trip covered four different resource areas during the 15 day trip: (1) the Cultivator Shoal and Northern Edge, (2) Southeast Part, (3) Great South Channel, and (4) the Canadian portion of Georges Bank. We were also able to evaluate the performance of a pre-Amendment #4 3.0 inch ring dredge against the 3.50 inch ring dredge in the area of the Great South Channel. The four trips in the mid-Atlantic were unique in the sense that they followed the recruitment of a very large year class which was documented by the 1993 NMFS Scallop Survey and the 3.25 inch ring scallop dredge gear trials conducted in November 1993. At that time, large numbers of 60 mm (2.4 inches) seed were harvested in several locations from east of the Delaware Bay south to the Virginia Capes.

Most of the resource areas on the U.S. portion of Georges Bank were characterized by hard bottom and low abundance of retainable scallops greater than 75 mm (3.0 inches) and a virtual absence of seed scallops less than 65 mm (2.6 inches). Consequently, the 3.50

inch ring dredge did not perform well on harvestable scallops up to 100 mm (3.9 inches). Harvesting efficiencies, determined by the number of scallops harvested, was 60% to 80% of the 3.25 inch ring dredge. Given the poor resource conditions and the type of bottom, the degree of escapement allowed by the 3.50 inch ring dredge is not surprising. From industry's perspective, however, escapement could present a problem until the stocks recover. In stark contrast, on the Canadian portion of Georges Bank, the 3.50 inch dredge performed in textbook fashion. The scallop resource was characterized by a large number of scallops from several year classes with a predominance of scallops in the 95 mm to 130 mm (3.7 - 5.1 inches) size range. Compared to the 3.25 inch ring dredge, the 3.50 inch ring dredge performed at 100% or better on scallops greater than 95 mm (3.7 inches) and allowed significant escapement of scallops smaller than 90 mm (3.5 inches). The low efficiencies noted for the 3.50 inch ring dredge on the U.S. portion of Georges Bank were offset by the high efficiency of the dredge in Canadian waters as offloading weights at the end of the trip were 2% greater than the 3.25 inch dredge. The performance of the 3.50 inch ring dredge in Canadian waters offers us an insight as to the potential gains of increasing ring size and advancing the age and size of harvestable scallops in a relatively healthy scallop resource. The opportunity to conduct our gear trials in Canadian waters was graciously provided by the Canadian Department of Fisheries and Oceans.

The comparison of a pre-Amendment #4 3.00 inch ring dredge to the 3.50 inch ring dredge showed dramatic differences in both size selectivity and harvesting efficiency. There was a 43.5% decrease in pounds of meats harvested (343 versus 607 lbs. as calculated from shell height:meat weight relationships) and an increase in the meat count of 14 meats per pound (53 versus 67) when comparing both dredges. Data indicated that the escapement of scallops smaller than 3.75 inch (95 mm) is considerable for the 3.50 inch ring dredge when compared to that of the 3.00 inch ring dredge (Table 1 and Figure 10).

The information obtained from the mid-Atlantic also gives us an opportunity to evaluate the effects and potential benefits of increasing ring size in a resource area dominated by a very large recruiting year class. In November 1993, the mid-Atlantic resource was dominated by a very large recruiting year class (probably spawned in 1990) in the 55 mm - 65 mm (2.2 - 2.6 inches) size range. These scallops were in excess of 100 meats per pound (MPP) and were still too small to shuck as the meat count restriction was still in effect. By June 1994 these scallops had grown to an average size of 70 mm - 75 mm (2.8 - 3.0 inches) with an average meat count of 57 MPP and were the target of commercial fishing operations. Data from the scallop gear trials indicated that the 3.25 inch ring dredge could effectively harvest these scallops but the 3.50 inch ring dredge was only 60% as efficient. By April 1995, this year class had grown to 90 mm - 95 mm (3.5 - 3.7 inches) and the efficiency of the 3.50 inch dredge had improved to over 80% of the 3.25 inch ring dredge (Table 3). Consequently, it is reasonable to conclude that the 3.50 inch ring dredge would allow a greater percentage of scallops in a given year class to survive to five years of age and 100 mm (3.9 inches) in size (28-30 MPP). These potential longer term gains that would be realized by harvesting older and larger scallops with higher yields are offset by the short-term losses in attempting to harvest scallops less than 3.5 inches (89 mm). For all trips in the mid-Atlantic, the 3.50 inch ring dredge had an average efficiency of 65% for scallops from 3.00 to 3.75 inches (76 - 94 mm) in shell height relative to the 3.25 inch ring dredge.

During our research trips on scallop vessels, we spend most of our time taking meat counts and counting and measuring the size of scallops to estimate gear efficiency and selectivity. However, we also determined the landed weights of scallops harvested by each dredge. We do this simply by separating the scallop bags in the fish-hold and at weigh-out, weighing the bags of scallops according to the dredge ring size. As we all know, we have to be concerned about the bottom-line; the number of pounds of scallops and the meat count determine the number of dollars received by the vessel. Also, it is important to remember that the harvest efficiency of a dredge determined by the number of scallops harvested may not be the same when determined by the pounds of scallops landed.

The average meat counts (determined on the vessel) for the 3.50 inch ring dredge were always lower than that for the 3.25 inch ring dredge. This result is not unexpected as the 3.50 inch ring dredge simply does not capture as many small scallops and the lower meat count is a reflection of fewer small meats. It is important to remember that the shucked meat count is a function of two selection processes; one of the dredge in the harvesting process and the other of the crew in the culling process on deck. Our data indicated that the crews selected (culled) scallops proportionally to size regardless of the ring size of the dredge. That is, for any given trip, the culling practices were the same for both dredges.

Size frequency distribution data for scallops retained for shucking (Figure 15) indicated that the culling practices of the crew change according to the predominant size of scallops in the catch. During the June 1994 and August 1994 trips in the mid-Atlantic, the predominant size of scallops harvested were in the 70 mm - 80 mm (2.6 - 3.1 inches) size range and in both cases, crews retained for shucking (culled) 50% of the scallops at the 60 mm - 65 mm (2.4 - 2.6 inches). During the November 1994 trip, the dominant size of scallops in the catch increased to 85 mm (3.4 inches) and the crews culled 50% of the scallops at 70 mm - 75 mm (2.6 - 3.0 inches). In April of 1995, two predominant sizes were noted in the catch; one at 90 mm - 95 mm (3.5 - 3.7 inches) and the other at 75 mm - 80 mm (3.0 - 3.1 inches). In this case, the crews culled 50% of the scallops at 75 mm - 80 mm (3.0 - 3.1 inches). This data indicated that the size of scallops that are retained at the 50% level, increased approximately 15 mm (0.6 inches) as the size of the scallops increased in the population over time. This shift in culling size to larger scallops can be considered as another positive aspect of increasing the average size of scallops and the number of year classes in the population.

During the April 1995 trip in the mid-Atlantic, both the 3.25 inch and the 3.50 inch ring dredge harvested significant numbers of seed scallops in the 50 mm - 60 mm (2.0 - 2.4 inches) size range which corresponds to the 1993 year class and scallops less than 70 mm (2.8 inches) which are probably part of the 1992 year class. The 3.50 inch ring dredge harvested about 50% fewer seed scallops than the 3.25 inch ring dredge; in either case most of the scallops were discarded. However, it was observed that numerous seed scallops were damaged or crushed by the dredge or during the culling process by the crew. There is only a modest amount of information available relative to discard mortality of juvenile scallops and questions are often asked as to its relative importance.

The sampling procedures used on the deck of the scallop vessel allow the size frequency data to be separated into those scallops retained for shucking and those scallops that will be discarded. Of the discards, counts were made on the number of scallops that were crushed or severely damaged. Analysis of the data indicated that 688 of 12,086 discard scallops harvested by the 3.50 inch ring dredge and 1,434 of 17,681 discard scallops harvested by the 3.50 inch ring dredge were destroyed; this approximates an 8% and a 5% mortality rate respectively (Figure 6).

At offloading, the difference in production for the 3.50 inch ring dredge ranged from -9.7% to -50.1% for the mid-Atlantic region. The largest difference occurred in June 1994 when the resource was dominated by a single year class in the 70 mm - 75 mm (2.8 - 3.0 inches) size range with meat counts at 55 to 60 MPP. Remember, these same scallops were 55 mm - 65 mm (2.2 - 2.6 inches) in November of 1993. The smallest difference, -9.7%, occurred in April 1995. At this time, the scallops in the large year class referred to earlier had grown to 90 mm - 100 mm (3.6 - 3.9 inches) and, in addition there was another year class in the 75 mm - 80 mm (3.0 - 3.2 inches) that were being retained for shucking. These data support the contention that the 3.50 inch ring dredge will cause short-term decreases in landings, but that over time, landings should recover as scallops are allowed to grow in size. It is fortunate that scallops grow rapidly between 50 mm and 100 mm (2.0 - 3.9 inches) which minimizes the time it takes for scallops to be recruited (harvested) by larger ring dredges. Preliminary analysis of the data indicate that scallops between 95 mm - 105 mm (3.7 - 4.1 inches) have an equal chance of being harvested by either a 3.25 inch or a 3.50 inch ring dredge. In the context of time, it would take about one year before the 3.50 inch ring dredge would perform as efficiently, in terms of numbers of scallops, as the 3.25 inch ring dredge.

A summation of shell height frequency data and relative harvest efficiency estimates for all trips in the mid-Atlantic is presented in Figure 20 and 21. Scallops 70 mm - 90 mm (2.6 - 3.5 inches) in size were predominate during the four gear trials conducted from June 1994 to April 1995. This is attributed to the large 1990 year class recruiting to the fishery during that time interval. For the same data, relative efficiency data for the 3.50 and 3.25 inch ring dredge showed a noticeable shift towards harvesting equality for scallops 95 mm - 100 mm (3.7 - 3.9 inches) in size. The same shift towards harvesting equality is noted for the relative efficiencies estimated for all trips including the data from Georges Bank (Figure 23). Preliminary estimates of harvesting equality for the 3.50 and 3.25 inch ring dredge occurs for scallops in the 95 mm - 105 mm (3.7 - 4.1 inches) size range.

The Bottom Line: How Much Do You Lose (Gain) With The 3.50 Inch Rings

The analyses presented, thus far, obviously scares the heck out of anyone whose income depends upon the harvesting of sea scallops. In the Mid-Atlantic, industry is facing a possible reduction of 34+% in number of scallops if they adopt the 3.5 inch rings and discontinue the use of the 3.25 inch rings. Even after adjusting for the fact that most fishermen do not shuck scallops smaller than 70 mm or 2.75 inches, industry still appears destined to experience a loss of 32% in terms of number of scallops harvested.

It is not the number of scallops, however, that is of concern to the industry. It is pounds, prices, and costs that drive industry. It must be remembered that the purpose of the 3.5 inch ring is to advance the age at entry, or increase the average size of scallops harvested while allowing escapement of small scallops. Larger scallops weigh more, have a lower meat count, contribute more to egg production, and often yield a higher price at the dock.

Limited data available from the gear experiments indicate that the growth of sea scallops is phenomenal between 60 and 110 mm or 2.36 and 4.33 inches. Between November 1993 and April 1995, shell size of the 1990 year class increased 48.1% (Figure 24). On a monthly basis, the rate of growth is approximately 2.83%. With this kind of growth, there are obvious reasons why the age at entry should be advanced.

When growth is examined on a weight basis, there are even more compelling reasons for advancing the age at entry. Examination of growth in weight terms for the 1990 year class indicates that weight increased by 233.33% over a 17 month period (Figure 25). It should be remembered, however, that this growth applies only to scallops between 2.36 and 4.33 inches. As scallops age or increase in size, the rate of growth will decrease and approach zero. When growth is assessed relative to meat count, the 1990 year class in November 1993 yielded a count of approximately 100 meats per pound (MPP); in April 1995, these same scallops yielded a meat count of approximately 30 MPP (Figure 26).

The critical issue to industry, however, is not the rate of growth of scallops, but what will happen to income if 3.50 inch rings are required. In order to offer even a limited assessment of this issue, we must examine the rate of growth over time, the efficiency of the 3.50 inch rings relative to the 3.25 inch rings at each shell size, gear and human selectivity, and the relationship between shell size and weight or product yield.

The Growth Equations:

As previously stated, data on growth are limited. In fact, there were only five time periods from the gear experiments which could be used to assess growth. Growth over time, however, has been estimated and the estimates are available in the Fishery Management Plan for sea scallops. Utilizing a simple growth model that allowed shell size to increase at an increasing rate, increase at a decreasing rate, reach a maximum, and decrease, the relationship between shell size and number of months was estimated:

(1) $\ln SH = 4.12714 + .008839 MONTHS + .07999 \ln MONTHS$

where SH equals shell height in millimeters, months is number of months between observations, and ln indicates natural logarithm. The adjusted R^2, after correcting for first-order autocorrelation, equalled 0.979. The estimates do not conform to the concept of providing a maximum shell height and subsequently decreasing. This is likely the result of available data. At best, the estimated growth equation is applicable only to scallops between 60 and 110 mm (Figure 27). The limited model does, nevertheless, permit a crude assessment of how scallops grow over time.

