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Fishery independent standing stock surveys of oyster populations in the Virginia sub estuaries of the Chesapeake Bay and a comparison with continuing estimates obtained from fishery dependent data

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Report for the period October 1, 1993 - September 30, 1994

submitted to:

The Chesapeake Bay Stock Assessment Committee:
attention: M. Elizabeth Gillelan, Division Chief
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National Marine Fisheries Service
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by

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for the program entitled:

Fishery independent standing stock surveys of oyster populations in the Virginia sub estuaries of the Chesapeake Bay and a comparison with continuing estimates obtained from fishery dependent data

Investigators: Dr. Roger Mann (SMS/VIMS) and Dr. James Wesson (VMRC).

date of report submission: November 4, 1994

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Introduction

History of the Virginia oyster resource and the need for stock assessment

Extensive description of the Virginia oyster resource and history of its utilization has been given by Haven, Hargis and Kendall (1981), and more recently reviewed by Hargis and Haven (1988). These contributions, among many others, describe a state of continuing decline. To facilitate resource management a fishery independent survey was proposed to and subsequently supported by the Chesapeake Bay Stock Assessment Committee in 1993. This report covers activity on that program for the period October of 1993 through September of 1994.

Spatial variability in distribution of oysters within an oyster reef system, and distribution of reefs in the intertidal and/or subtidal regions complicate fishery independent estimation of standing stock. By contrast, fishery dependent estimates of oyster standing stock can be made, where adequate data on effort and temporal changes in landings exist, through application of Leslie-DeLury regression analysis (Barber and Mann, 1991). Intensive, fishery independent estimates are rare but pivotal to examination of spawning capabilities of broodstock supporting commercial fisheries and related requirements for establishment of fishery catch quotas. The James River, Virginia has served as the focal point for the Virginia oyster industry for over a century, being the source of the majority of seed oysters that were transplanted for grow-out to locations within the Virginia portion of the Chesapeake Bay and much further afield in the Middle Atlantic states (Haven et al, 1981). The Rappahannock River in Virginia was, for many years, a source of large and valued oysters for both the shucking and half shell trade. It is surprising that comparatively little effort has been previously expended to estimate standing stock in both the James and Rappahannock Rivers given the acknowledged need for such data in fishery management. Continuing losses of productive oyster reef over the past three decades to Haplosporidium nelsoni, commonly known as MSX, and Perkinsus marinus, commonly known as "Dermo", in the higher salinity regions of both rivers, combined with increased fishing pressure on all remaining stocks, have emphasized the need for working estimates of standing stock. This need has been further exaggerated in the James River by a change in emphasis in the past decade from the harvesting of "seed" oysters to larger "market" oysters, and the reduction in size limit of the latter from three to two-and-one-half inches maximum dimension (although this action was reversed with an increase in minimum market size to three inches for the 1994-1995 season). The fishery is now facing the dilemma of exploiting the limited remaining broodstock from the James River in order to retain a viable fishery for" market" oysters, while simultaneously threatening the long term future of the river as a seed producing location.

Fishery Independent Sampling

The primary objective of the study was to effect a fishery independent study of the standing stock of oysters, both market and seed, in the Virginia portion of the Chesapeake Bay and the Seaside of the Eastern Shore. For the period reported here the focus of activity was on the James and Rappahannock Rivers.

Methods

The selection of sample numbers and locations

James River

The initial focus of the program was the oyster resource of the James River. We designed a quantitative sampling program using quadrats located in a random grid placed over a map of the known oyster resources in the James. In essence, this is a stratified random grid with the documented oyster reefs or rocks forming the strata. The area surveyed is described in extensive surveys made by VIMS and reported by Haven and Whitcomb (1983). These areas have been subjected to regular survey by VMRC and VIMS personnel for at least two decades by dredge. The limits of the known oyster reef were mapped by the Surveying Engineering Department at VMRC and the grids for sampling set with Loran coordinates (Loran was checked daily when in the field from known markers at both the beginning and end of the day). Sampling areas are described in Figures 1 and 2. Figure 1 relates sampling areas to bottom type. Figure 2 identifies the sampled rocks by number. These numbers are used throughout this report in summary tables and graphics. Sampling areas 1 through 11 in Figure 2 represent the limits of hard oyster rock strata selected, mapped and sampled within the larger public oyster grounds in those regions. The limits of hard oyster rock strata within sampling areas 12 through 19 were not mapped seperately because of the large areas involved; consequently, we knew beforehand that sampling grids selected in areas 12-19 would include both oyster rock strata as well as bare sandy or muddy strata. Sampling sites were picked by random numbers within the grids and oysters were sampled with a hydraulically operated patent tong. In this manner a total of 823 stations were occupied in the James River.

Rappahannock River

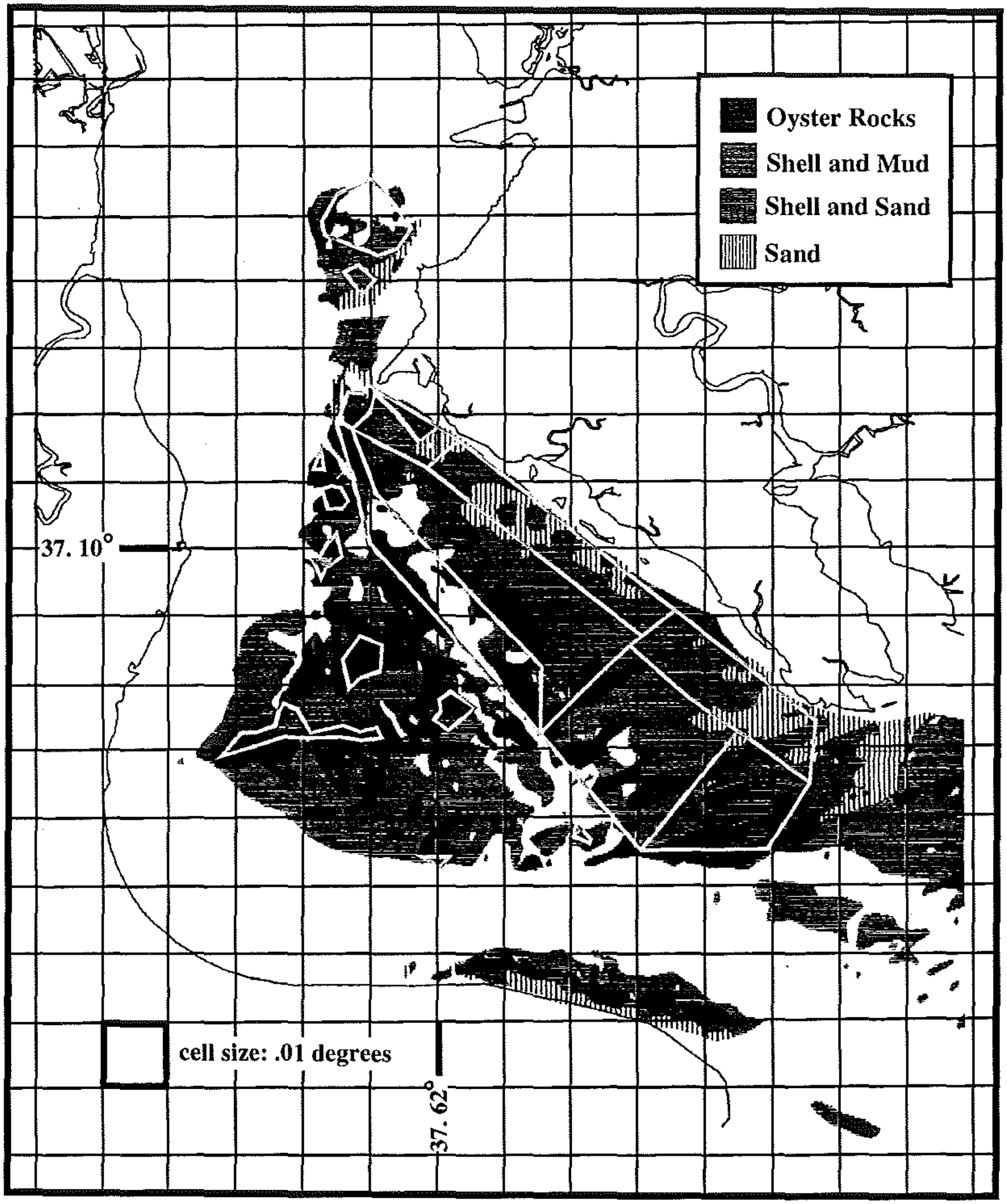
The sampling protocol for the Rappahannock River was as for the James River and employed a quantitative sampling program using quadrats located in a random grid placed over a map of the known oyster resources. Although once extensive, these are now limited to the upper part of the Rappahannock above Bowlers Rock and Morattico Bar. The only commercially exploited reef of any consequence is Russ' Rock. The reefs were again the basis for stratified random sampling. The area surveyed is described in Haven and Whitcomb (1989). The limits of the known oyster reef were mapped by the Surveying Engineering Department at VMRC and the grids for sampling set with Loran coordinates. Loran was, again, checked daily when in the field from known markers at both the beginning and end of the day. Sampling sites were picked by random numbers within the grids and oysters were sampled with a hydraulically operated patent tong.

Sampling gear

Both tongs and dredeges are commonly used to examine oyster populations; however, only the former are good quantitative tools (see Chai et al, 1992). Initially, we examined a standard patent tong of known area; however, tests proved this to be an unpredictable sampling tool in that penetration into the hard bottom on the reef surface was inconsistent resulting in high variability in replicate samples on the same site. We replaced the tong with an hydraulically operated tong which separates the closing actions of the tong from the retrieval action. This has proven to be vastly superior in providing consistent penetration of

Figure 1

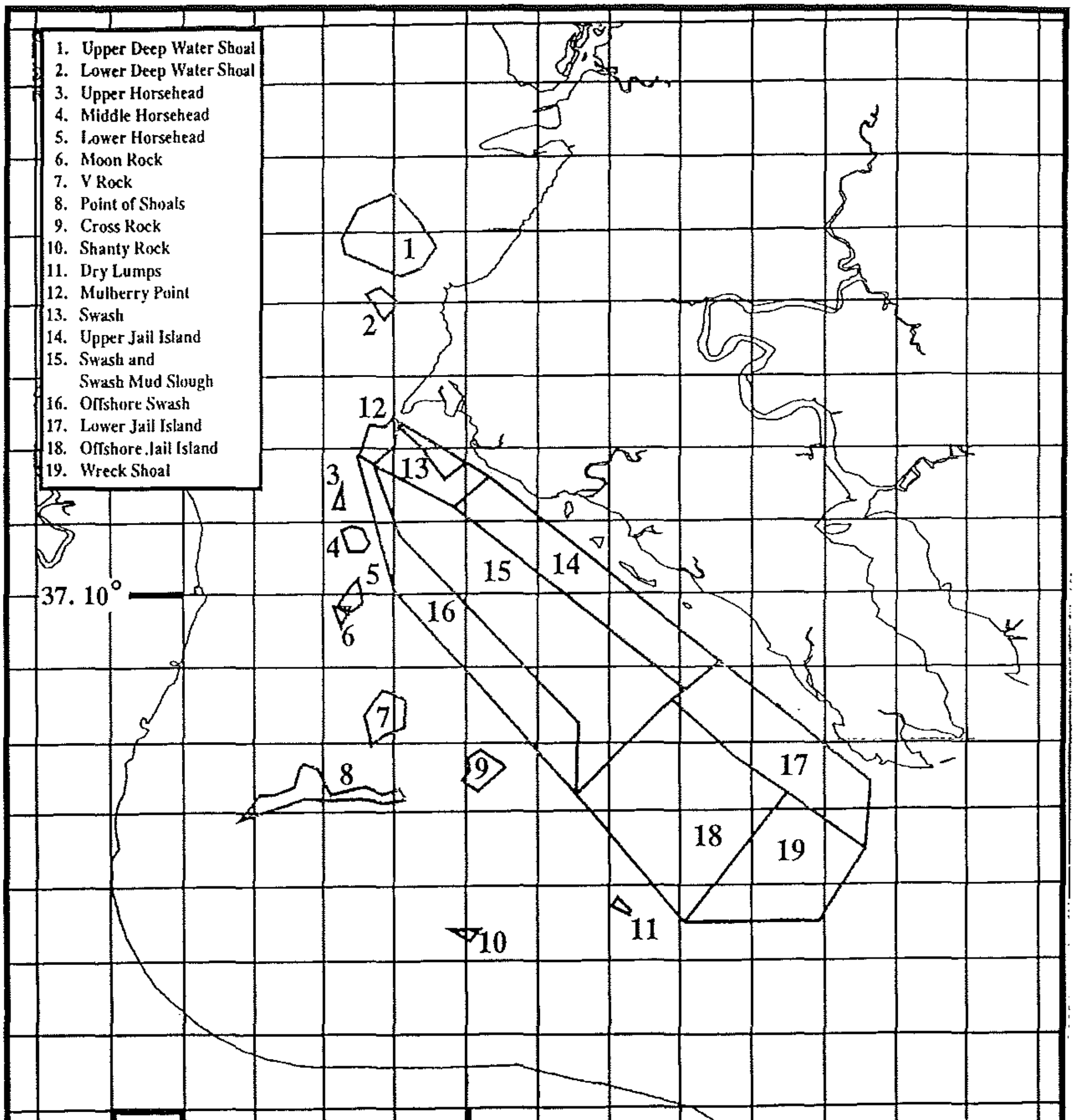
James River
Public (Baylor) Oyster Grounds



Outline of areas sampled during Fall 1993 oyster stock assessment survey: superimposed over chart of bottom types modified from Haven, Whitcomb and Kendall (1981) by the VIMS Center for Coastal Management and Policy. Areas in white represent soft mud primarily.