A similar model for meat weight of scallops was also estimated relative to time or months:

$\ln WT = 1.47687 + .03386 \ln MONTHS + .06366 \ln MONTHS$

where WT is weight in grams. The adjusted R^2, after correcting for first-order autocorrelation, was 0.958.

The Shell-Height, Meat-Weight Relationship:

Using the estimated growth equations relative to shell height and meat weights, values for shell height and meat weight were estimated for a 28 month period. These estimates of shell height and meat weights provided a basis for estimating the relationship between meat weight and shell height:

$\ln WT = -18.39814 + 4.7044 \ln SH$

where WT and SH are estimated values of WT and SH obtained from the shell size and weight growth equations. The adjusted R^2 for the weight-length relationship equalled 0.965.

Relative Efficiency:

The last part of the system of equations necessary to assess the economic performance of the 3.5 inch rings relative to the 3.25 inch rings is relative efficiency. In the study, relative efficiency is defined as the ratio of the number of scallops harvested with the 3.5 inch rings to the number of scallops harvested with the 3.25 inch rings (Table 5). Preliminary analysis revealed no statistically significant differences between number of scallops harvest with the 3.5 and 3.25 inch rings at a size of 95-100 mm. This was determined by an analysis of the number of scallops using a Poisson or count regression model; results are omitted from this report but obtainable from the authors.

The shell size ranges critical for assessing the economic impacts of the 3.5 inch rings relative to the 3.25 inch rings are 85-90 and 95-100 mm. The study assumes that the 3.25 inch ring is 100% efficient for scallops between 85 and 90 mm. This does not mean that all scallops between 85 and 90 mm in the path of the dredge are harvested, but rather that the dredge is operating at maximum efficiency for this size range of sea scallops. We further assume 100% efficiency for larger scallops relative to the 3.25 inch ring dredge. Since the analysis revealed no statistically significant differences in number of scallops between the 3.25 and 3.5 inch rings once scallops were 95-100 mm in height, it was assumed that scallops between 95 and 100 mm were consistent with maximum efficiency for the 3.5 inch ring dredge.

Economic Performance or
the Bottom Line:

To gain a better appreciation of the importance of advancing the age at entry, we consider the case of allowing the 1990 year class observed in November 1993 to remain unharvested until April 1995. We also assume a natural mortality of 20% per year or 1.667% per month. Alternatively, we assume an annual survival rate of 80%. By not harvesting the scallops between 62.16 and up to 90 mm and allowing them to grow between November 1993 and April 1995, industry realizes a 147.11 percent increase in production Table 6). Alternatively, scallops that had an average shell height of 62.16 mm (2.45 inches) in November 1993 decreased to 92.5 mm (3.64 inches) by April 1995. The average meat count increased from approximately 100 meats per pound to 30 meats per pound over a 17 month period. Even after adjusting for natural mortality, the one pound of 100 count scallops in November 1993 increased to 2.47 pounds of 30 MPP scallops by April 1995.

If we consider a price of \$4.50 per pound, the one pound of 100 MPP scallops in November 1993 were worth \$4.50; those same scallops yielded the fishermen \$11.12 in April 1995. In essence, this is equivalent to an individual depositing \$4.50 in the bank in November 1993 and earning an annual rate of interest of 89.32%. That is a phenomenal rate of interest.

Now, what about the 3.5 inch relative to the 3.25 inch rings? Standardizing our number of scallops caught by size and 50 hours of fishing time, we can assess the marginal changes in performance of the 3.5 inch rings. For 50 hours of fishing, the 3.25 inch rings yielded, on average, 22,448 scallops or when converted to both dredges and pounds approximately 1,397.45 pounds of 85-90 mm (3.44 inch) scallops (Table 7). If the 3.50 inch rings were used, 50 hours of fishing would yield approximately 917.684 pounds of the same size scallops. If the difference in catch (7,771 scallops) of 85-90 mm scallops were allowed to grow for six months, 449.298 pounds would be harvested by the 3.5 inch ring dredge. The remaining scallops, those not harvested by the 3.5 inch ring dredge, would yield 229.312 pounds five months later. In total, the 3.5 inch ring dredge allowed 1,596.2 pounds to be harvested over 11 months while the 3.25 inch ring dredge only allowed 1,397.45 pounds to be harvested.

If the price per pound were $5.00 per pound, a vessel using the 3.25 inch ring dredge and harvesting all 22,448 85-90 mm scallops would earn $6,987.25 for 50 hours of fishing. In comparison, a vessel using the 3.50 inch ring dredge would earn $4,588.42 in the initial harvest. Because of growth over the next 11 months, however, the vessel using the 3.5 inch rings would earn $7,981.47; this represents a gain of $994.22. Alternatively, we can view this as though the fishermen invested $2,398.83 and 11 months earned 994.22 in interest. This gain equates to an annual rate of interest of 45.98%.

In simple terms, the marginal benefits of increasing ring size to 3.5 inches appear to be quite substantial. The preceding analysis is, however, quite limited in that there are many unknown factors which have not been considered. Imports could change and affect domestic prices over time. At this point, the possible ramifications of imports have not been analyzed. The 3.50 inch rings also could increase or decrease the cost of fishing; the possible changes in fishing costs have not yet been analyzed. Considerable more analyses must be done before a precise assessment of the benefits and costs of changing to 3.5 inch rings can be made.

Reference

DuPaul, William D. and James E. Kirkley. 1994. Harvest efficiency and size selectivity of 3.00 and 3.25-inch sea scallop dredge rings. Virginia Marine Resource Report 94-5. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia.

APPENDIX A.

LIST OF TABLES

Table 1.

AVERAGE MEAT COUNTS

MEATS PER POUND (MPP)

		RING SIZE (INCHES)		
RESOURCE AREA	DATE	3.0	3.25	3.50
Mid-Atlantic	06/94	-	57	53
Mid-Atlantic	08/94	-	47	43
Mid-Atlantic	11/94	-	44	41
Mid-Atlantic	04/95	-	36	33
Georges Bank NE	08/94	-	28	21
Georges Bank SE	09/94	-	42	39
Georges Bank CAN	09/94	-	33	33
Georges Bank SC	09/94	67	-	53

Table 2.

OFFLOADING WEIGHTS

POUNDS

		RING SIZE (INCHES)		
RESOURCE AREA	DATE	3.25	3.50	% Difference
Mid-Atlantic	06/94	3633	1813	- 50.1
Mid-Atlantic	08/94	3394	2621	- 22.8
Mid-Atlantic	11/94	1463	990	- 32.3
Mid-Atlantic	04/95	1966	1775	- 9.7
Georges Bank	08-09/94	4925	5022	+ 2.0

Table 3.

YEAR CLASS COMPOSITION OF SCALLOPS
IN THE MID-ATLANTIC REGION

November 1993 - April 1995

(Modal Shell Heights)

Year Class	1990	1991	1992
Nov. 1993	60-65 mm (100+ MPP*)		
June 1994	70-75 mm (57 MPP)		
Aug. 1994	75-80 mm (56 MPP)	50-55 mm (150+ MPP)	
Nov. 1994	80-85 mm (48 MPP)	50-55 mm (150+ MPP)	
Apr. 1995	90-95 mm (30 MPP)	75-80 mm (50 MPP)	50-55 mm (150+ MPP)

*MPP = meats per pound.

Table 4.

SCALLOP MEAT PRODUCTION

ESTIMATED USING SH:MW RELATIONSHIPS

	RING SIZE (INCHES)			
RESOURCE AREA	3.25	3.50	3.00	% Difference
Georges Bank NE	569	507	-	- 10.9
Georges Bank SE	280	280	-	- 0.0
Georges Bank CAN	5122	5431	-	+ 5.7
Georges Bank SC	-	607	343	- 43.5

Table 5. Relative efficiency between the 3.5 and 3.25 inch rings in the mid-Atlantic resource area based on 50 hours of towing time.

Shell Height	3.25 inch	3.5 inch	Efficiency[a]
20-25	3	3	100.00
25-30	27	13	48.15
30-35	223	100	44.84
35-40	861	435	50.52
40-45	2326	1103	47.42
45-50	3791	2065	54.47
50-55	4926	2963	60.15
55-60	2955	1661	56.21
60-65	3230	1931	59.78
65-70	9330	5262	56.38
70-75	28318	17616	62.21
75-80	49804	32845	65.95
80-85	46467	30639	65.94
85-90	22448	14677	65.38
90-95	10388	7428	71.51
95-100	5348	4900	91.62
100-105	3247	3049	93.90
105-110	1802	1611	89.40
110-115	1012	1045	103.26
115-120	768	753	98.05
120-125	509	608	119.45
125-130	452	446	98.68
130-135	334	331	99.10
135-140	209	211	100.96
140-145	107	99	92.52
145-150	50	37	74.00
150-155	14	21	150.00
155-160	2	2	100.00
160-165	1	2	200.00
165-170	1	0	0.00

[a]Relative efficiency is measured as the ratio of number of scallops caught by the 3.5 inch ring to the number caught by the 3.25 inch ring.

Table 6. Amortized valuation of scallops from 62.16 (2.45 in) to 92.05 mm (3.62 in), November 1993 through April 1995.

Month	Year	Shell Height	Meat Count	Weight pounds	Price $4.50	Price $3.00
November	1993	62.16	100	1.00	4.50	3.00
June	1994	78.87	57	1.54	6.93	4.62
August	1994	80.17	56	1.52	6.84	4.56
November	1994	82.03	48	1.69	7.61	5.07
April	1995	92.50	30	2.47	11.12	7.41
Total gain in weight and revenue:				147.00%	147.00%	147.00%

Annual rate of interest realized: 89.32% per year.

Table 7. Economic performance of 3.5 inch ring relative to 3.25 inch ring.

Shell Size	Pounds Harvest 3.25 in	Pounds Harvest 3.50 in	Meat Count	Revenue ($5.00/lb) 3.25	Revenue ($5.00/lb) 3.50
85-90	1397.45	917.68	32.13	6987.25	4588.42
90-95	0.00	449.30	24.74	0.00	2246.49
95-100	0.00	229.31	19.31	0.00	1146.56
Total Harvest:	1397.45	1596.29			
Total Revenue:				6987.25	7981.47
Revenue Gain					994.22

Overall gain in revenue: 14.23%

Income lost in first period by using 3.5 inch rings: $2,398.83

Income earned after 11 months by using 3.5 inch rings: $3,393.05

If fishermen invested $2,398.83 and allowed to earn 45.98% interest per year, interest plus deposit equals $3,393.05.

APPENDIX B.

LIST OF FIGURES

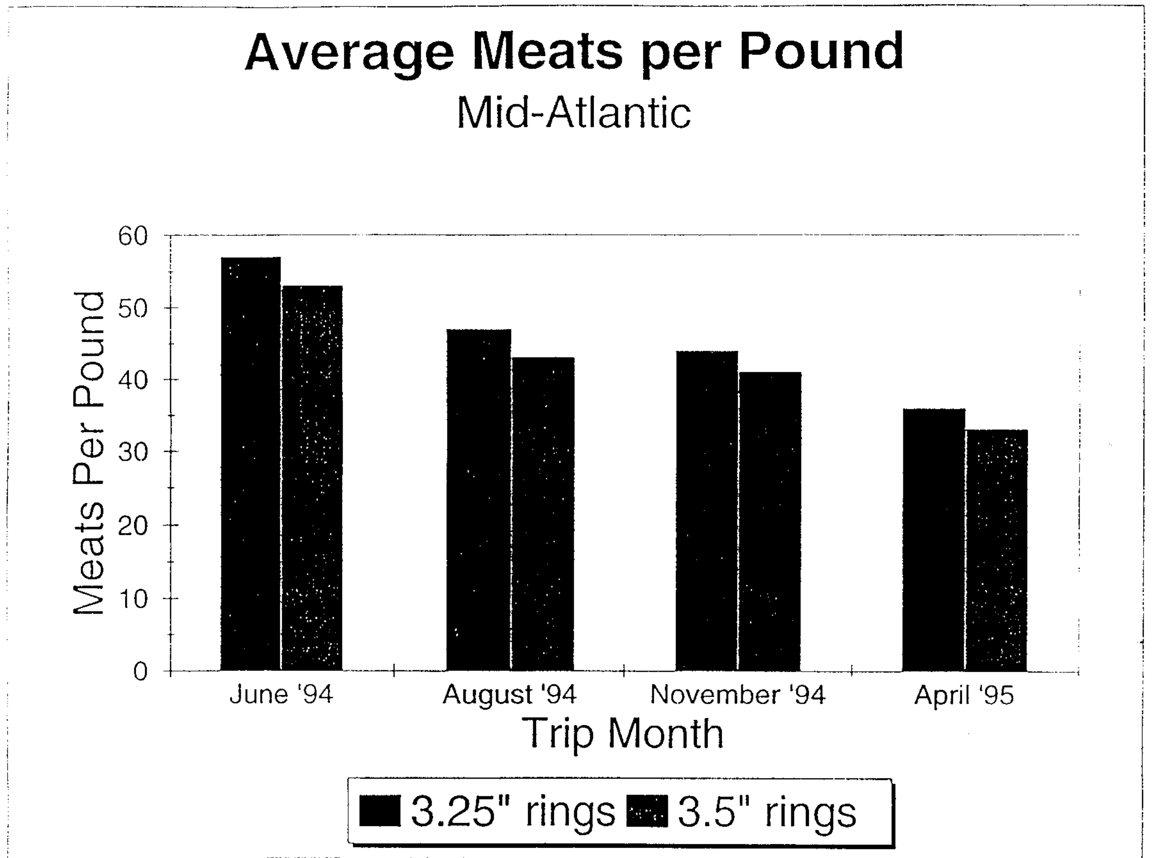


Figure 1.