James River Oyster Stock Assessment: Fall 1993

Location of oyster rocks sampled. Individual rocks are as in the previous description of bottom type and are identified by number in the key. These numbers cross reference with the summary table of standing stock estimates, all data plots relating to sampling adequacy, and data summary tables for the individual rocks.



the bottom and replication sampling. The hydraulic tong was installed on the VMRC vessel Wolftrap. This vessel was used in all survey work described herein.

Data collection

The open dimensions of the tong were such that it sampled one square meter. Upon retrieval the sample was washed on the cull board and processed for counts of live oysters as spat (young of the year), small oysters (less than 2.5 inches), and market (greater than 2.5 inches) oysters. In addition, the opportunity was taken to collect data on dead oysters with paired valves (boxes, indicating recent mortality). The volume of shell retrieved in each tong was also recorded as an index of the quantity of cultch material present at each station. Between six and nine people were on board on each day of sampling, and all were trained to avoid inconsistency in categorization of oysters. This process was much more labor intensive than originally envisaged, with between 30 and 60 samples being processed each day depending on weather conditions, crew size and the time required to wash and separate samples. Sampling of the James River was completed in late December of 1993. A further effort in early January of 1994 focused on sampling in the Rappahannock River.

Data reduction and archiving

A custom database program for field data was developed by the Fisheries Data Managemeny Unit in the Department of Fisheries Science at the School of Marine Science and Virginia Institute of Marine Science. Archived material is available on request. Size distribution data was additionally archived and preliminary analysis effected using commercial spreadsheet software (Microsoft Excel).

Results and Discussion

Data analysis

Prior to using data to estimate standing stock initial questions relating to sampling design and adequacy need to be addressed. As mentioned earlier, there is a lack of previous quantitative assessment data for this resource. Two primary questions arise:

1. Are there strata reasonable? The background behind this question is that recent surveys by Haven and Whitcomb (1983, 1989) illustrate varying bottom type within the chosen strata - from mud to hard shell bottom. This could present a significant sampling problem in that strata are sufficiently heterogeneous to be of limited ecological and statistical value.

2. Assuming 1 (above) is not a problem, are there sufficient samples to adequately represent the strata and allow estimates of abundance per unit area and, subsequently, total standing stock.

Bros and Cowell (1987) offer a good discussion of methods of estimating sample size in situations where minimum detectable difference cannot be specified a priori, as is the case in this situation. Their proposed method incorporates use of resolving power as a primary factor and sampling feasibility (an issue here with time and cost) as a secondary factor. They suggest the standard error of the mean be used as a measure of appropriate sampling effort. We have adopted their suggestion.

Questions 1 and 2 above were primarily addressed by a single analysis in which data were examined collectively within each strata. A plot was generated of mean number of oysters per patent tong (one square meter) sample and standard error of the mean versus number of samples included in the calculation. This calculation was repeated ten times for data within a strata with samples being chosen at random from those available. Random sampling eliminated any bias that resulted from sequential data entry in accordance with sampling in the field sampling (the latter may have resulted, inadvertently in temporally focused sampling on a particular substrate type). In a regime where variability with bottom type was high and the sample size was low then the mean would not stabilize, and where sampling was insufficient the standard error of the mean would not demonstrate a stable trend of decreasing value - remembering of course that the standard error value will eventually continue to decrease with increasing number of samples included in the calculation because the standard error is inversely proportional to the square root of the number of observations of the mean. Increasing sample size will eventually solve both these problems, but the number of samples required might be very large.

Figures 3 through 23 provide the visual description of all 19 sampling areas in the James when subjected to plotting estimates of the standard error of the mean versus number of samples collected (included in the analysis) for each of the sampling areas. The bold numeral in the bottom left corner of each plot provides the cross reference to Figure 2. As mentioned earlier, sampling areas 1 through 11 (figures 3 through 15) represent the limits of well defined hard oyster rock strata within the public oyster grounds in those regions. Sampling grids selected in areas 12-19 (figures 16 through 23) included both oyster rock strata as well as bare sandy or muddy strata, and heterogeneity within the strata was expected to be more acute in these areas. The area of each reef was quite variable , and resulted in a variation in the number of stations sampled. Each figure represents the means of 10 randomized groups of samples subjected to the previously described analysis for each strata. In addition, areas 4 (Horsehead Middle) and 8 (Point of Shoals) have plots generated with one randomized set of data for the strata. These pairs of plots are identified with the bold characters 4 and 4b, and 8 and 8b respectively (figures 6 and 7, and 11 and 12 respectively). There is generally good agreement between the plots (figure 6 versus 7, and 11 versus 12). These plots suggest adequate sampling within the strata to account for bottom type variability and for general spatial coverage.

Interspersed between the individual plots of standard error versus number of samples included are statistical summaries for the corresponding sampling areas. Upper Deep Water Shoal (Figure 3) is a large area (234 acres) and the mean did not stabilize until approximately 40 samples were included in the analysis, although the standard error measurements settled into a steady decline at about 30 samples. This is a good example of an area with small scale bottom variability directly adjacent to a deep channel. Future surveys will not require a repetition of 99 individual samples. The standard error remains high at approximately 10 even with 60 samples included in the analysis. This is indicative of limited but consistent small scale heterogeneity in abundance within the strata; however, our sampling was more than adequate to compensate for this. Lower Deep Water Shoal (Figure 4) is much smaller by comparison (20 acres) but gave relatively stable estimates of mean oyster density at small sample numbers.

Some reefs such as Upper Horsehead (Figure 5, 3 acres), Moon Rock (Figure 9, 4 acres), Shanty Rock (Figure 14, 3.5 acres), and Dry Lumps (Figure 15, 6 acres), are all rather small with limited sample numbers. Despite this the analysis suggests relative homogeneity within the small strata and good estimates of standing stock.

Some of the larger reefs with well defined hard rock bottom types (areas 1 through 11 on Figure 2, corresponding to figures 3 through 15) such as Horsehead middle and lower, V Rock, Point of Shoals, and Cross Rock all exhibit stability in estimates of the mean with fairly small sample sizes. This is also the case for some of the strata with less well defined bottoms such as Swash & Swash Mud Slough (Figure 19). This suggests, again, that future studies will require a smaller number of sample stations than were employed in 1993. Moving to strata with less well defined bottom types (areas 12 through 19 on Figure 2, corresponding to Figures 16 through 23)) was often accompanied by a decrease in mean oyster density (compare Mulberry Point at 24 per sample (Figure 16) and Swash at 4.8 per sample (Figure 17) with earlier values for Deep Water Shoal, Point of Shoals, and V Rock). Care is required when examining some of these latter plots (for example Figures 21 and 22, Jail Island Lower and Offshore) in that the values appear initially unstable up to quite large sample sizes - this is a function of the axes in that the absolute numbers are small by comparison with earlier plots. Jail Island Offshore in particular is a very large area with low oyster density. Wreck Shoal (Figure 23) is the most down stream position of all of the sampled strata and has been subjected to intense disease pressure for the past several years with corresponding mortalities. It is also a very large reef (585 acres). Both the mean and the standard error values stabilize when between 40 and 50 samples included in the analysis. The abundance data of less than 9 oysters per square meter illustrate the cumulative disease impact in that this was a major oyster producing reef in the upper James during the 1982-1986 period when market oyster production was high.

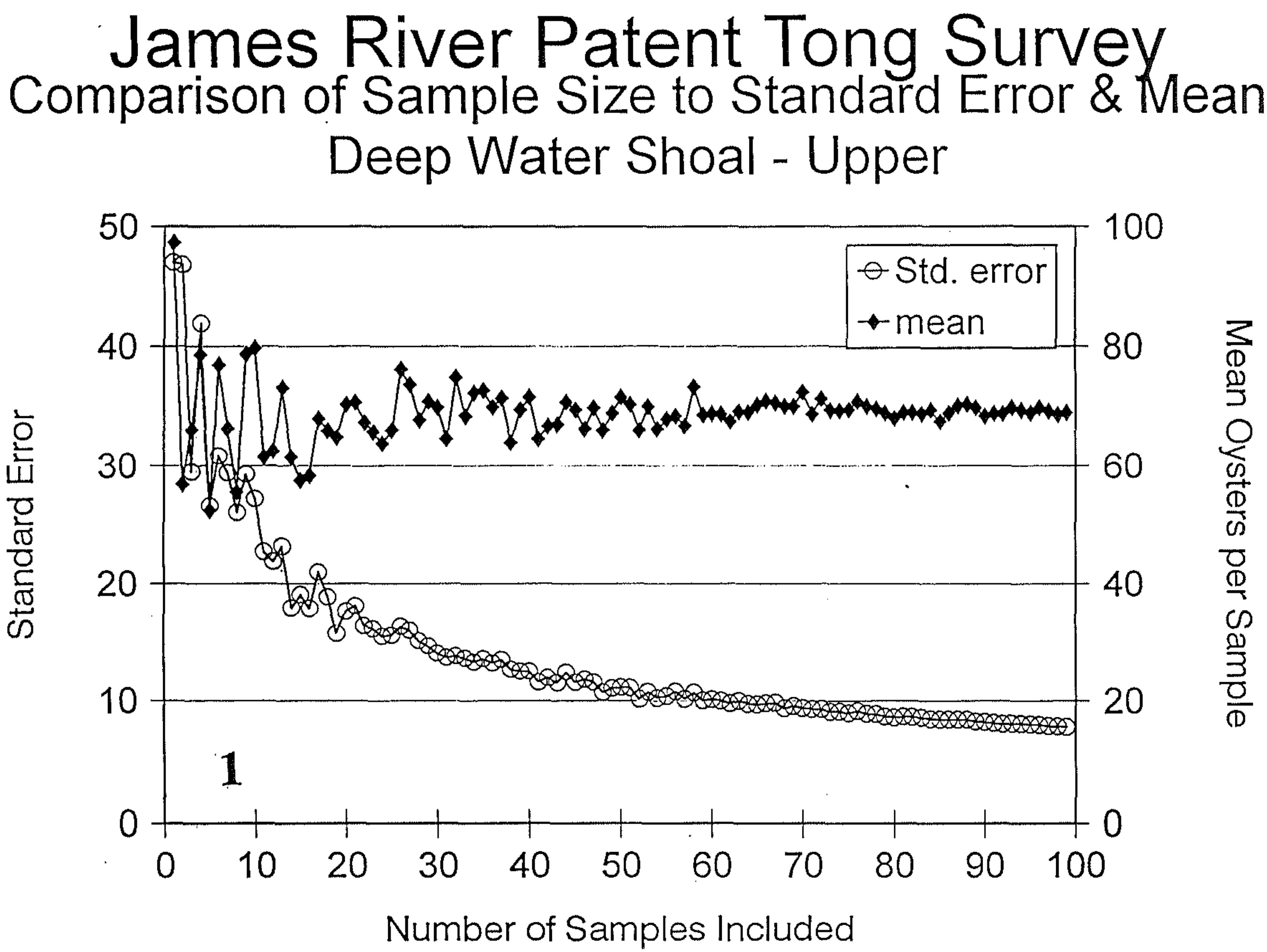

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Deep Water Shoal - Upper
Std. error
mean
Standard Error
Mean Oysters per Sample
Number of Samples Included
0
10
20
30
40
50
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80
90
100
1

Figure 3

STATISTICAL SUMMARY FOR UPPER DEEP WATER SHOAL (1)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)		237	84	291		16	22	22	20
MEAN NO. PER SQ. METER		49.1	19.8	68.9		1.7	0.9	2.6	5.6
STD.DEV.		60.4	23.8	78.3		2.6	2.7	3.8	5.5
NO. SAMPLES (n)		99	99	99		99	99	99	99
STD. ERROR (SE)		6.1	2.4	7.9		0.3	0.3	0.4	0.6
t.05 VALUE FOR n (t.05)		2.571	2.571	2.571		2.571	2.571	2.571	2.571
(SE)*(t.05) = t.05SE		15.61	6.16	20.23		0.67	0.69	0.99	1.42
UPPER 95% CONF. INTVL. FOR MEAN		64.7	26.0	89.2		2.3	1.6	3.6	7.0
LOWER 95% CONF. INTVL FOR MEAN		33.5	13.7	48.7		1.0	0.2	1.6	4.2
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		233.92	233.92						
MEAN NO. BUSHELS PER ACRE		198.7	160.6	359					
UPPER 95% CONF. INTVL. FOR THIS MEAN		261.8	210.5	472					
LOWER 95% CONF. INTVL. FOR THIS MEAN		135.5	110.8	246					
MEAN TOTAL BUSHELS IN WHOLE ROCK		46472	37579	84051					
UPPER 95% CONF. INTVL. FOR THIS MEAN		61252	49240	110492					
LOWER 95% CONF. INTVL. FOR THIS MEAN		31692	25918	57610					

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Deep Water Shoal - Lower

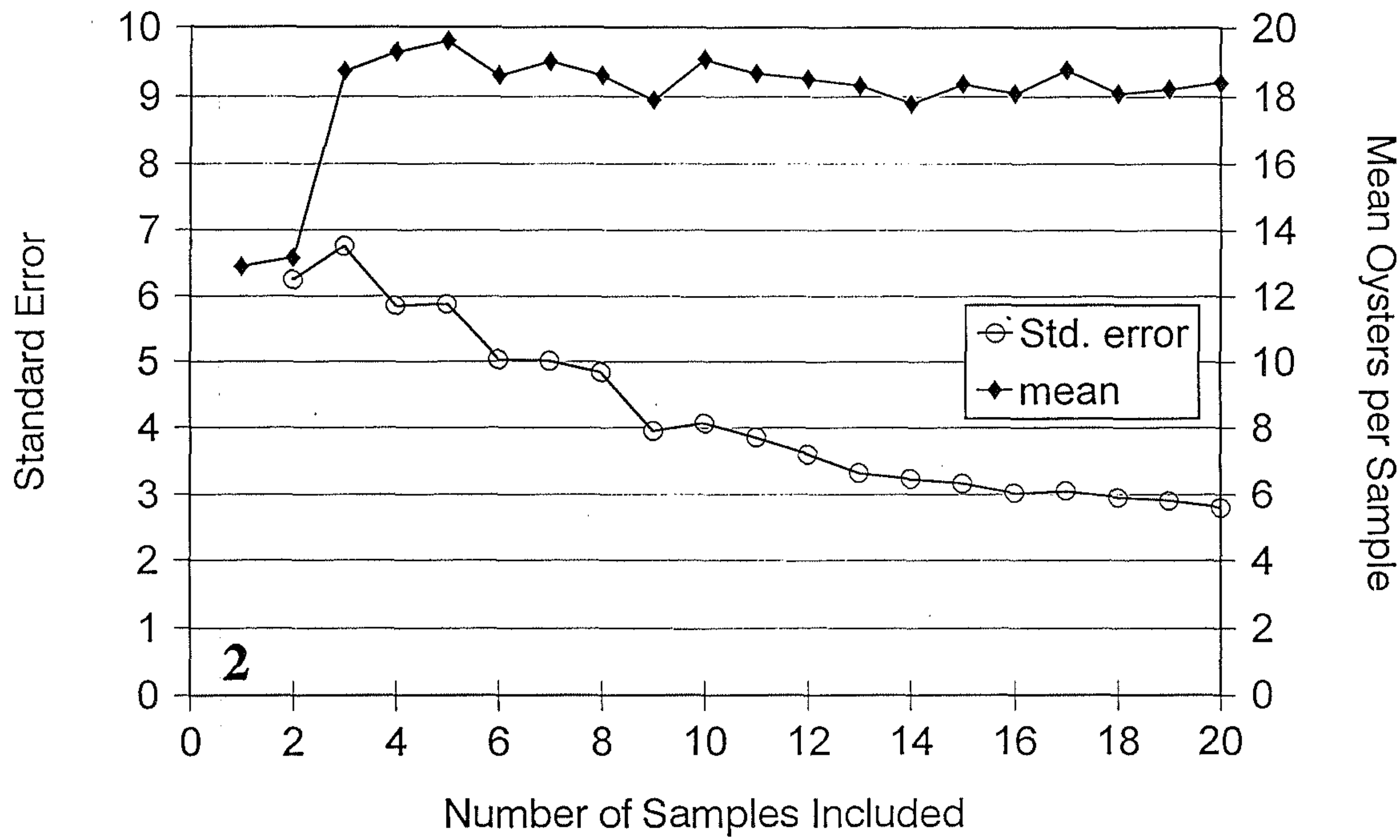
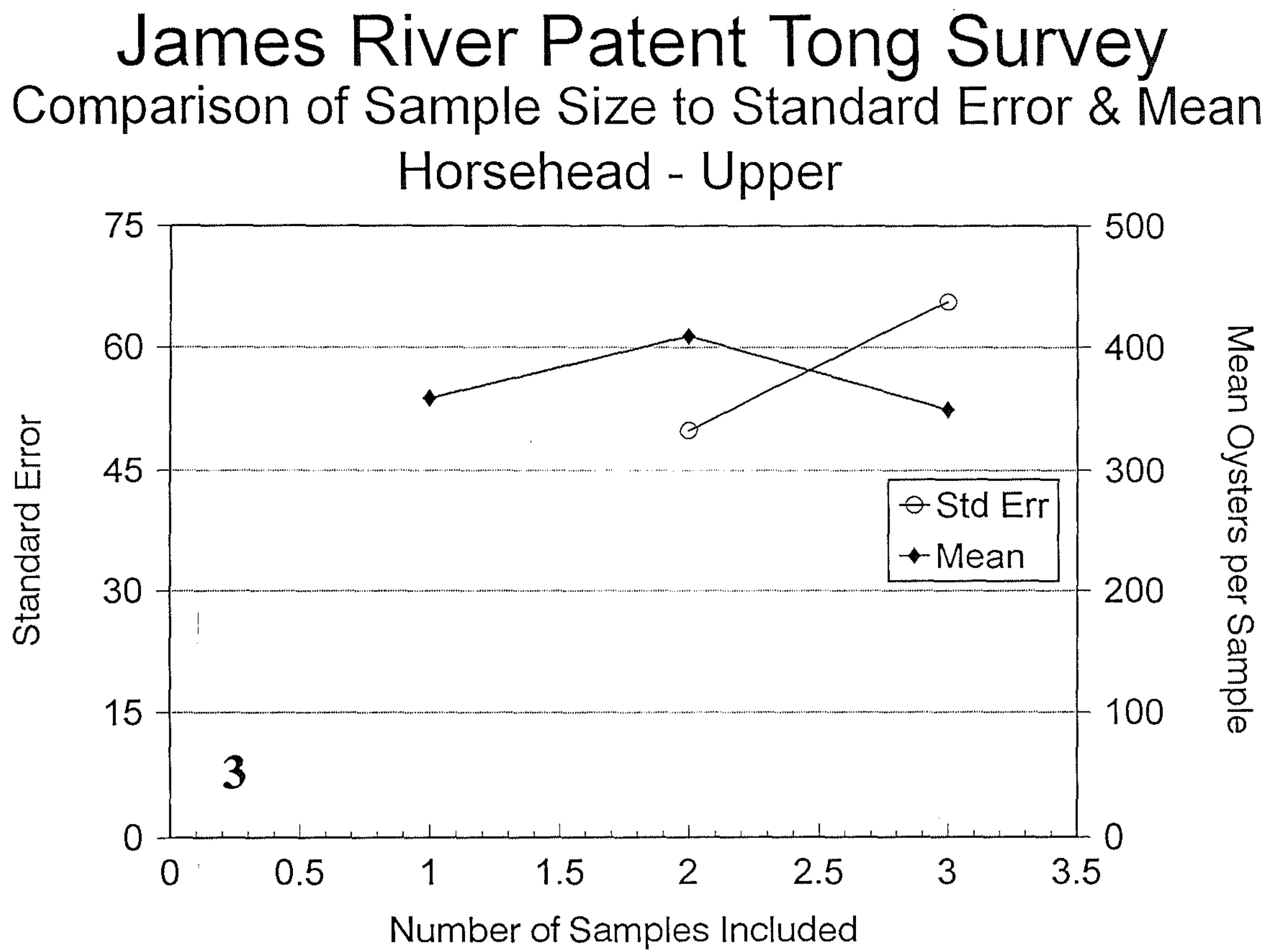


Figure 4

STATISTICAL SUMMARY FOR LOWER DEEP WATER SHOAL (2)

	LIVE OYSTERS				BOXES				SHELL
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0.5
HIGH VALUE (PER SQ. METER)		28	21	44		6	8	12	17
MEAN NO. PER SQ. METER		9.9	8.5	18.4		1.3	1.1	2.4	5.9
STD.DEV.		7.7	5.3	12.5		1.5	2.1	3.2	4.4
NO. SAMPLES (n)		20	20	20		20	20	20	20
STD. ERROR (SE)		1.7	1.2	2.8		0.3	0.5	0.7	1.0
t.05 VALUE FOR n (t.05)		2.093	2.093	2.093		2.093	2.093	2.093	2.093
(SE)*(t.05) = t.05SE		3.60	2.49	5.86		0.71	0.99	1.49	2.07
UPPER 95% CONF. INTVL. FOR MEAN		13.5	11.0	24.3		2.0	2.1	3.8	7.9
LOWER 95% CONF. INTVL FOR MEAN		6.3	6.0	12.5		0.5	0.1	0.9	3.8
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		19.93	19.93						
MEAN NO. BUSHELS PER ACRE		40	69	109					
UPPER 95% CONF. INTVL. FOR THIS MEAN		55	89	144					
LOWER 95% CONF. INTVL. FOR THIS MEAN		26	49	74					
MEAN TOTAL BUSHELS IN WHOLE ROCK		798	1371	2170					
UPPER 95% CONF. INTVL. FOR THIS MEAN		1089	1773	2862					
LOWER 95% CONF. INTVL. FOR THIS MEAN		508	969	1477					



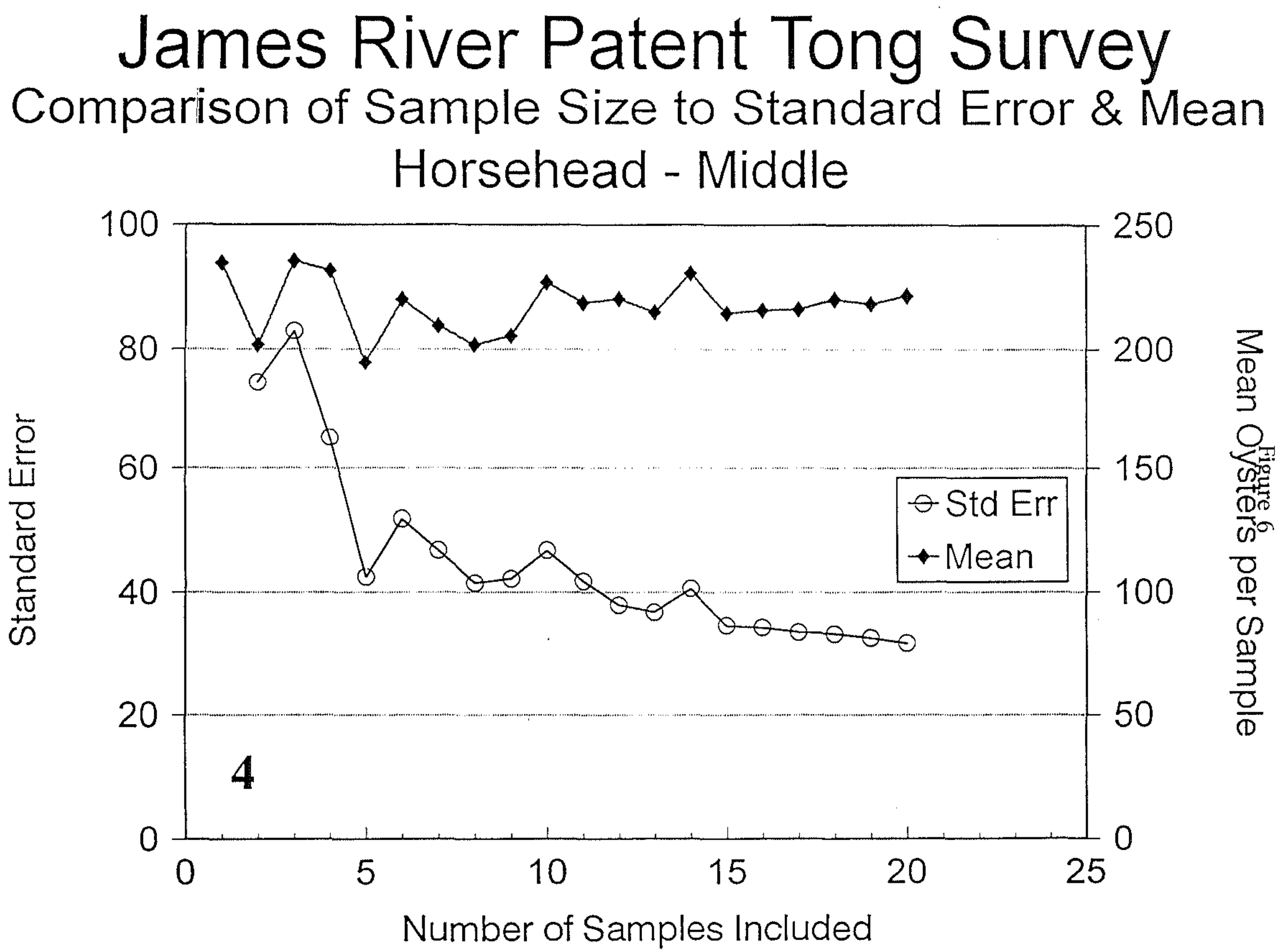
James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Horsehead - Upper
Standard Error
Mean Oysters per Sample
Number of Samples Included
Std Err
Mean
75
60
45
30
15
0
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5

3

Figure 5

STATISTICAL SUMMARY FOR UPPER HORSEHEAD (3)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		179	36	232		7	0	7	1.5
HIGH VALUE (PER SQ. METER)		382	77	459		33	2	33	10
MEAN NO. PER SQ. METER		294.7	55.3	350.0		17.7	0.7	18.3	7.2
STD.DEV.		104.4	20.6	113.8		13.6	1.2	13.3	4.9
NO. SAMPLES (n)		3	3	3		3	3	3	3
STD. ERROR (SE)		60.3	11.9	65.7		7.9	0.7	7.7	2.8
t.05 VALUE FOR n (t.05)		4.303	4.303	4.303		2.093	2.093	2.093	2.093
(SE)*(t.05) = t.05SE		259.42	51.18	282.64		16.45	1.40	16.09	5.93
UPPER 95% CONF. INTVL. FOR MEAN		554.1	106.5	632.6		34.1	2.1	34.4	13.1
LOWER 95% CONF. INTVL FOR MEAN		35.2	4.2	67.4		1.2	-0.7	2.2	1.2
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		3.009	3.009						
MEAN NO. BUSHELS PER ACRE		1192	448	1640					
UPPER 95% CONF. INTVL. FOR THIS MEAN		2242	862	3104					
LOWER 95% CONF. INTVL. FOR THIS MEAN		143	34	176					
MEAN TOTAL BUSHELS IN WHOLE ROCK		3588	1348	4936					
UPPER 95% CONF. INTVL. FOR THIS MEAN		6747	2594	9341					
LOWER 95% CONF. INTVL. FOR THIS MEAN		429	101	530					



James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Horsehead - Middle
Standard Error
Mean Oysters per Sample
Number of Samples Included
Std Err
Mean
4
100
80
60
40
20
0
250
200
150
100
50
0
0
5
10
15
20
25