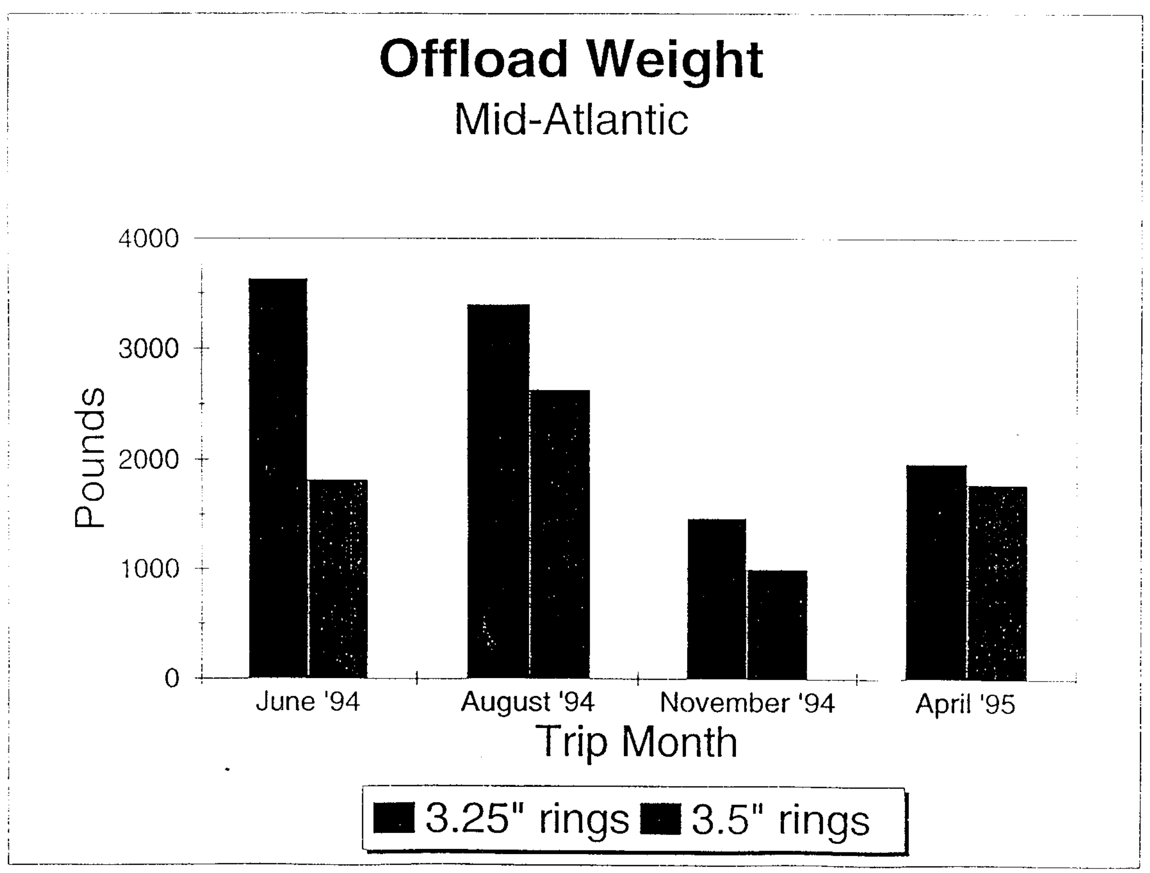


Figure 2.

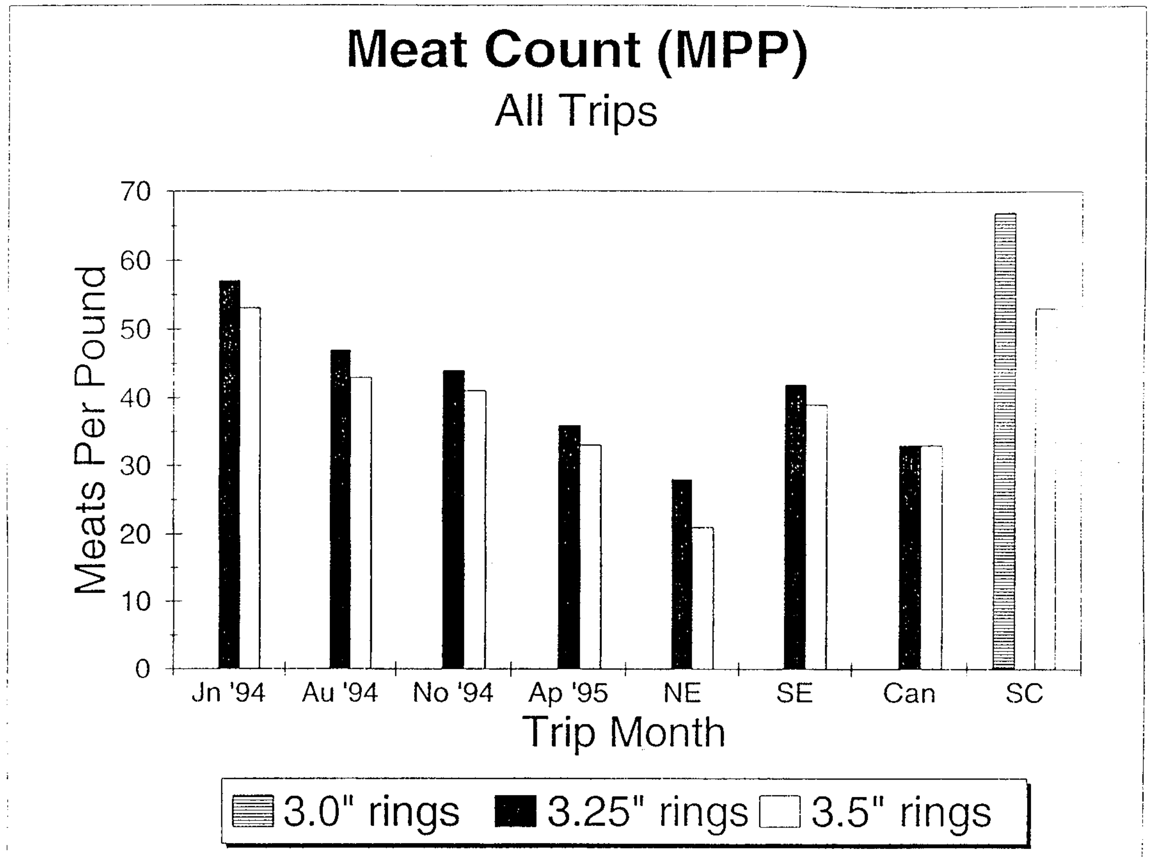


Figure 3.

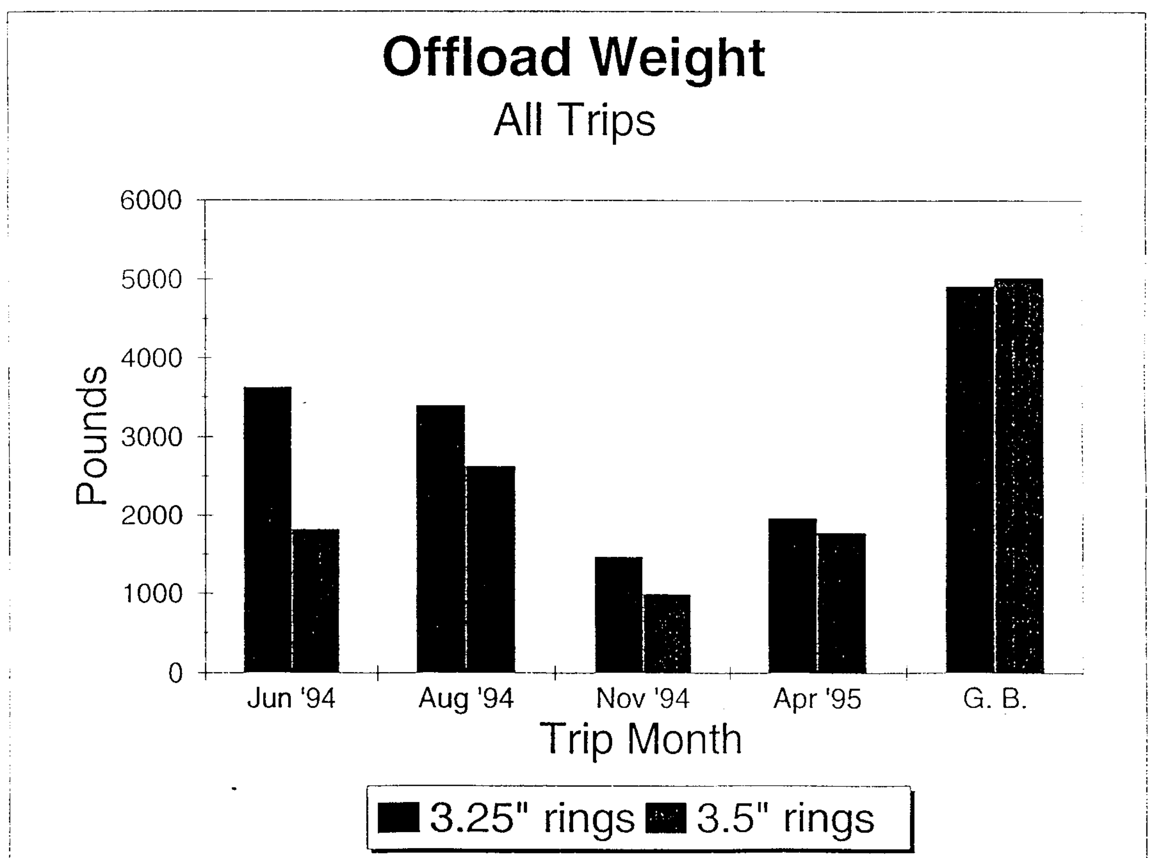
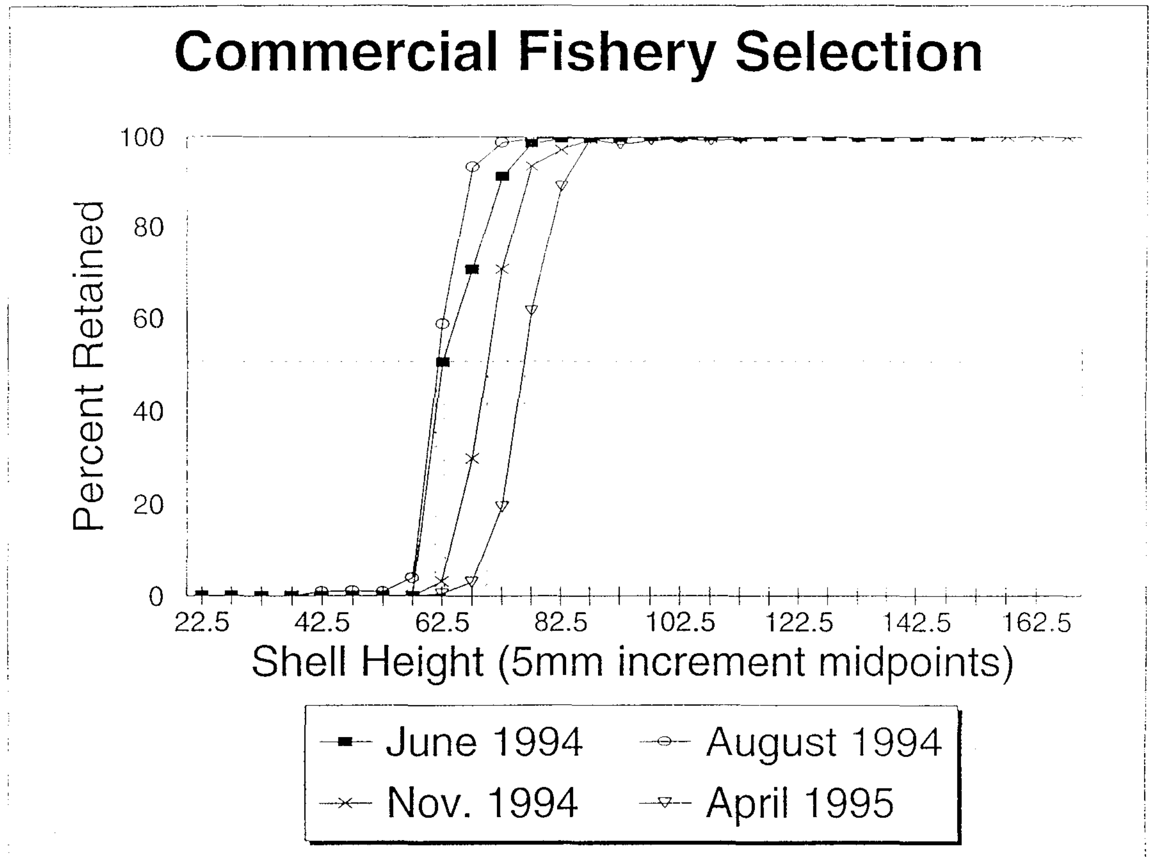


Figure 4.