Figure 6

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Horsehead - Middle

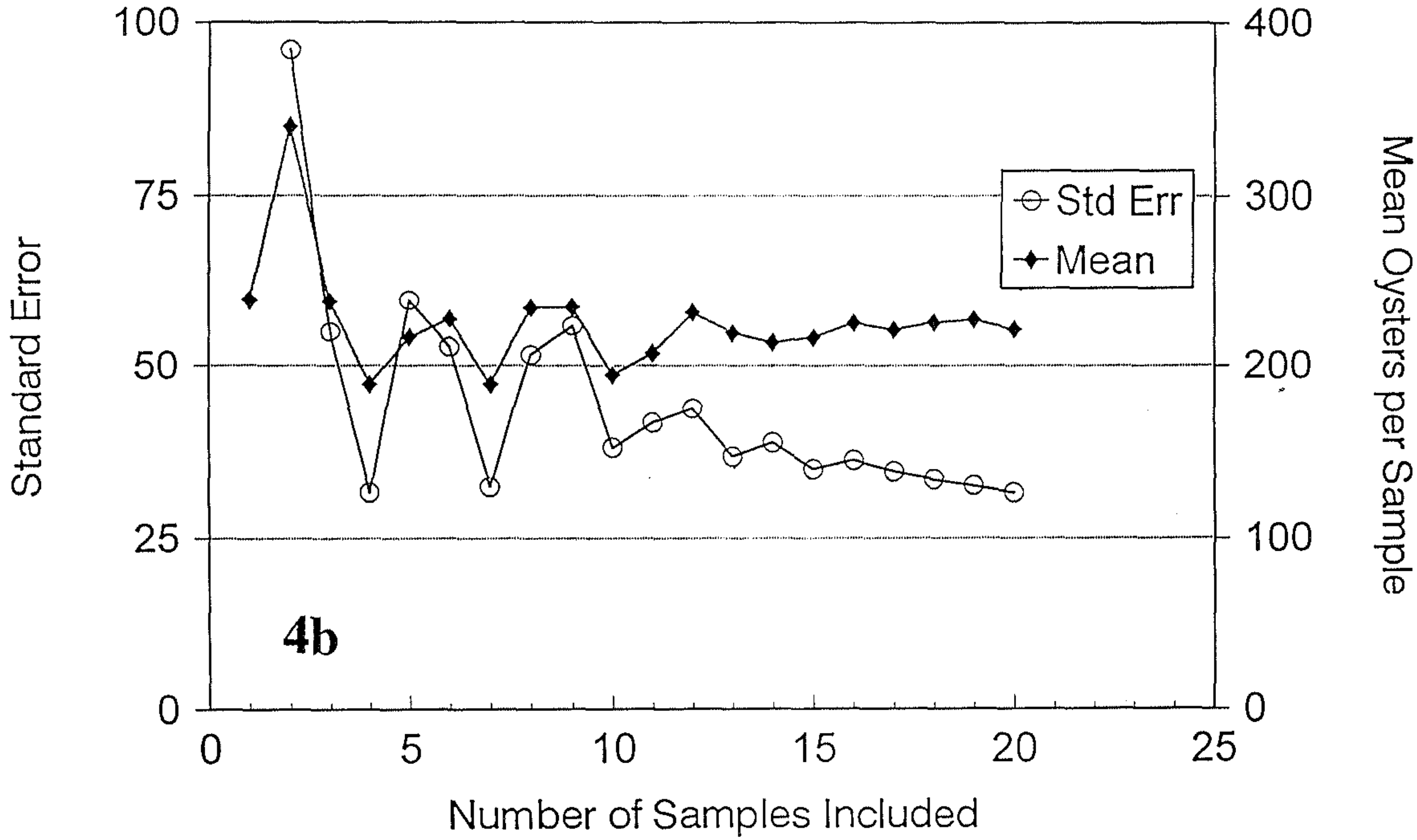


Figure 7

STATISTICAL SUMMARY FOR MIDDLE HORSEHEAD (4)

	LIVE OYSTERS				BOXES				SHELL
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	VOL (l)
LOW VALUE (PER SQ. METER)		64	0	65		4	0	5	2
HIGH VALUE (PER SQ. METER)		579	32	594		32	2	32	26
MEAN NO. PER SQ. METER		214.3	7.4	221.6		13.5	0.4	13.9	13.0
STD.DEV.		138.7	8.5	141.2		8.8	0.6	8.7	6.6
NO. SAMPLES (n)		20	20	20		20	20	20	20
STD. ERROR (SE)		31.0	1.9	31.6		2.0	0.1	1.9	1.5
t.05 VALUE FOR n (t.05)		2.093	2.093	2.093		2.093	2.093	2.093	2.093
(SE)*(t.05) = t.05SE		64.91	3.97	66.07		4.11	0.28	4.08	3.10
UPPER 95% CONF. INTVL. FOR MEAN		279.2	11.3	287.7		17.6	0.7	17.9	16.1
LOWER 95% CONF. INTVL FOR MEAN		149.3	3.4	155.5		9.3	0.1	9.8	9.9
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		19.465	19.465						
MEAN NO. BUSHELS PER ACRE		867	59	927					
UPPER 95% CONF. INTVL. FOR THIS MEAN		1130	92	1221					
LOWER 95% CONF. INTVL. FOR THIS MEAN		604	27	632					
MEAN TOTAL BUSHELS IN WHOLE ROCK		16877	1158	18035					
UPPER 95% CONF. INTVL. FOR THIS MEAN		21990	1784	23774					
LOWER 95% CONF. INTVL. FOR THIS MEAN		11764	532	12297					

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Horsehead - Lower

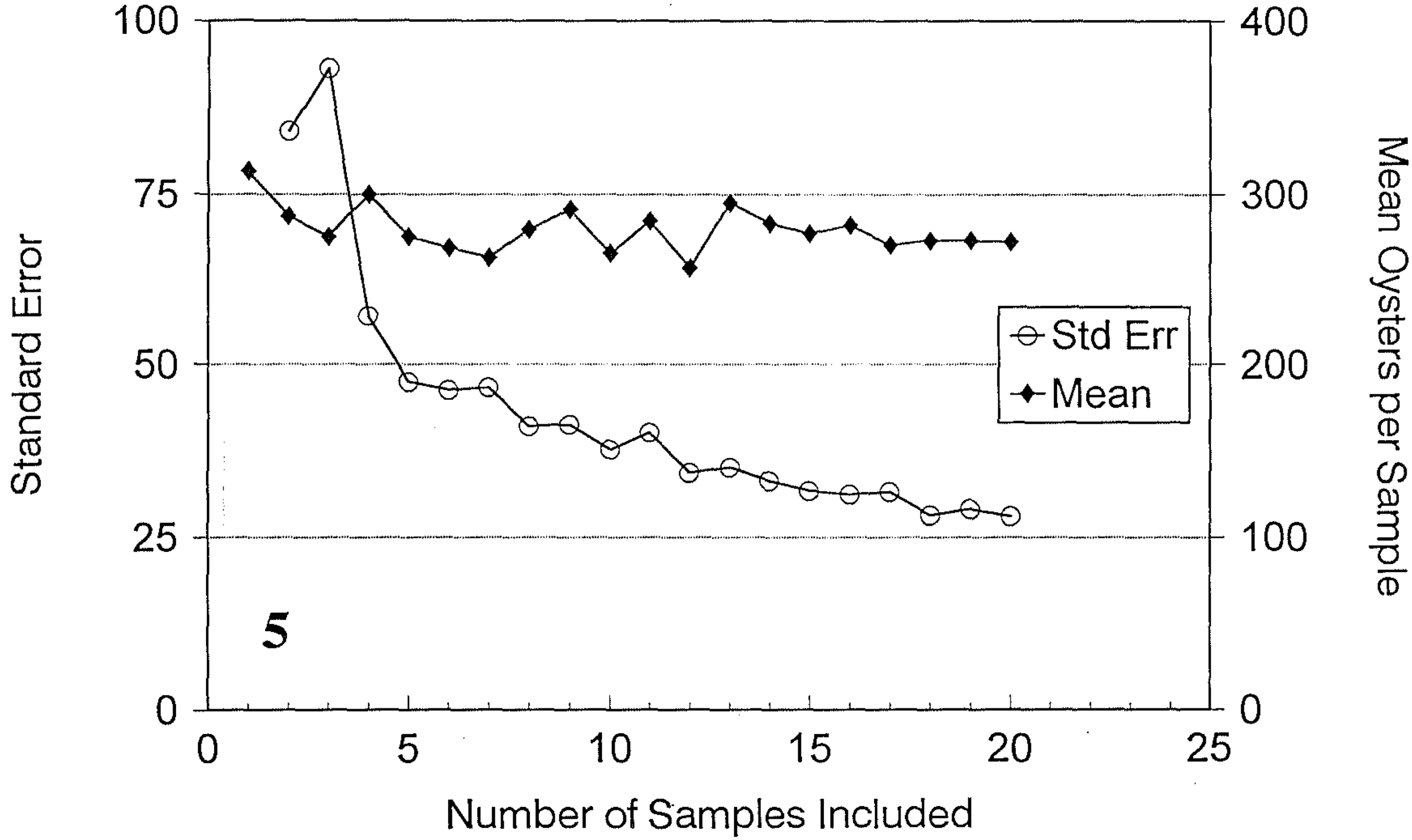


Figure 8

STATISTICAL SUMMARY FOR LOWER HORSEHEAD (5)

	LIVE OYSTERS				BOXES				SHELL
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	VOL (l)
LOW VALUE (PER SQ. METER)		15	0	15		4	0	6	6
HIGH VALUE (PER SQ. METER)		470	110	484		19	4	19	22
MEAN NO. PER SQ. METER		253.4	18.8	272.2		9.8	0.9	10.6	13.1
STD.DEV.		120.5	23.6	125.0		4.3	1.3	3.7	4.3
NO. SAMPLES (n)		20	20	20		20	20	20	20
STD. ERROR (SE)		26.9	5.3	28.0		1.0	0.3	0.8	1.0
t.05 VALUE FOR n (t.05)		2.093	2.093	2.093		2.093	2.093	2.093	2.093
(SE)*(t.05) = t.05SE		56.40	11.06	58.52		2.00	0.59	1.73	2.00
UPPER 95% CONF. INTVL. FOR MEAN		309.8	29.8	330.7		11.8	1.4	12.3	15.1
LOWER 95% CONF. INTVL FOR MEAN		197.0	7.7	213.6		7.7	0.3	8.9	11.1
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		19.467	19.467						
MEAN NO. BUSHELS PER ACRE		1025	152	1177					
UPPER 95% CONF. INTVL. FOR THIS MEAN		1254	241	1495					
LOWER 95% CONF. INTVL. FOR THIS MEAN		797	62	859					
MEAN TOTAL BUSHELS IN WHOLE ROCK		19963	2954	22917					
UPPER 95% CONF. INTVL. FOR THIS MEAN		24406	4697	29104					
LOWER 95% CONF. INTVL. FOR THIS MEAN		15520	1211	16731					

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Moon Rock

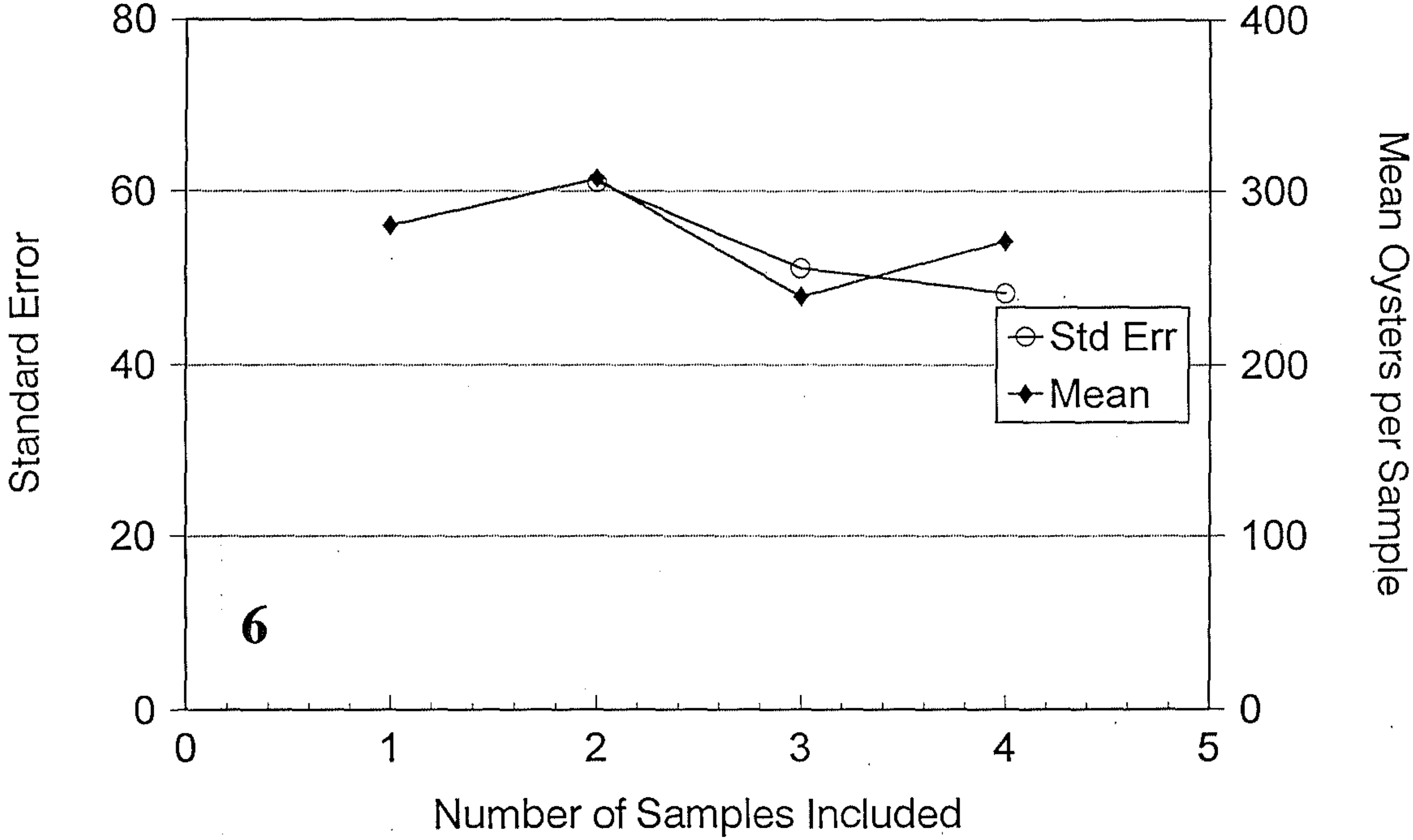


Figure 9

STATISTICAL SUMMARY FOR MOON ROCK (6)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		148	10	158		3	0	3	8
HIGH VALUE (PER SQ. METER)		338	36	368		16	2	18	18
MEAN NO. PER SQ. METER		247.0	24.8	271.8		10.5	0.5	11.0	14.0
STD.DEV.		86.7	11.2	96.7		5.4	1.0	6.2	4.5
NO. SAMPLES (n)		4	4	4		4	4	4	4
STD. ERROR (SE)		43.3	5.6	48.4		2.7	0.5	3.1	2.3
t.05 VALUE FOR n (t.05)		3.182	3.182	3.182		3.182	3.182	3.182	3.182
(SE)*(t.05) = t.05SE		137.88	17.78	153.93		8.67	1.59	9.81	7.23
UPPER 95% CONF. INTVL. FOR MEAN		384.9	42.5	425.7		19.2	2.1	20.8	21.2
LOWER 95% CONF. INTVL FOR MEAN		109.1	7.0	117.8		1.8	-1.1	1.2	6.8
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		3.95	3.95						
MEAN NO. BUSHELS PER ACRE		999.6	200.3	1200					
UPPER 95% CONF. INTVL. FOR THIS MEAN		1557.6	344.2	1902					
LOWER 95% CONF. INTVL. FOR THIS MEAN		441.6	56.4	498					
MEAN TOTAL BUSHELS IN WHOLE ROCK		3948	791	4740					
UPPER 95% CONF. INTVL. FOR THIS MEAN		6152	1360	7512					
LOWER 95% CONF. INTVL. FOR THIS MEAN		1744	223	1967					

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
V Rock

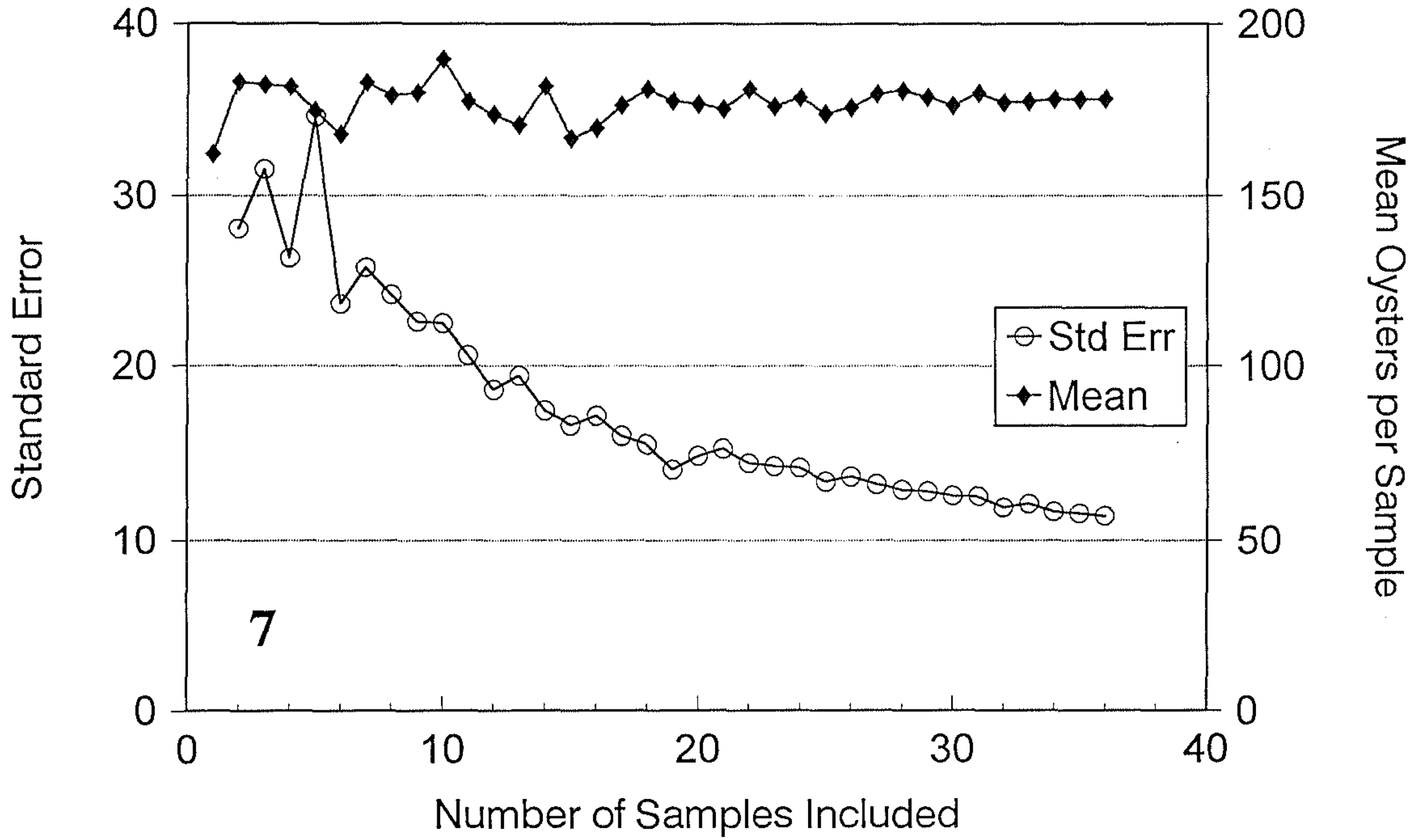


Figure 10

STATISTICAL SUMMARY FOR V-ROCK (7)

	LIVE OYSTERS				BOXES				SHELL
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)	0	0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)	99	326	43	344		30	7	37	25
MEAN NO. PER SQ. METER	30.9	157.6	20.3	173.4		10.8	1.2	12.0	14.4
STD.DEV.	38.4	62.6	10.5	74.7		6.7	1.6	8.3	4.6
NO. SAMPLES (n)	15	36	36	36		36	36	36	36
STD. ERROR (SE)	9.9	10.4	1.7	12.4		1.1	0.3	1.4	0.8
t.05 VALUE FOR n (t.05)	2.131	2.029	2.029	2.029		2.029	2.029	2.029	2.029
(SE)*(t.05) = t.05SE	21.125	21.1589	3.5401	25.25119		2.253	0.537	2.789946	1.568419
UPPER 95% CONF. INTVL. FOR MEAN	52.1	178.7	23.8	198.7		13.1	1.8	14.8	16.0
LOWER 95% CONF. INTVL FOR MEAN	9.8	136.4	16.8	148.2		8.6	0.7	9.2	12.9
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		72.053	72.053						
MEAN NO. BUSHELS PER ACRE		638	164	802					
UPPER 95% CONF. INTVL. FOR THIS MEAN		723	193	916					
LOWER 95% CONF. INTVL. FOR THIS MEAN		552	136	688					
MEAN TOTAL BUSHELS IN WHOLE ROCK		45950	11842	57792					
UPPER 95% CONF. INTVL. FOR THIS MEAN		52120	13906	66026					
LOWER 95% CONF. INTVL. FOR THIS MEAN		39780	9777	49557					