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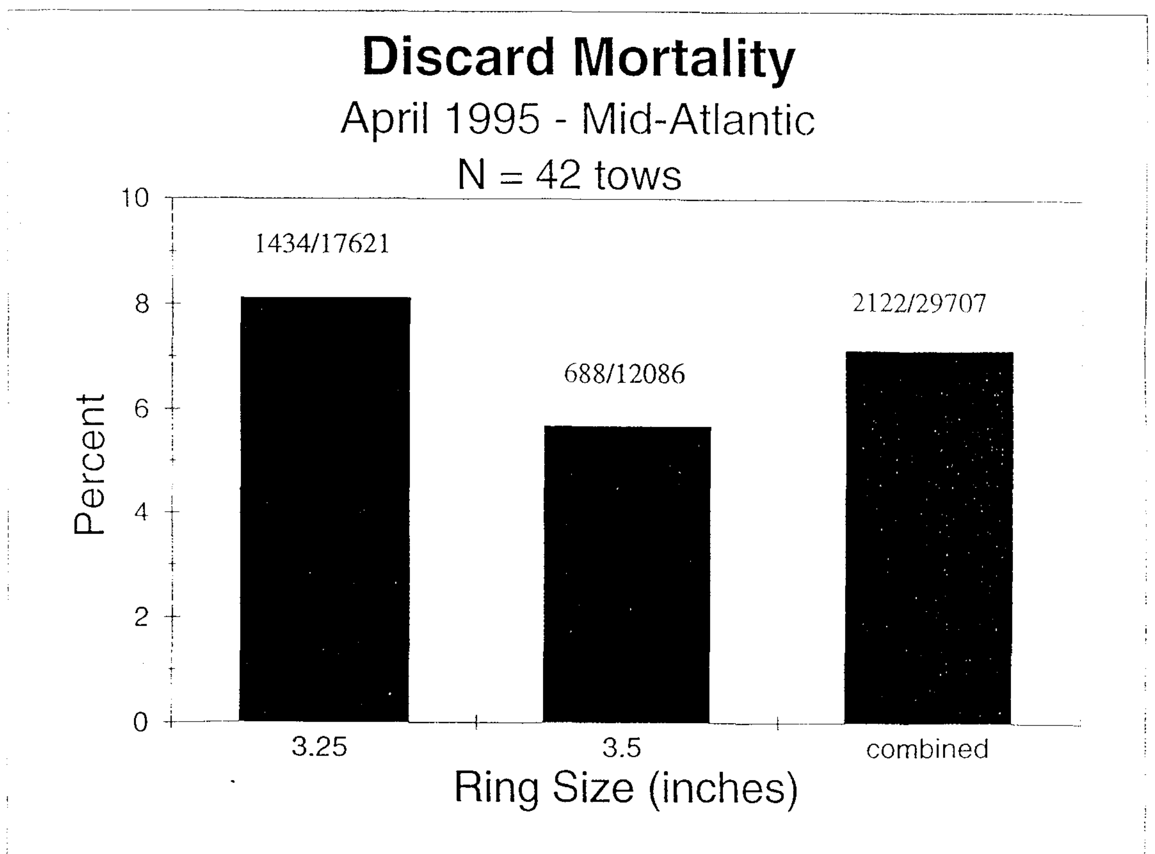

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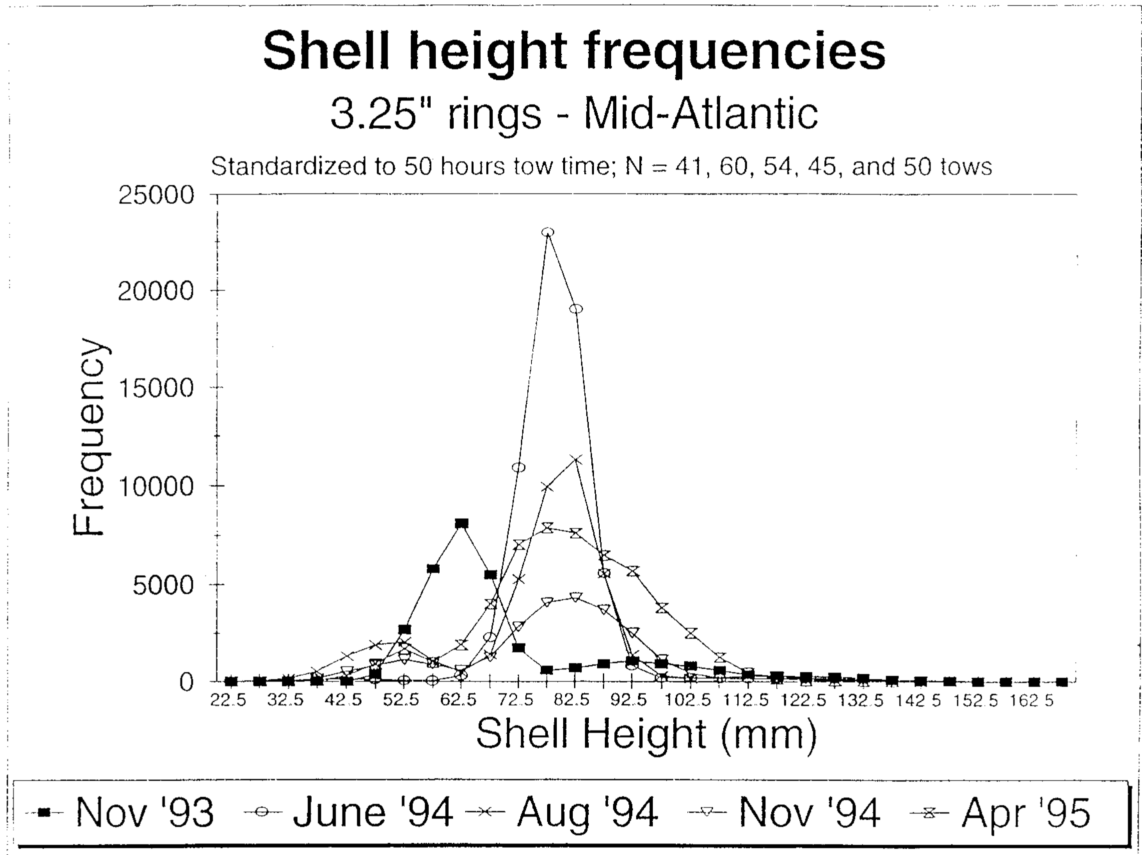

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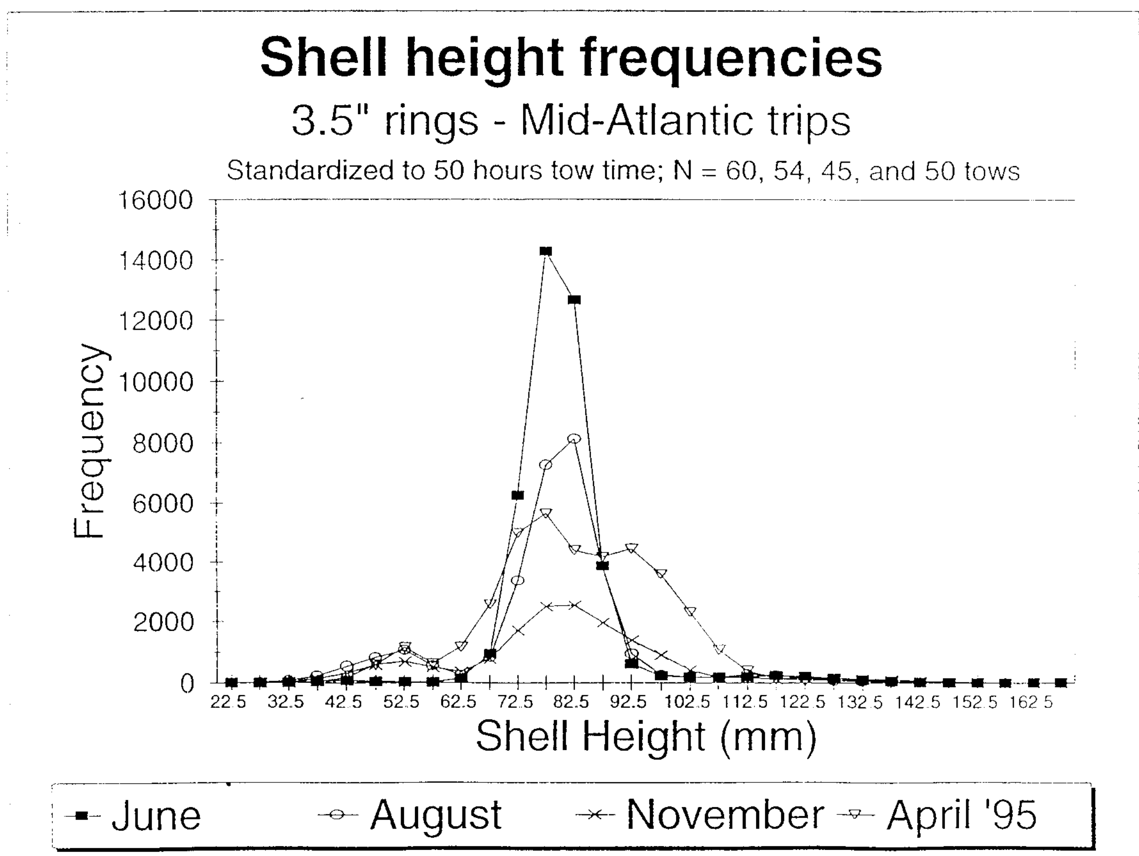

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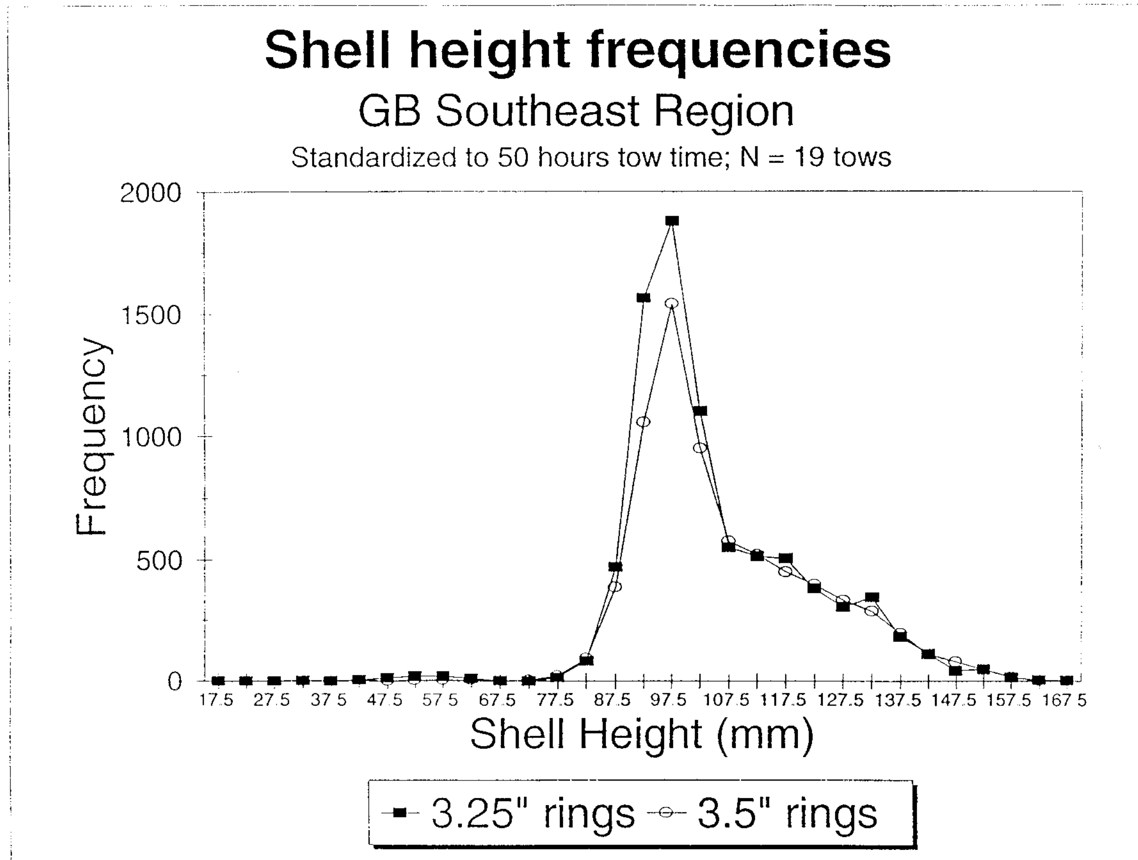

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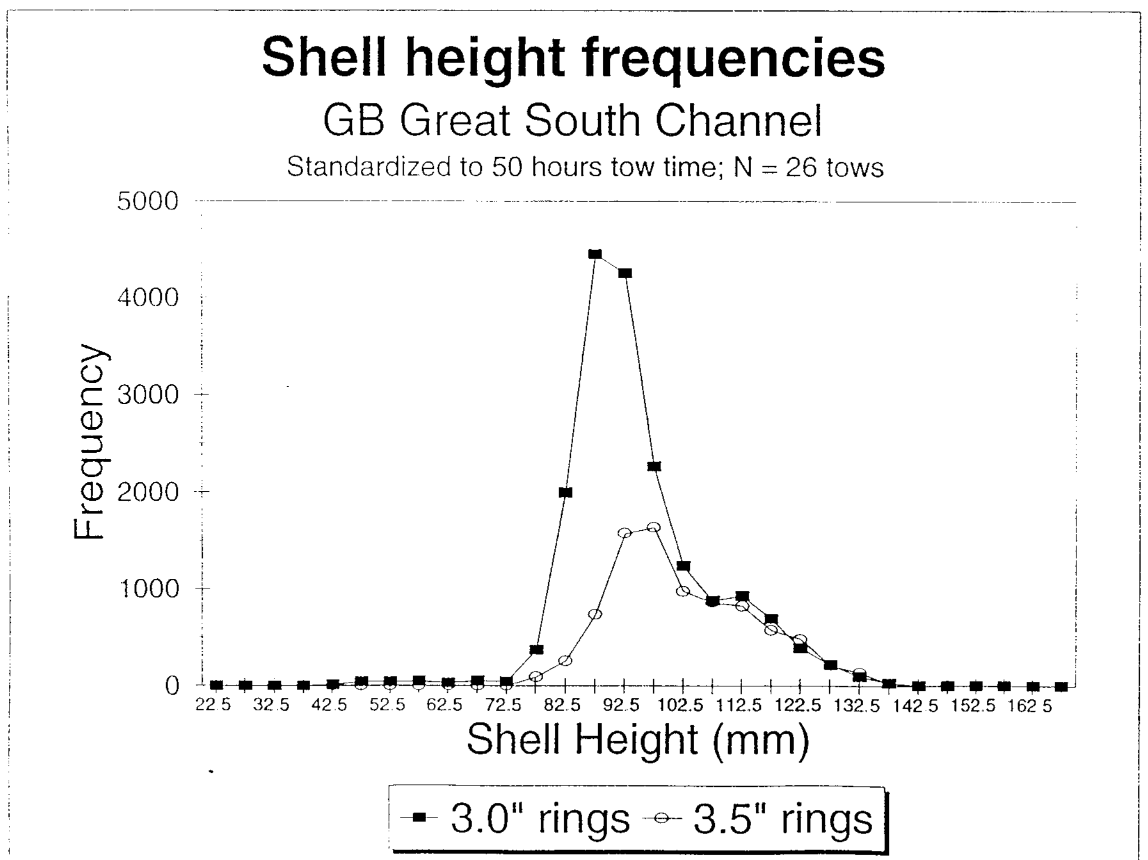

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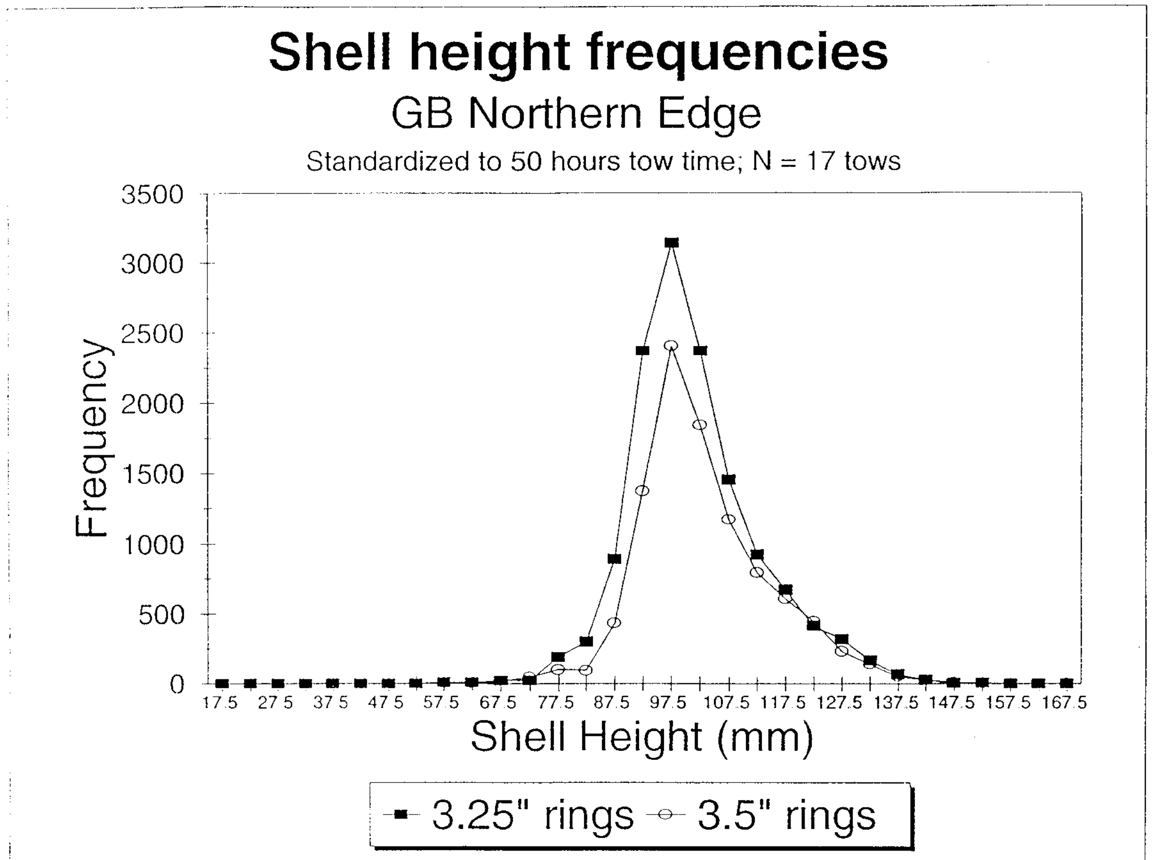

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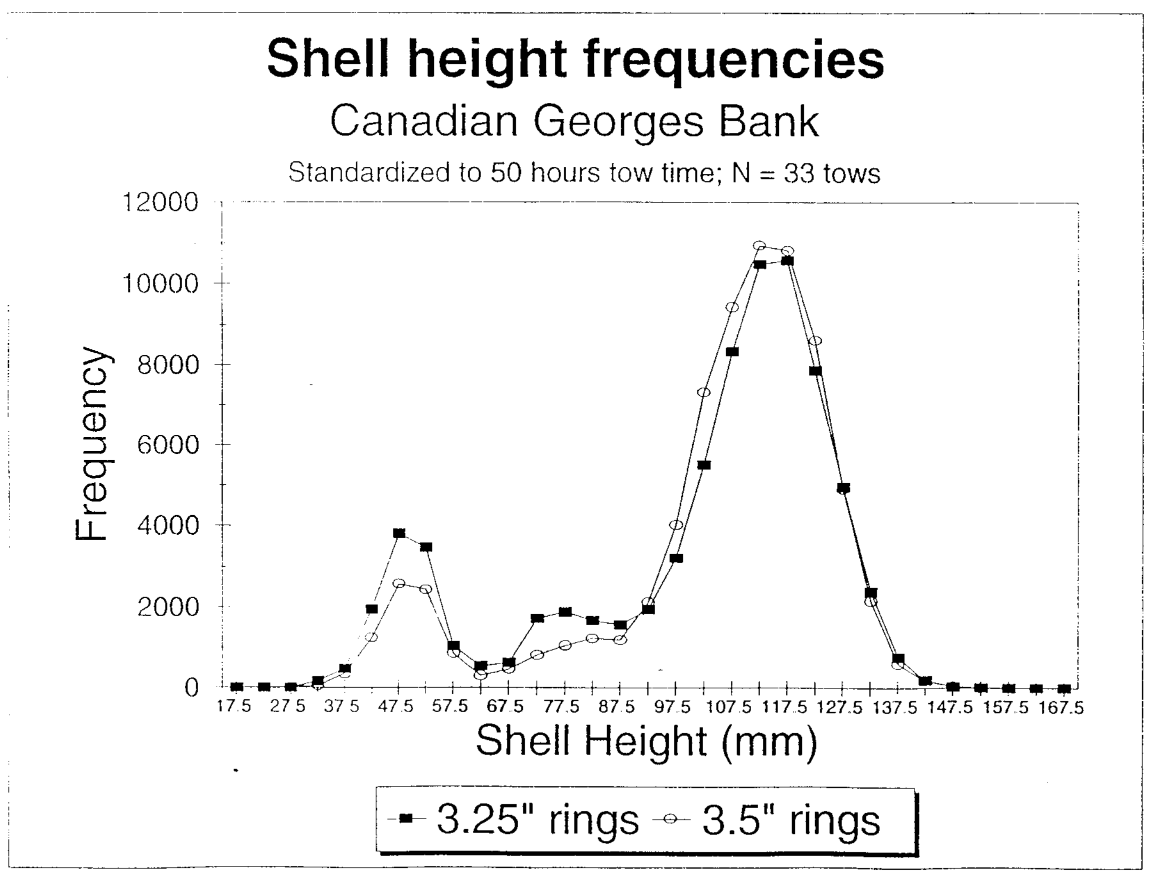

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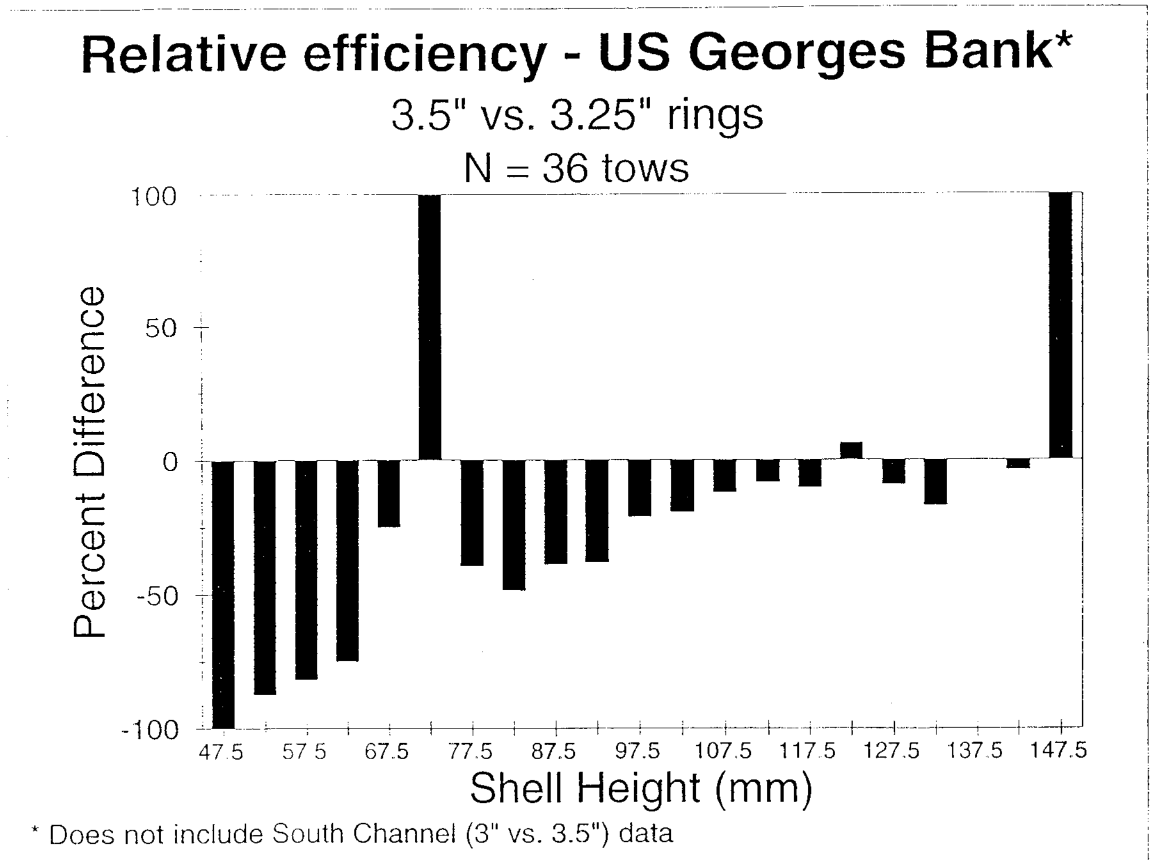

Relative efficiency - US Georges Bank*
3.5" vs. 3.25" rings
N = 36 tows
Percent Difference
100
50
0
-50
-100
47.5
57.5
67.5
77.5
87.5
97.5
107.5
117.5
127.5
137.5
147.5
Shell Height (mm)
* Does not include South Channel (3" vs. 3.5") data

Figure 13.