James River Patent Tong Survey

Comparison of Sample Size to Standard Error & Mean

Point of Shoals

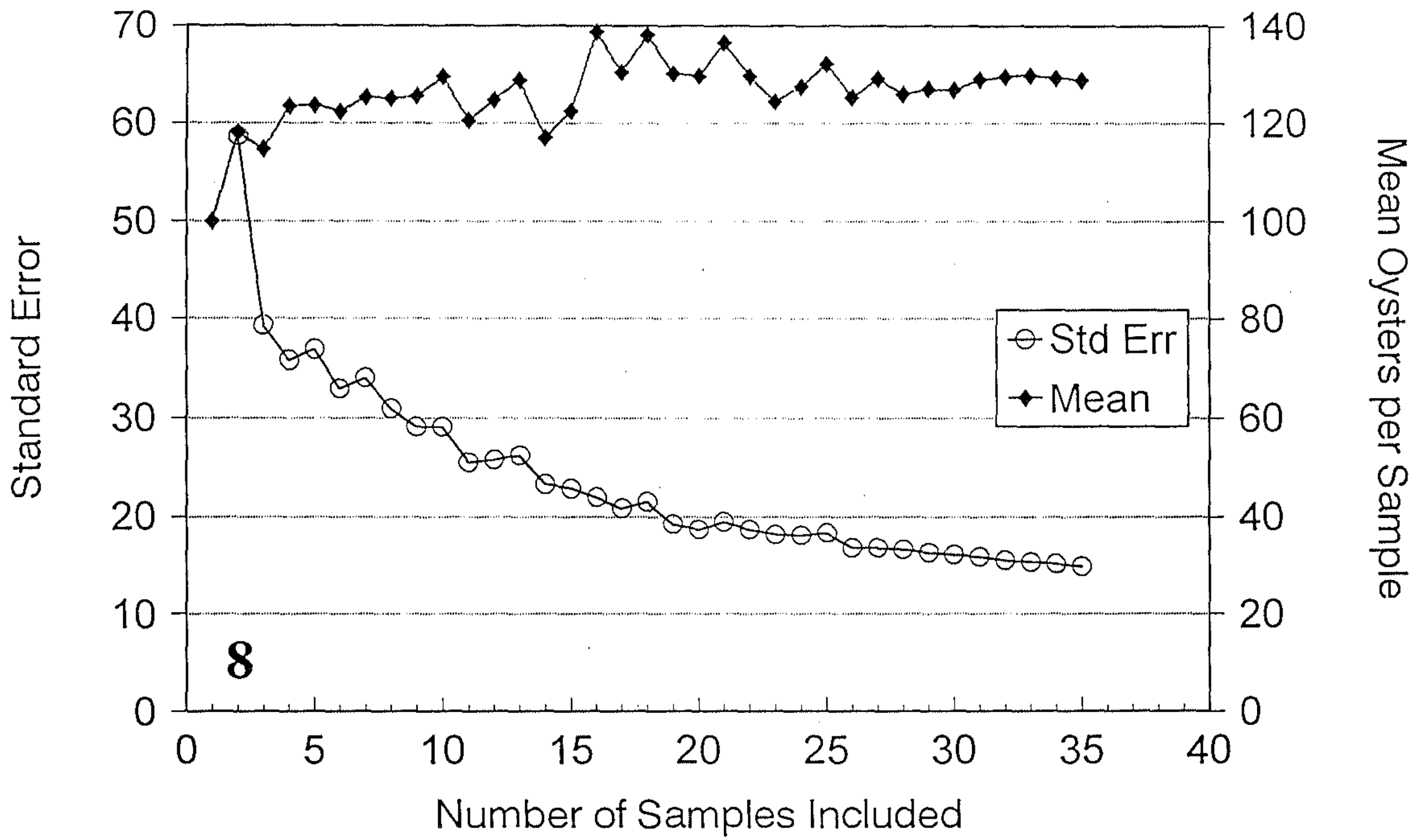


Figure 11

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Point of Shoals

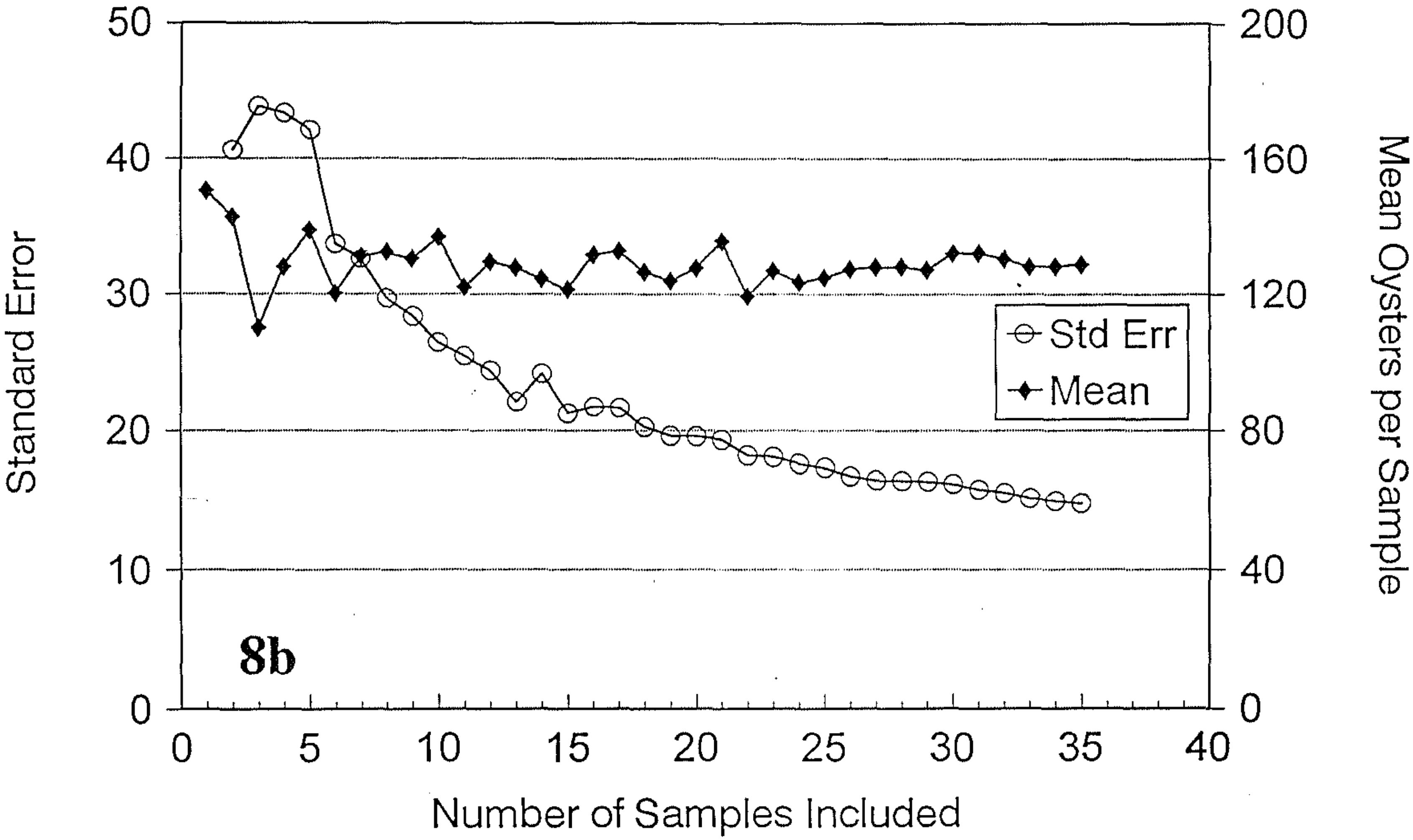
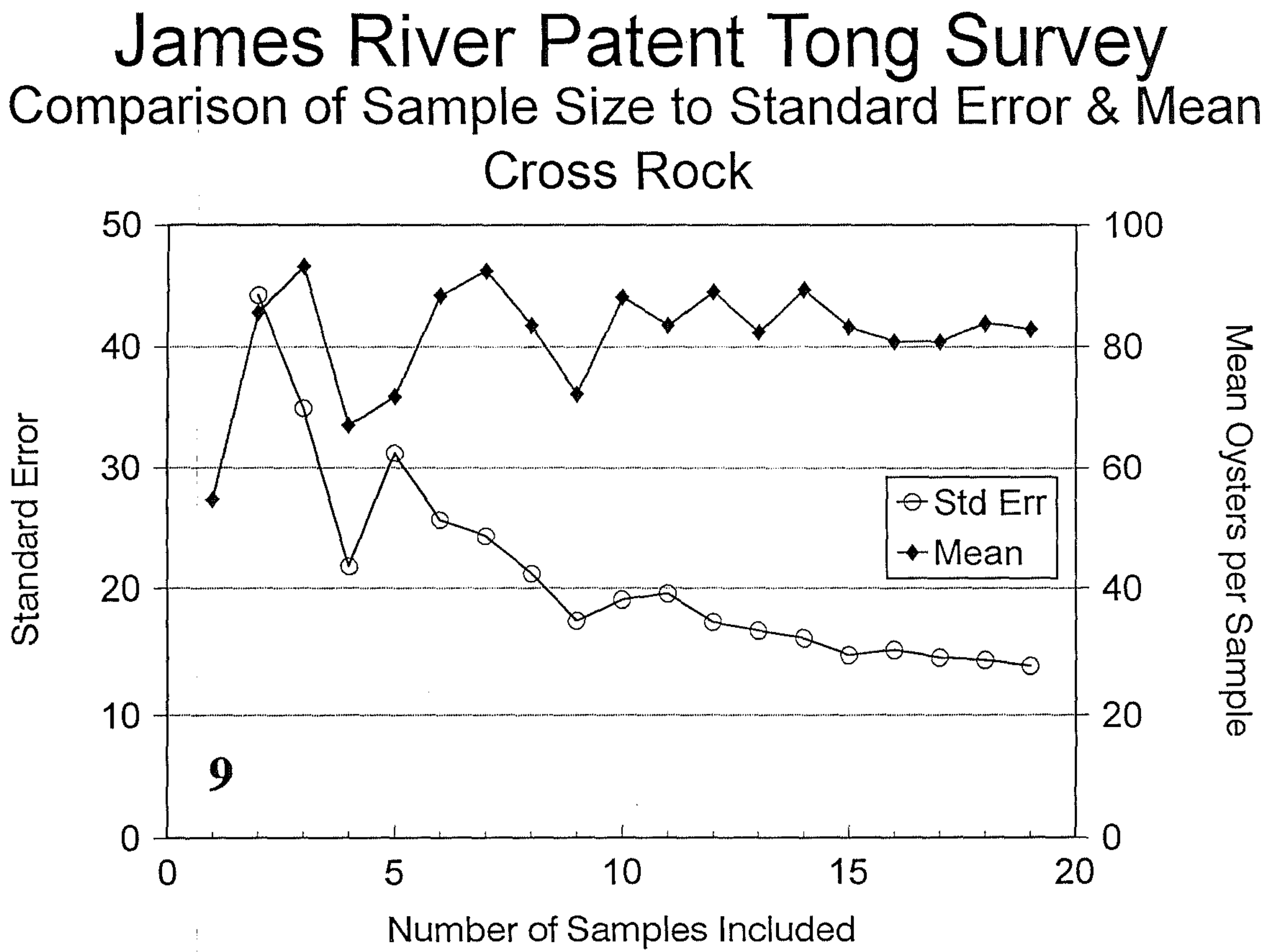


Figure 12

STATISTICAL SUMMARY FOR POINT OF SHOALS (8)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		3	2	0		0	0	0	0.5
HIGH VALUE (PER SQ. METER)		253	69	299		28	6	28	17
MEAN NO. PER SQ. METER		104.9	23.9	128.6		5.1	1.5	6.6	8.0
STD.DEV.		72.7	17.2	87.9		5.7	1.5	5.8	4.6
NO. SAMPLES (n)		35	35	35		35	35	35	35
STD. ERROR (SE)		12.3	2.9	14.9		1.0	0.3	1.0	0.8
t.05 VALUE FOR n (t.05)		1.982	1.982	1.982		1.982	1.982	1.982	1.982
(SE)*(t.05) = t.05SE		24.36	5.77	29.45		1.92	0.50	1.94	1.55
UPPER 95% CONF. INTVL. FOR MEAN		129.3	29.7	158.1		7.1	2.0	8.5	9.5
LOWER 95% CONF. INTVL FOR MEAN		80.5	18.1	99.2		3.2	1.0	4.7	6.4
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		131.71	131.71						
MEAN NO. BUSHELS PER ACRE		424	193	618					
UPPER 95% CONF. INTVL. FOR THIS MEAN		523	240	763					
LOWER 95% CONF. INTVL. FOR THIS MEAN		326	147	472					
MEAN TOTAL BUSHELS IN WHOLE ROCK		55906	25463	81369					
UPPER 95% CONF. INTVL. FOR THIS MEAN		68893	31617	100509					
LOWER 95% CONF. INTVL. FOR THIS MEAN		42919	19309	62229					



James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Cross Rock
Standard Error
Mean Oysters per Sample
Number of Samples Included
Std Err
Mean
50
40
30
20
10
0
100
80
60
40
20
0
0
5
10
15
20
9

Figure 13

STATISTICAL SUMMARY FOR CROSS ROCK (9)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		3	1	6		0	0	0	0.5
HIGH VALUE (PER SQ. METER)		193	18	204		39	8	47	23
MEAN NO. PER SQ. METER		75.1	7.8	82.9		12.7	2.9	15.6	13.0
STD.DEV.		57.5	4.5	60.6		10.7	2.3	12.2	7.4
NO. SAMPLES (n)		19	19	19		19	19	19	19
STD. ERROR (SE)		13.2	1.0	13.9		2.5	0.5	2.8	1.7
t.05 VALUE FOR n (t.05)		2.093	2.093	2.093		2.093	2.093	2.093	2.093
(SE)*(t.05) = t.05SE		27.62	2.17	29.10		5.14	1.10	5.84	3.55
UPPER 95% CONF. INTVL. FOR MEAN		102.7	10.0	112.0		17.8	4.0	21.4	16.5
LOWER 95% CONF. INTVL FOR MEAN		47.5	5.7	53.9		7.5	1.8	9.7	9.4
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		36.688	36.688						
MEAN NO. BUSHELS PER ACRE		303.9	63.5	367					
UPPER 95% CONF. INTVL. FOR THIS MEAN		415.7	81.0	497					
LOWER 95% CONF. INTVL. FOR THIS MEAN		192.2	45.9	238					
MEAN TOTAL BUSHELS IN WHOLE ROCK		11151	2329	13480					
UPPER 95% CONF. INTVL. FOR THIS MEAN		15252	2972	18224					
LOWER 95% CONF. INTVL. FOR THIS MEAN		7050	1685	8735					

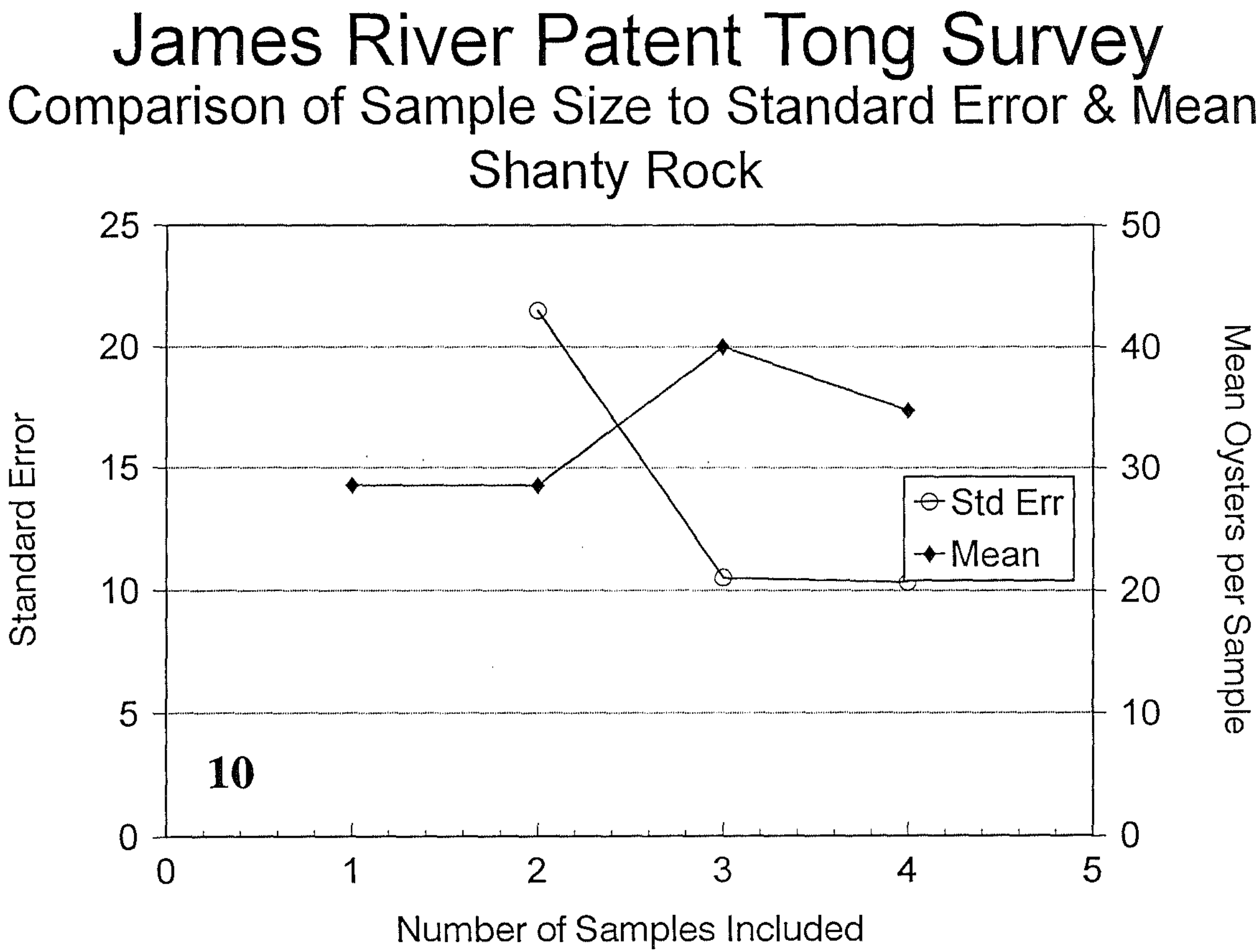

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Shanty Rock
Standard Error
Mean Oysters per Sample
Number of Samples Included
Std Err
Mean
25
20
15
10
5
0
50
40
30
20
10
0
0
1
2
3
4
5
10

Figure 14

STATISTICAL SUMMARY FOR SHANTY ROCK (10)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		7	0	7		2	0	4	10
HIGH VALUE (PER SQ. METER)		48	5	51		29	7	36	14
MEAN NO. PER SQ. METER		32.5	2.3	34.8		14.3	3.0	17.3	12.8
STD.DEV.		19.0	2.1	20.7		11.1	2.9	13.5	1.9
NO. SAMPLES (n)		4	4	4		4	4	4	4
STD. ERROR (SE)		9.5	1.0	10.3		5.6	1.5	6.7	0.9
t.05 VALUE FOR n (t.05)		3.182	3.182	3.182		3.182	3.182	3.182	3.182
(SE)*(t.05) = t.05SE		30.26	3.28	32.87		17.7	4.68	21.40	3.01
UPPER 95% CONF. INTVL. FOR MEAN		62.8	5.5	67.6		32.0	7.7	38.6	15.8
LOWER 95% CONF. INTVL FOR MEAN		2.2	-1.0	1.9		-3.5	-1.7	-4.1	9.7
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		3.58	3.58						
MEAN NO. BUSHELS PER ACRE		132	18	150					
UPPER 95% CONF. INTVL. FOR THIS MEAN		254	45	299					
LOWER 95% CONF. INTVL. FOR THIS MEAN		9	0	9					
MEAN TOTAL BUSHELS IN WHOLE ROCK		471	65	536					
UPPER 95% CONF. INTVL. FOR THIS MEAN		909	160	1069					
LOWER 95% CONF. INTVL. FOR THIS MEAN		32	0	32					