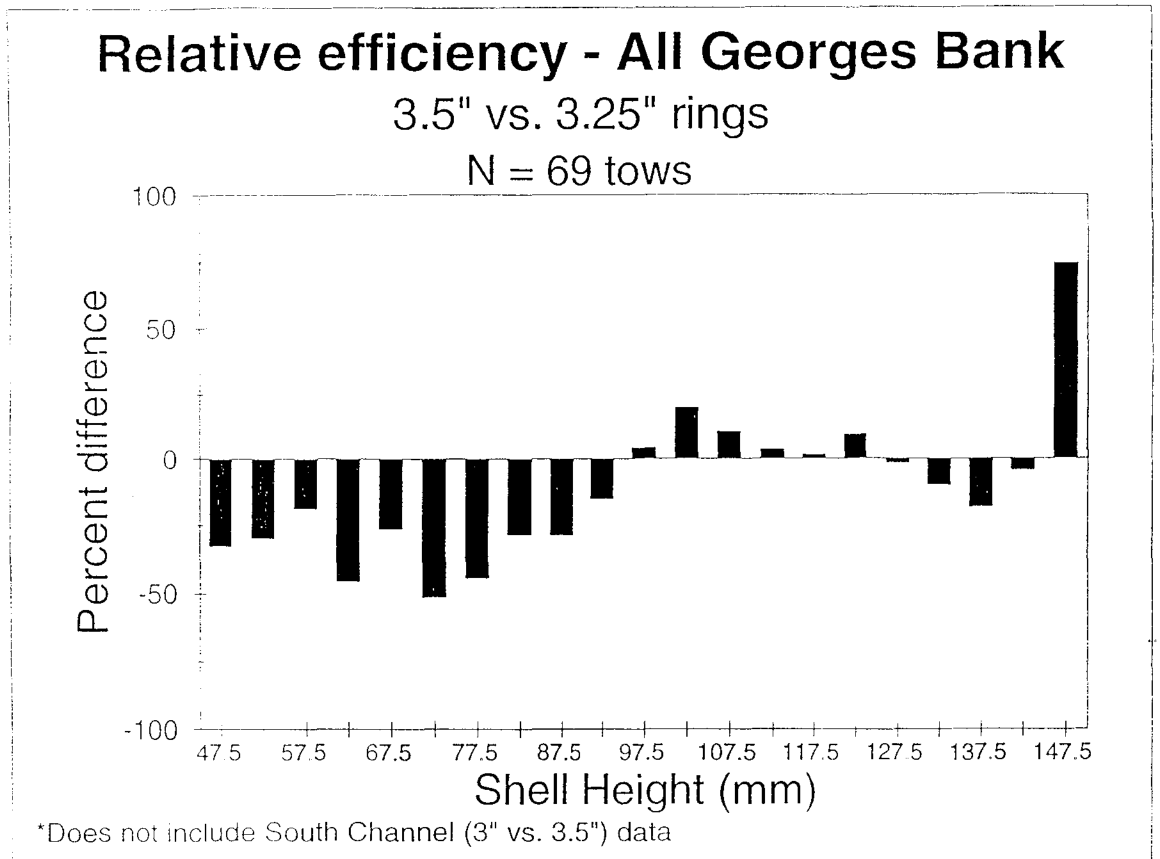
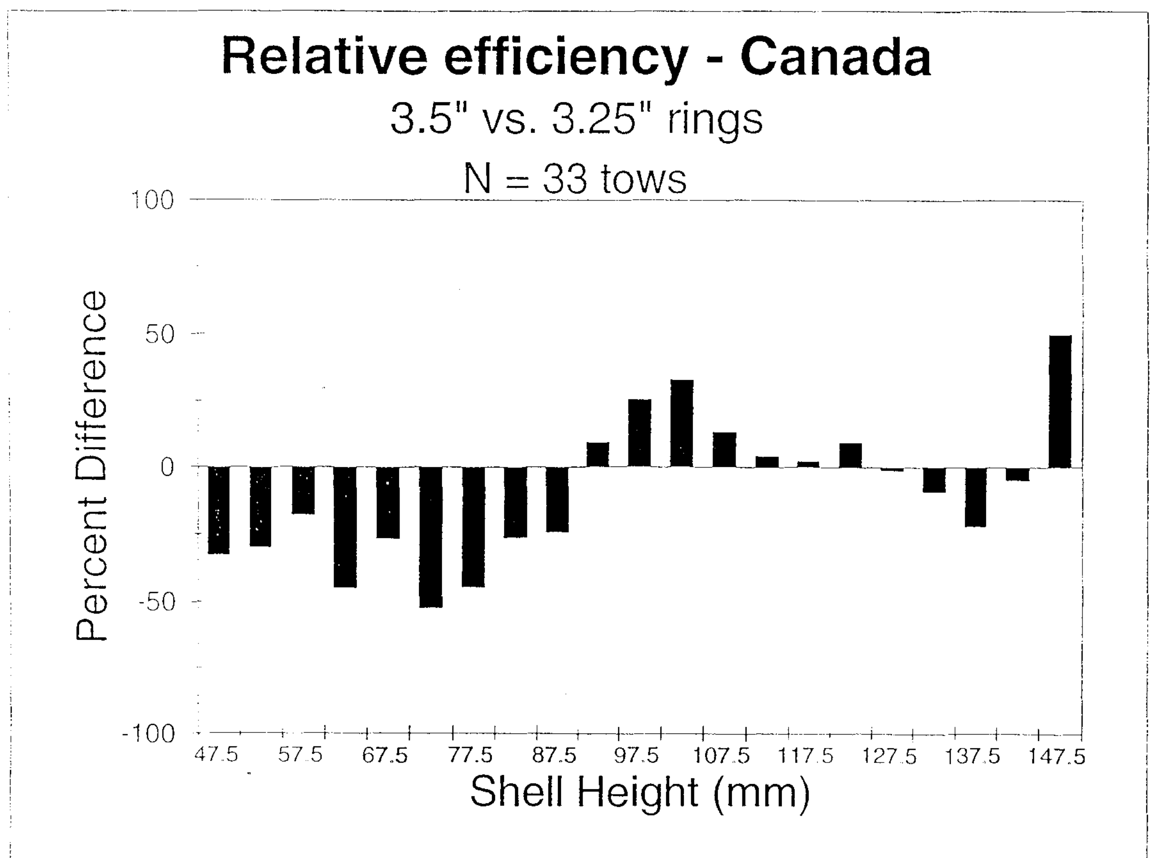


Figure 14.



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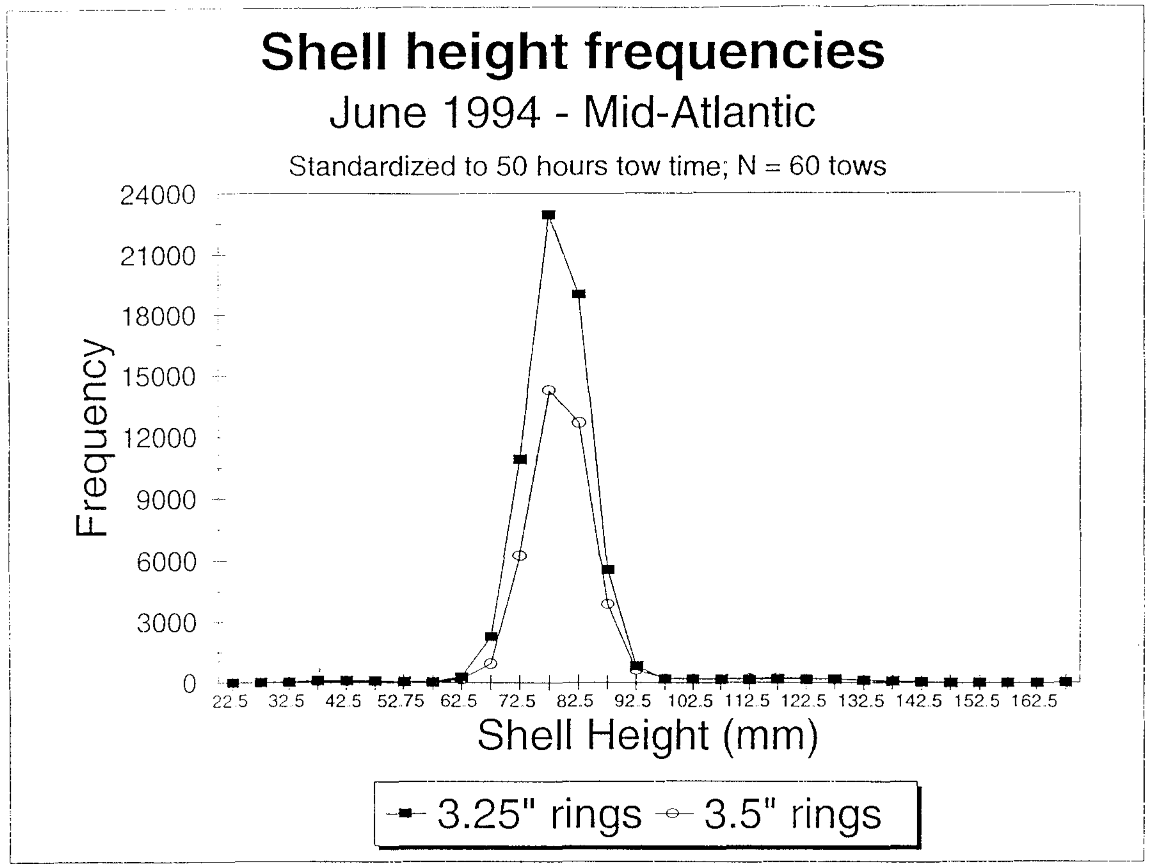


Figure 16.

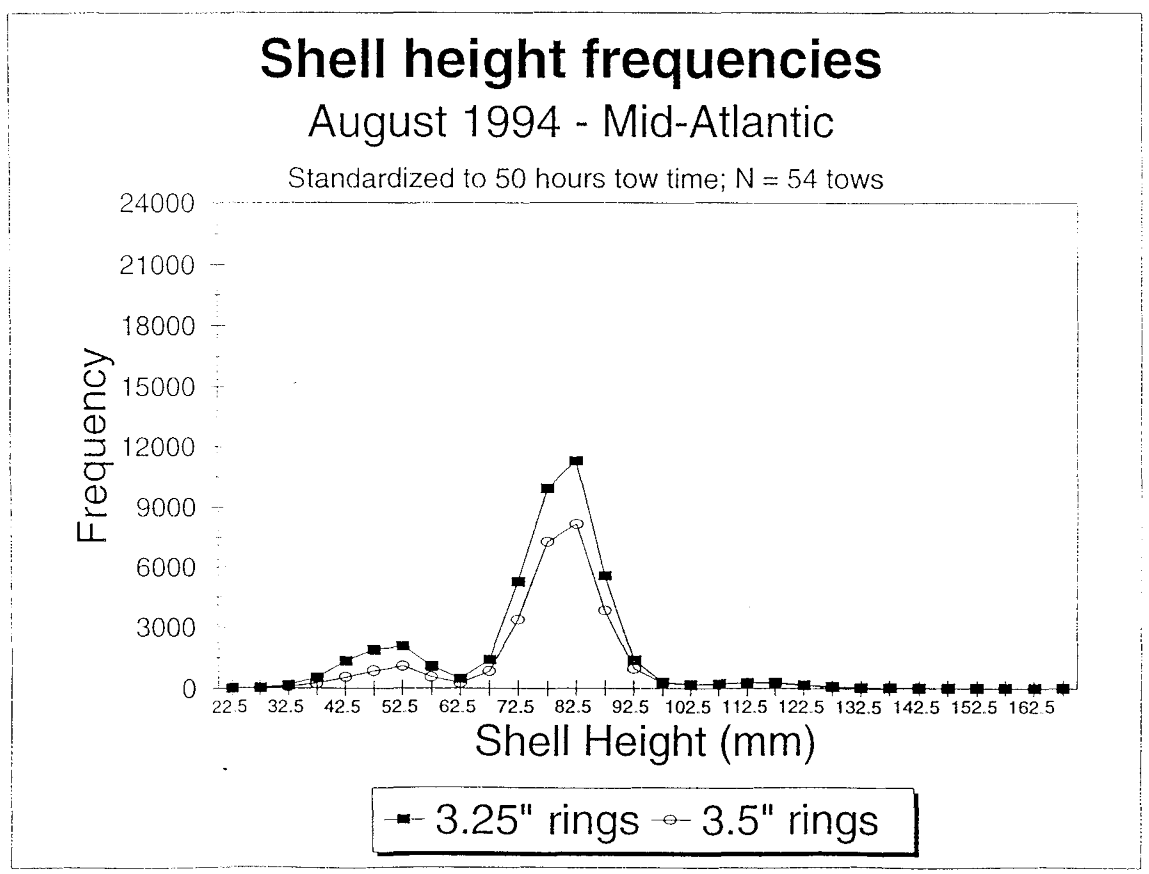
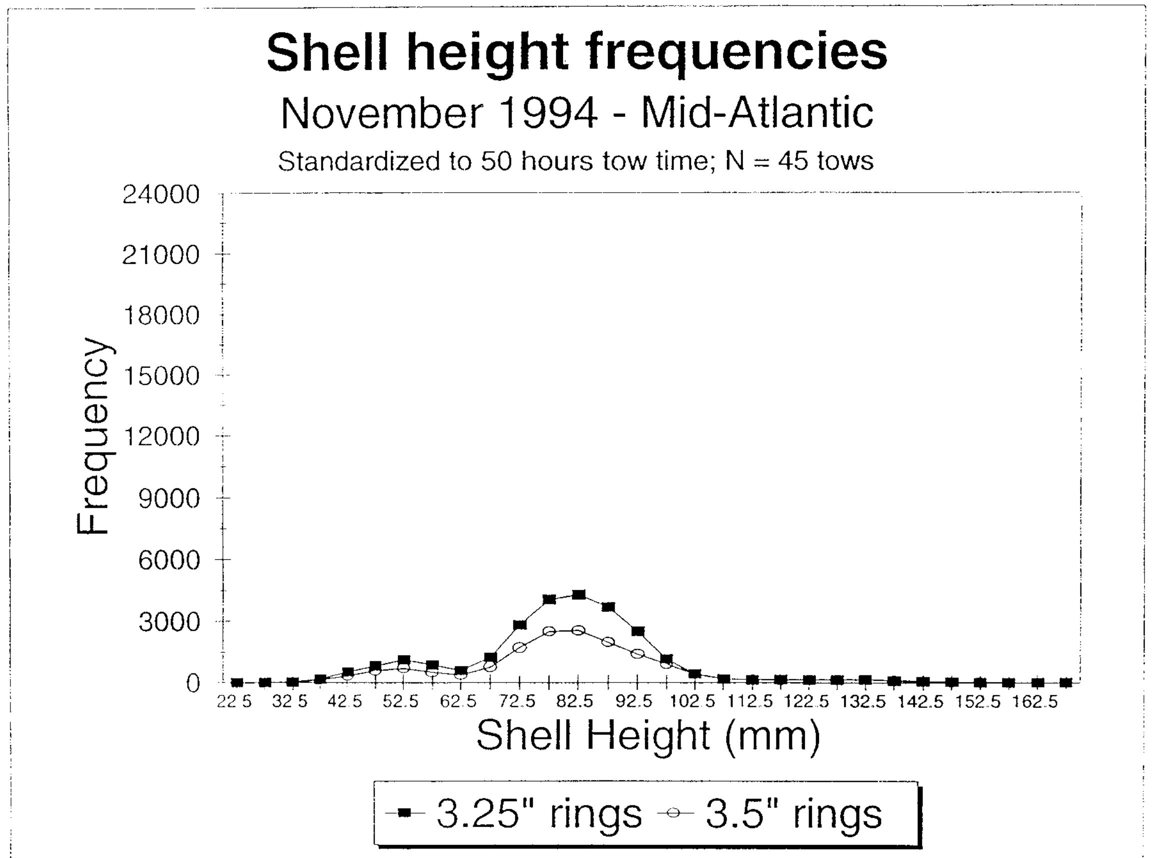


Figure 17.



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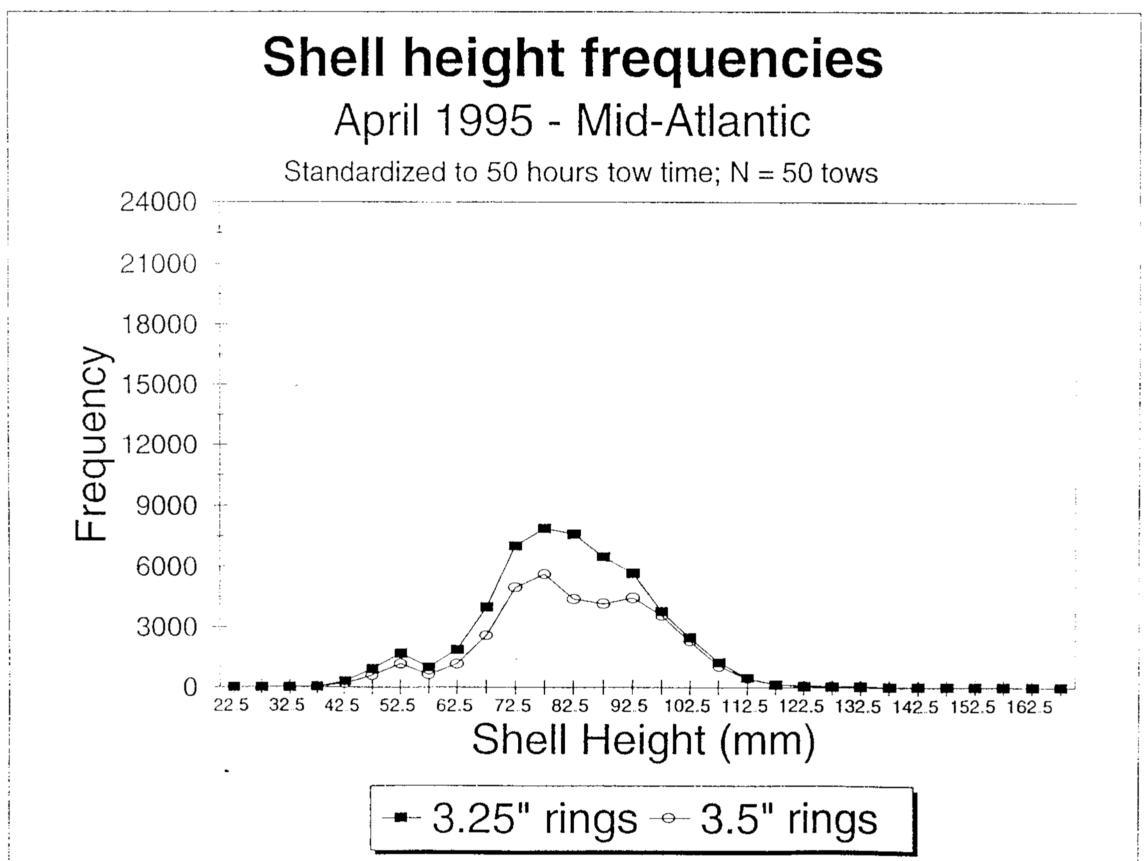

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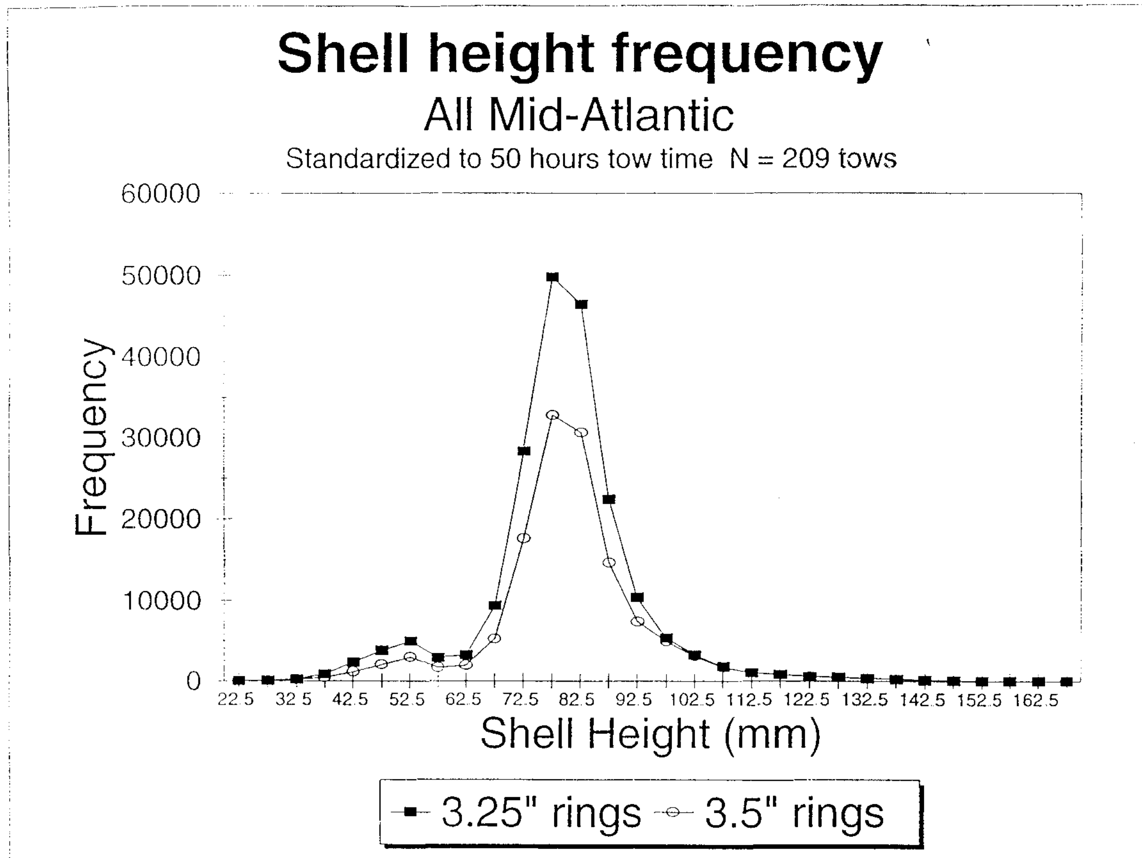