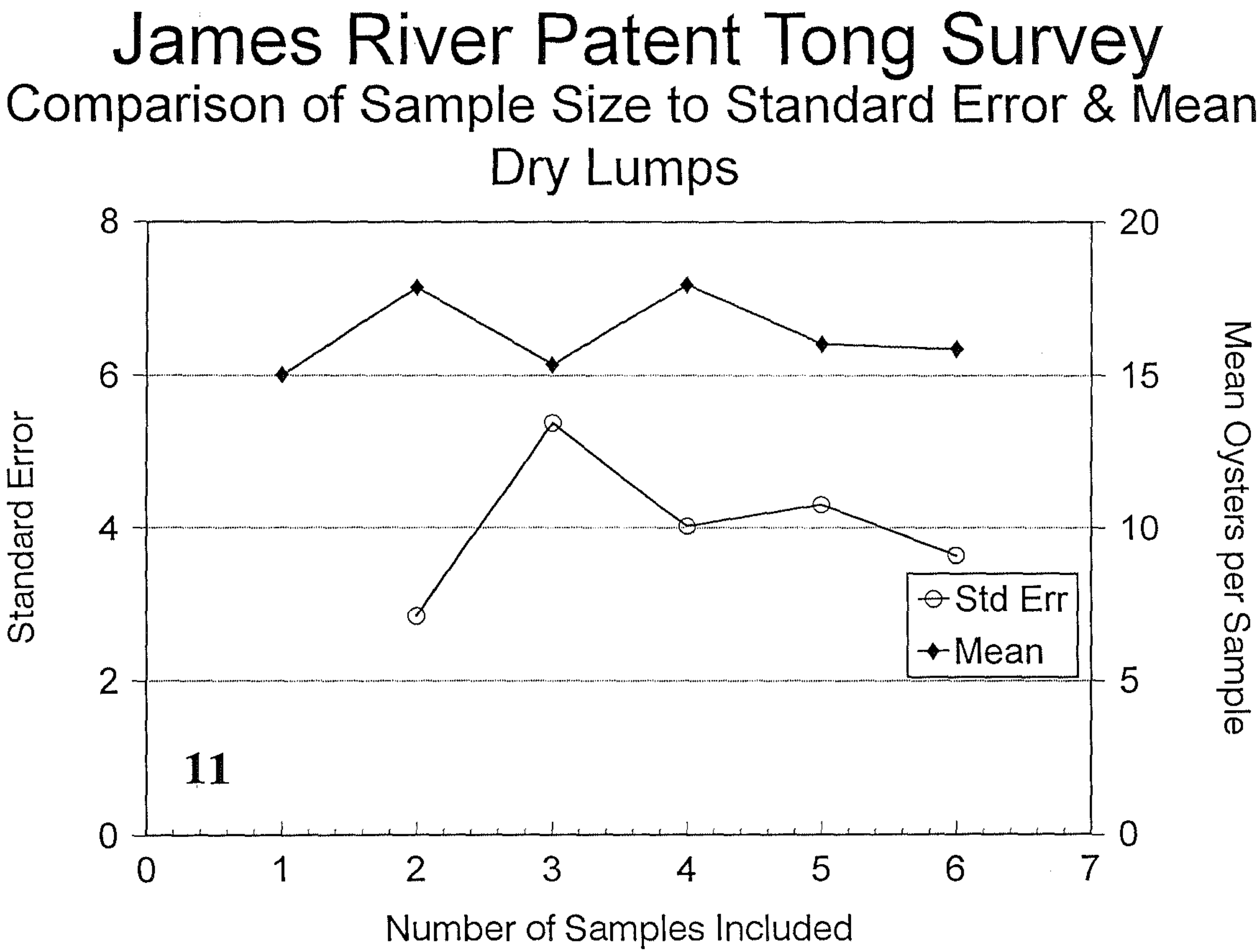

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Dry Lumps
Standard Error
Mean Oysters per Sample
Number of Samples Included
0
2
4
6
8
0
5
10
15
20
0
1
2
3
4
5
6
7
Std Err
Mean
11

Figure 15

STATISTICAL SUMMARY FOR DRY LUMPS (11)

	LIVE OYSTERS				BOXES				SHELL VOL. (l)
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	
LOW VALUE (PER SQ. METER)		3	0	3		2	0	2	4
HIGH VALUE (PER SQ. METER)		25	2	26		14	2	16	39
MEAN NO. PER SQ. METER		15.0	0.8	15.8		6.3	0.5	6.8	21.3
STD.DEV.		8.6	1.0	8.9		4.1	0.8	4.8	13.5
NO. SAMPLES (n)		6	6	6		6	6	6	6
STD. ERROR (SE)		3.5	0.4	3.6		1.7	0.3	1.9	5.5
t.05 VALUE FOR n (t.05)		2.571	2.571	2.571		2.571	2.571	2.571	2.571
(SE)*(t.05) = t.05SE		9.08	1.03	9.33		4.29	0.88	4.99	14.17
UPPER 95% CONF. INTVL. FOR MEAN		24.1	1.9	25.2		10.6	1.4	11.8	35.5
LOWER 95% CONF. INTVL FOR MEAN		5.9	-0.2	6.5		2.0	-0.4	1.8	7.2
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		5.93	5.93						
MEAN NO. BUSHELS PER ACRE		60.7	6.7	67					
UPPER 95% CONF. INTVL. FOR THIS MEAN		97.4	15.1	113					
LOWER 95% CONF. INTVL. FOR THIS MEAN		24.0	0.0	24					
MEAN TOTAL BUSHELS IN WHOLE ROCK		360	40	400					
UPPER 95% CONF. INTVL. FOR THIS MEAN		578	90	667					
LOWER 95% CONF. INTVL. FOR THIS MEAN		142	0	142					

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Mulberry Point

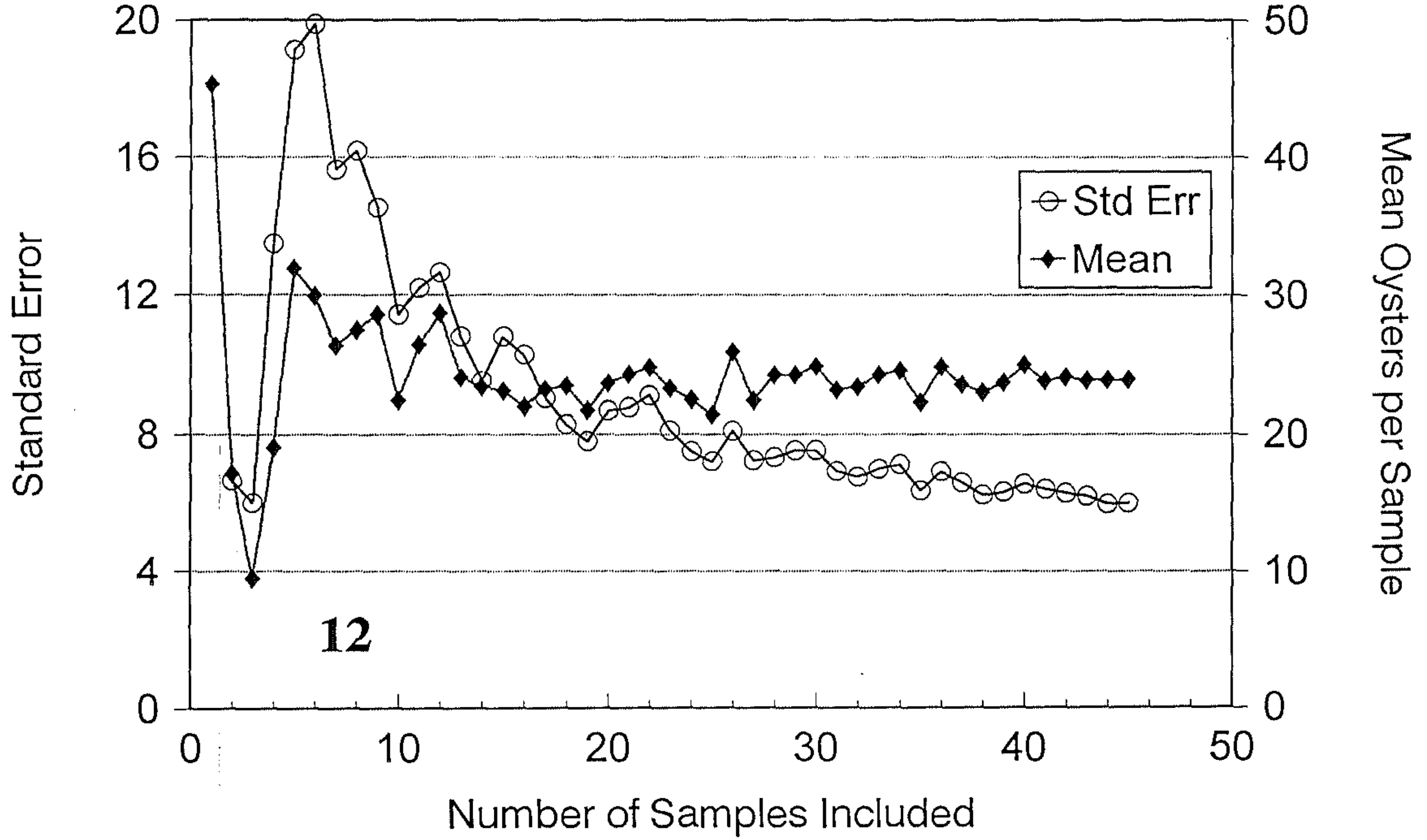


Figure 16

STATISTICAL SUMMARY FOR MULBERRY POINT (12)
(Combination of "Mulberry Pt." and "Mulberry-Swash")

	LIVE OYSTERS				BOXES				SHELL
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	VOL (l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)		160	39	199		8	5	11	7
MEAN NO. PER SQ. METER		18.3	5.6	23.9		1.6	0.6	3.1	2.1
STD.DEV.		32.8	8.0	40.3		2.1	1.0	3.0	2.0
NO. SAMPLES (n)		45	45	45		45	45	27	45
STD. ERROR (SE)		4.9	1.2	6.0		0.3	0.1	0.6	0.3
t.05 VALUE FOR n (t.05)		2.013	2.013	2.013		2.013	2.013	2.013	2.013
(SE)*(t.05) = t.05SE		9.85	2.41	12.10		0.63	0.30	1.17	0.59
UPPER 95% CONF. INTVL. FOR MEAN		28.2	8.0	36.0		2.2	0.9	4.2	2.7
LOWER 95% CONF. INTVL FOR MEAN		8.5	3.2	11.8		0.9	0.3	1.9	1.5
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		86.85	86.85						
MEAN NO. BUSHELS PER ACRE		74	45	119					
UPPER 95% CONF. INTVL. FOR THIS MEAN		114	65	179					
LOWER 95% CONF. INTVL. FOR THIS MEAN		34	26	60					
MEAN TOTAL BUSHELS IN WHOLE ROCK		6436	3937	10372					
UPPER 95% CONF. INTVL. FOR THIS MEAN		9899	5633	15532					
LOWER 95% CONF. INTVL. FOR THIS MEAN		2973	2240	5213					