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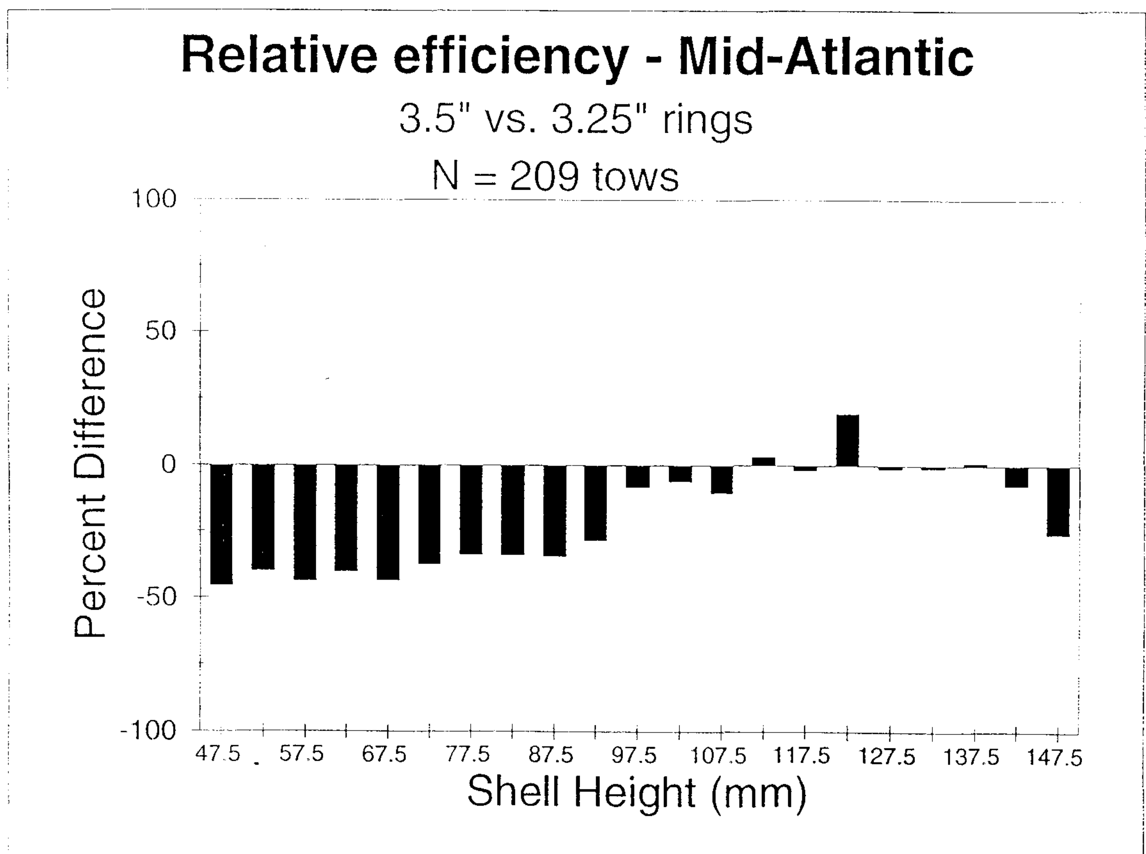
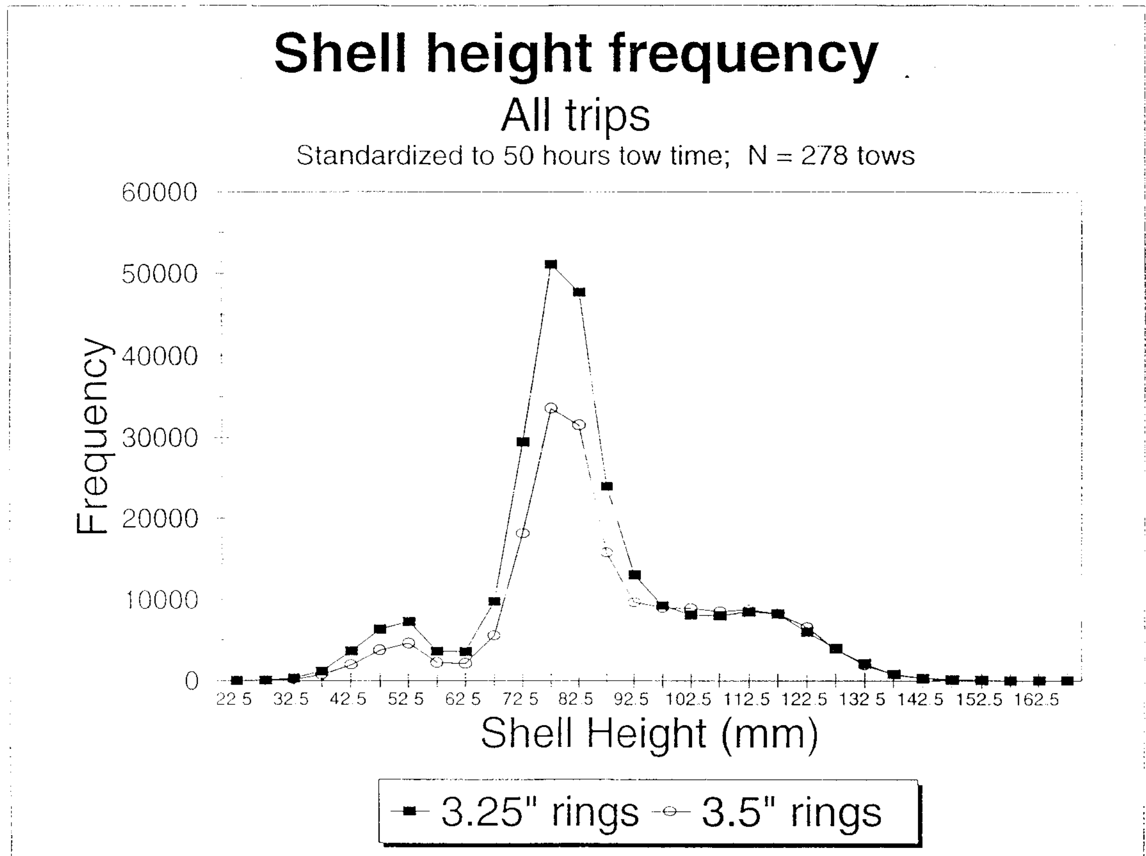


Figure 21.



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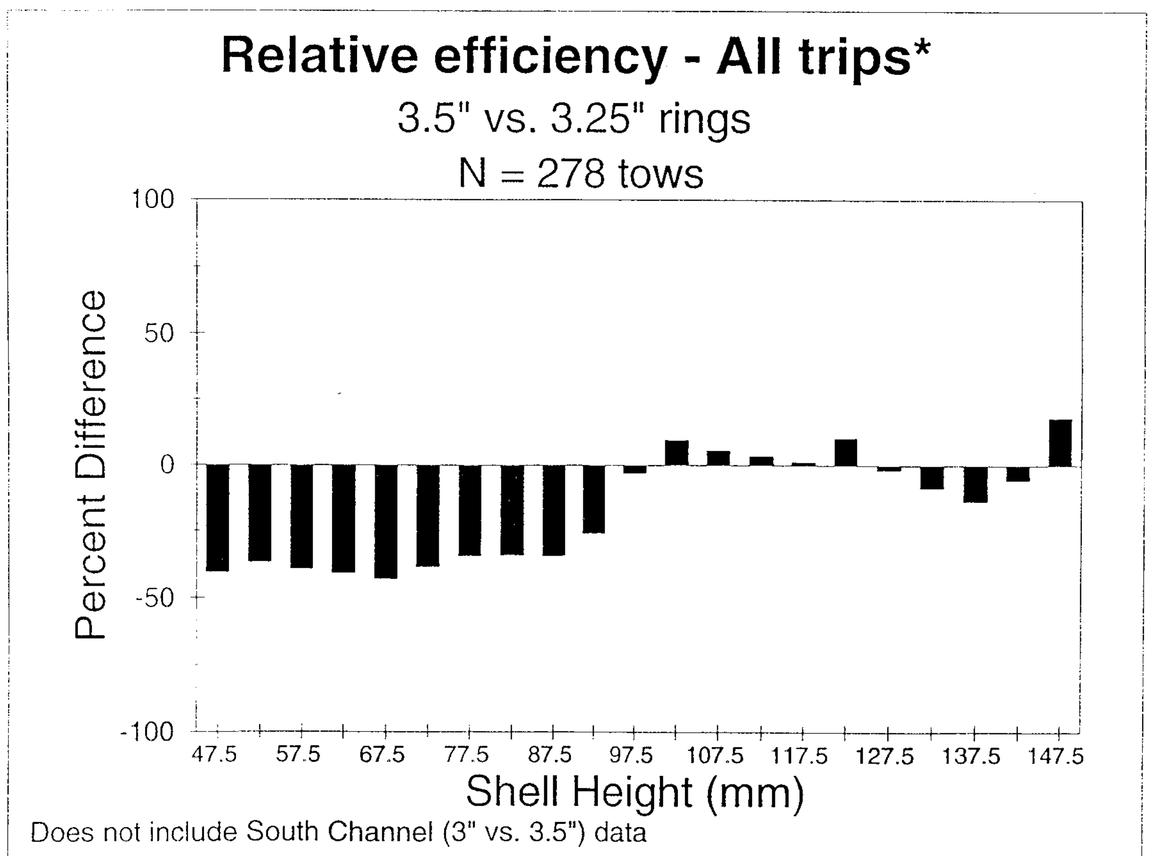


Figure 23.

Figure 24. Growth of 1990 year class between November 1993 and April 1995

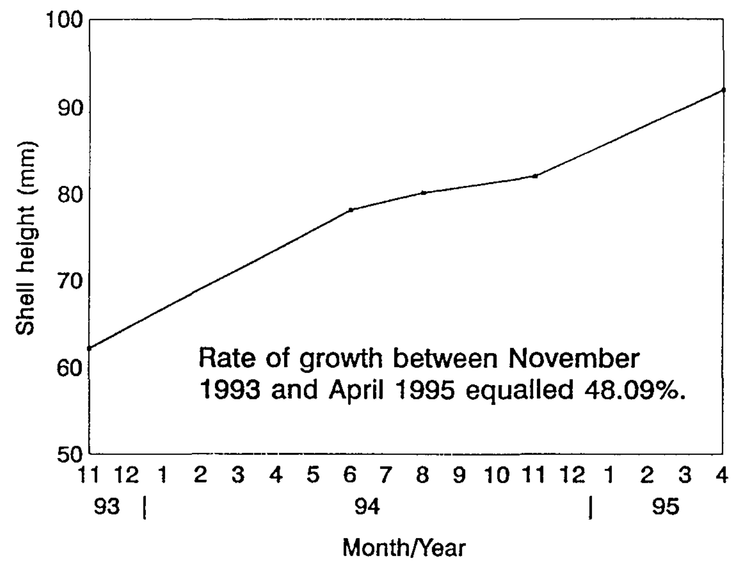


Figure 25. Growth of 1990 year class between November 1993 and April 1995

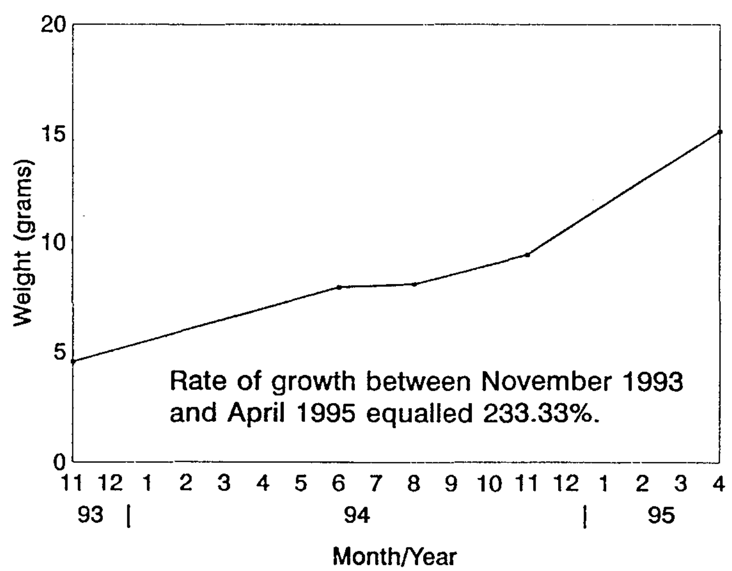


Figure 26. Growth of 1990 year class between November 1993 and April 1995

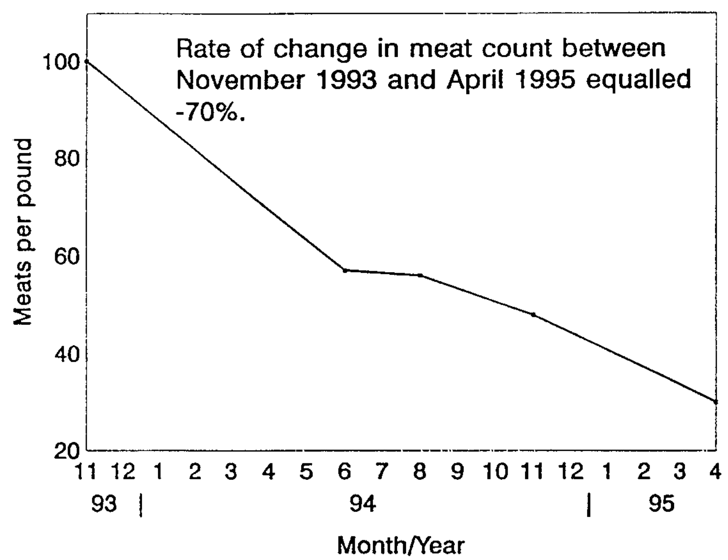
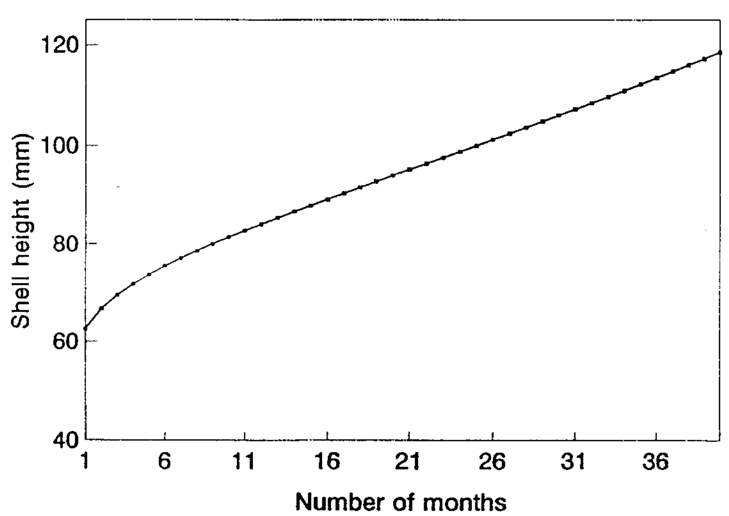


Figure 27. Growth of sea scallops over time



Number of months does not equal age of scallops