James River Patent Tong Survey

Comparison of Sample Size to Standard Error & Mean

Swash

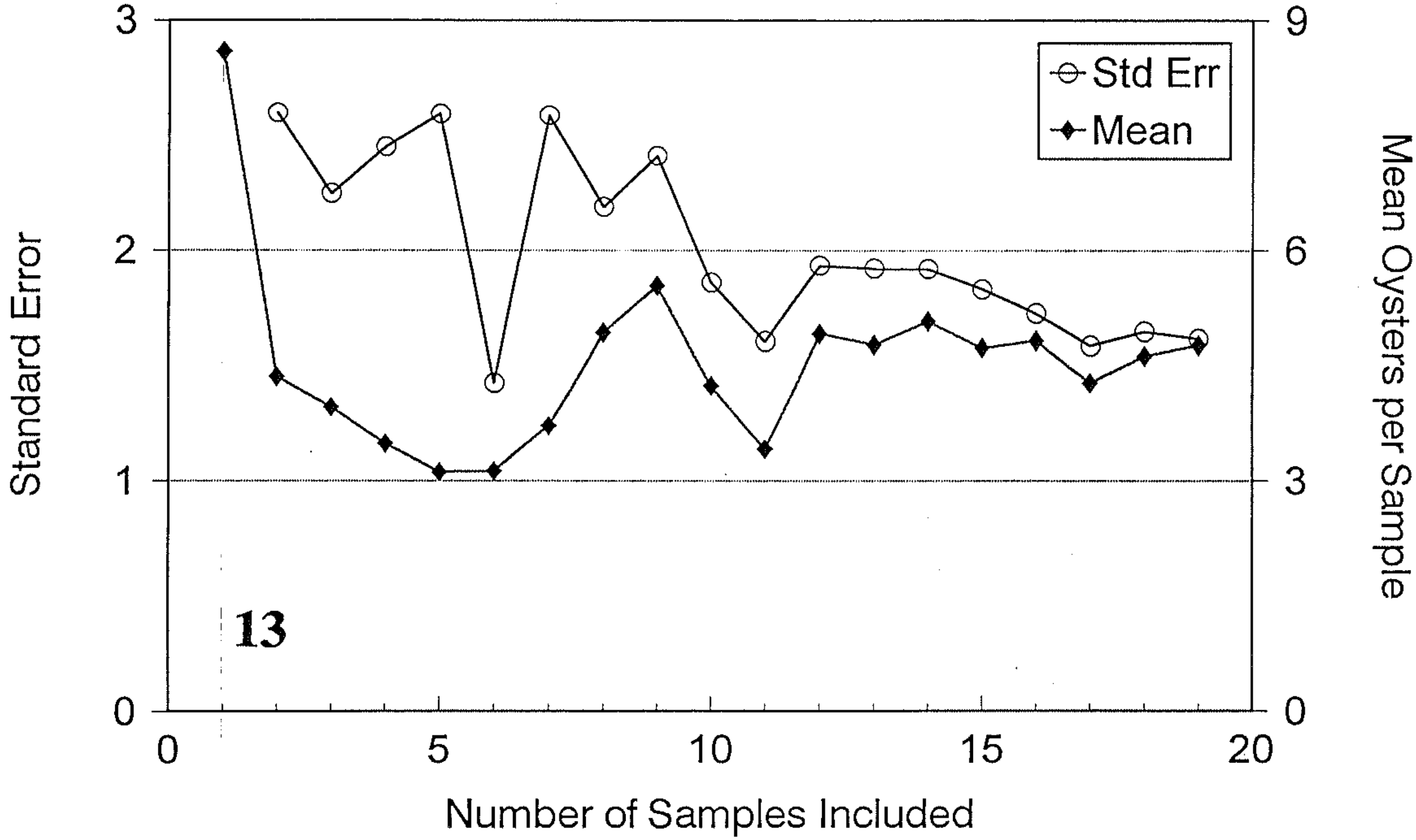


Figure 17

STATISTICAL SUMMARY FOR SWASH (13)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)		19	7	25		8	5	9	9
MEAN NO. PER SQ. METER		3.5	1.3	4.8		0.7	0.5	1.2	1.2
STD.DEV.		5.3	2.0	7.1		1.9	1.2	2.3	2.3
NO. SAMPLES (n)		19	19	19		19	19	19	19
STD. ERROR (SE)		1.2	0.5	1.6		0.4	0.3	0.5	0.5
t.05 VALUE FOR n (t.05)		2.101	2.101	2.101		2.101	2.101	2.101	2.101
(SE)*(t.05) = t.05SE		2.54	0.98	3.41		0.90	0.59	1.10	1.10
UPPER 95% CONF. INTVL. FOR MEAN		6.1	2.2	8.2		1.6	1.1	2.3	2.3
LOWER 95% CONF. INTVL FOR MEAN		1.0	0.3	1.4		-0.2	-0.1	0.1	0.1
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		165	165						
MEAN NO. BUSHELS PER ACRE		14	10	24					
UPPER 95% CONF. INTVL. FOR THIS MEAN		25	18	43					
LOWER 95% CONF. INTVL. FOR THIS MEAN		4	2	6					
MEAN TOTAL BUSHELS IN WHOLE ROCK		2355	1687	4042					
UPPER 95% CONF. INTVL. FOR THIS MEAN		4052	2989	7042					
LOWER 95% CONF. INTVL. FOR THIS MEAN		657	385	1042					

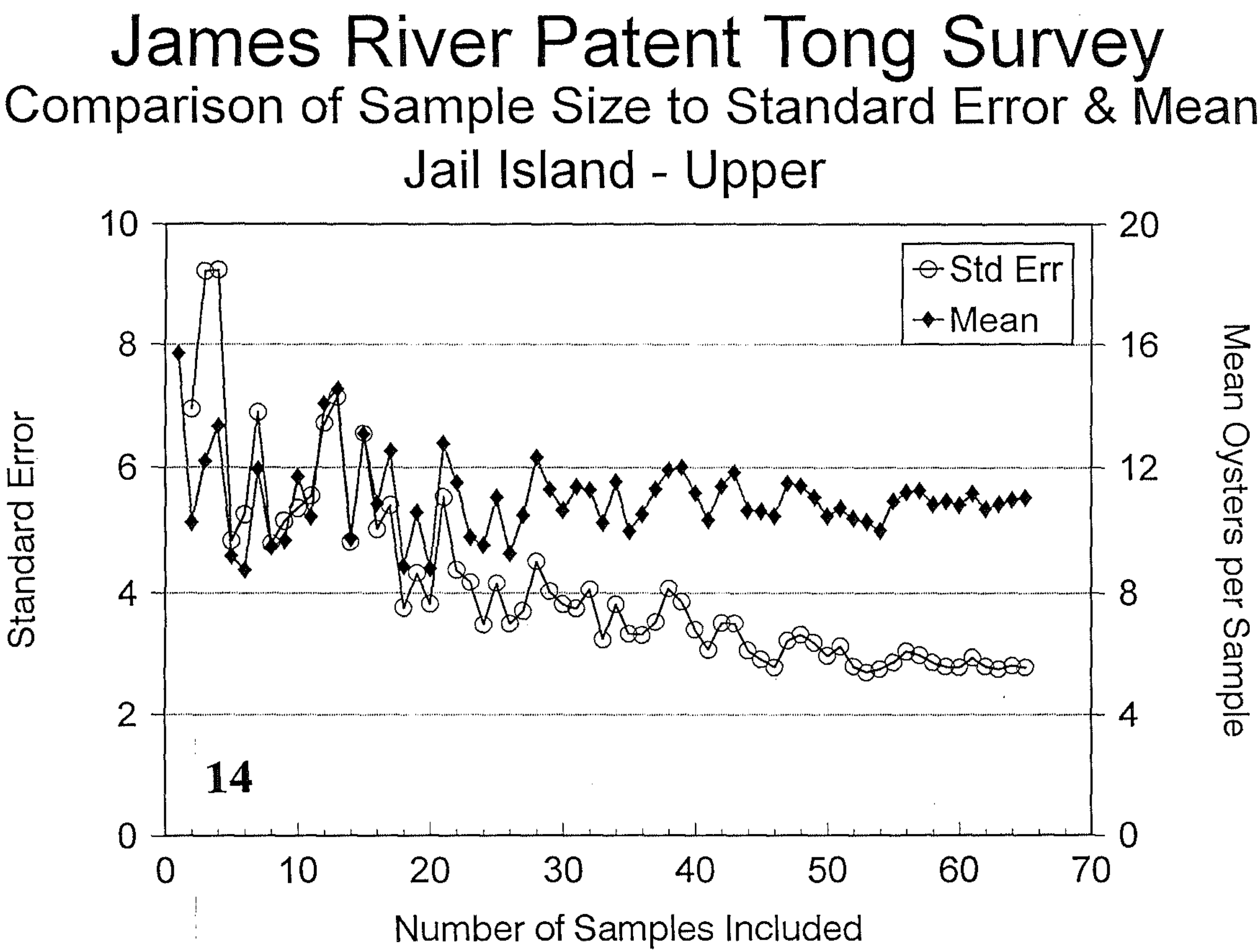

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Jail Island - Upper
Std Err
Mean
Standard Error
Mean Oysters per Sample
Number of Samples Included
0
2
4
6
8
10
0
4
8
12
16
20
0
10
20
30
40
50
60
70
14

Figure 18

STATISTICAL SUMMARY FOR UPPER JAIL ISLAND (14)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)		56	84	140		20	21	41	9
MEAN NO. PER SQ. METER		5.5	5.6	11.0		1.6	1.5	3.1	1.6
STD.DEV.		9.9	12.8	22.5		3.2	3.0	5.8	1.7
NO. SAMPLES (n)		65	65	65		65	65	65	65
STD. ERROR (SE)		1.2	1.6	2.8		0.4	0.4	0.7	0.2
t.05 VALUE FOR n (t.05)		1.997	1.997	1.997		2.00	2.00	1.997	1.997
(SE)*(t.05) = t.05SE		2.45	3.18	5.57		0.79	0.73	1.44	0.43
UPPER 95% CONF. INTVL. FOR MEAN		7.9	8.8	16.6		2.3	2.2	4.5	2.0
LOWER 95% CONF. INTVL FOR MEAN		3.0	2.4	5.5		0.8	0.8	1.6	1.1
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		611.8	611.8						
MEAN NO. BUSHELS PER ACRE		22	45	67					
UPPER 95% CONF. INTVL. FOR THIS MEAN		32	71	103					
LOWER 95% CONF. INTVL. FOR THIS MEAN		12	19	32					
MEAN TOTAL BUSHELS IN WHOLE ROCK		13560	27578	41138					
UPPER 95% CONF. INTVL. FOR THIS MEAN		19624	43337	62961					
LOWER 95% CONF. INTVL. FOR THIS MEAN		7497	11818	19315					

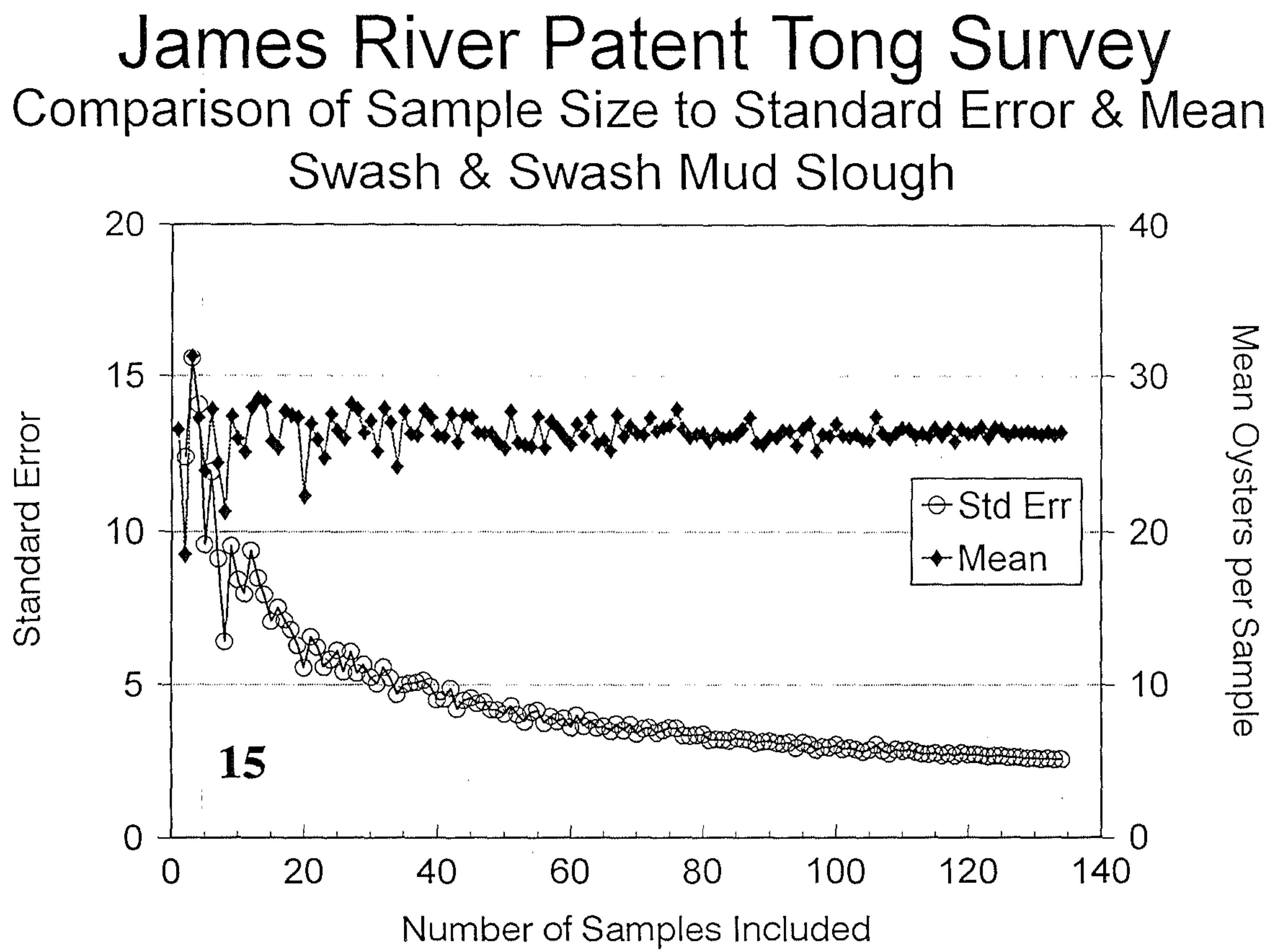

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Swash & Swash Mud Slough
Standard Error
Mean Oysters per Sample
Number of Samples Included
Std Err
Mean
15
0
5
10
15
20
0
10
20
30
40
0
20
40
60
80
100
120
140

Figure 19

STATISTICAL SUMMARY FOR SWASH AND SWASH MUD SLOUGH (15)

	LIVE OYSTERS				BOXES				SHELL
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	VOL (l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)		129	27	143		18	7	20	24
MEAN NO. PER SQ. METER		20.8	5.6	26.4		2.4	1.1	3.4	3.0
STD.DEV.		24.7	6.0	29.6		3.2	1.4	4.0	3.3
NO. SAMPLES (n)		134	134	134		134	134	134	134
STD. ERROR (SE)		2.1	0.5	2.6		0.3	0.1	0.3	0.3
t.05 VALUE FOR n (t.05)		1.96	1.96	1.96		1.96	1.96	1.96	1.96
(SE)*(t.05) = t.05SE		4.18	1.02	5.01		0.54	0.24	0.67	0.56
UPPER 95% CONF. INTVL. FOR MEAN		25.0	6.6	31.4		2.9	1.3	4.1	3.6
LOWER 95% CONF. INTVL FOR MEAN		16.6	4.5	21.3		1.8	0.9	2.8	2.5
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		1244.9	1244.9						
MEAN NO. BUSHELS PER ACRE		84	45	129					
UPPER 95% CONF. INTVL. FOR THIS MEAN		101	53	154					
LOWER 95% CONF. INTVL. FOR THIS MEAN		67	37	104					
MEAN TOTAL BUSHELS IN WHOLE ROCK		104703	56092	160796					
UPPER 95% CONF. INTVL. FOR THIS MEAN		125738	66346	192084					
LOWER 95% CONF. INTVL. FOR THIS MEAN		83669	45838	129507					

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Swash - Offshore

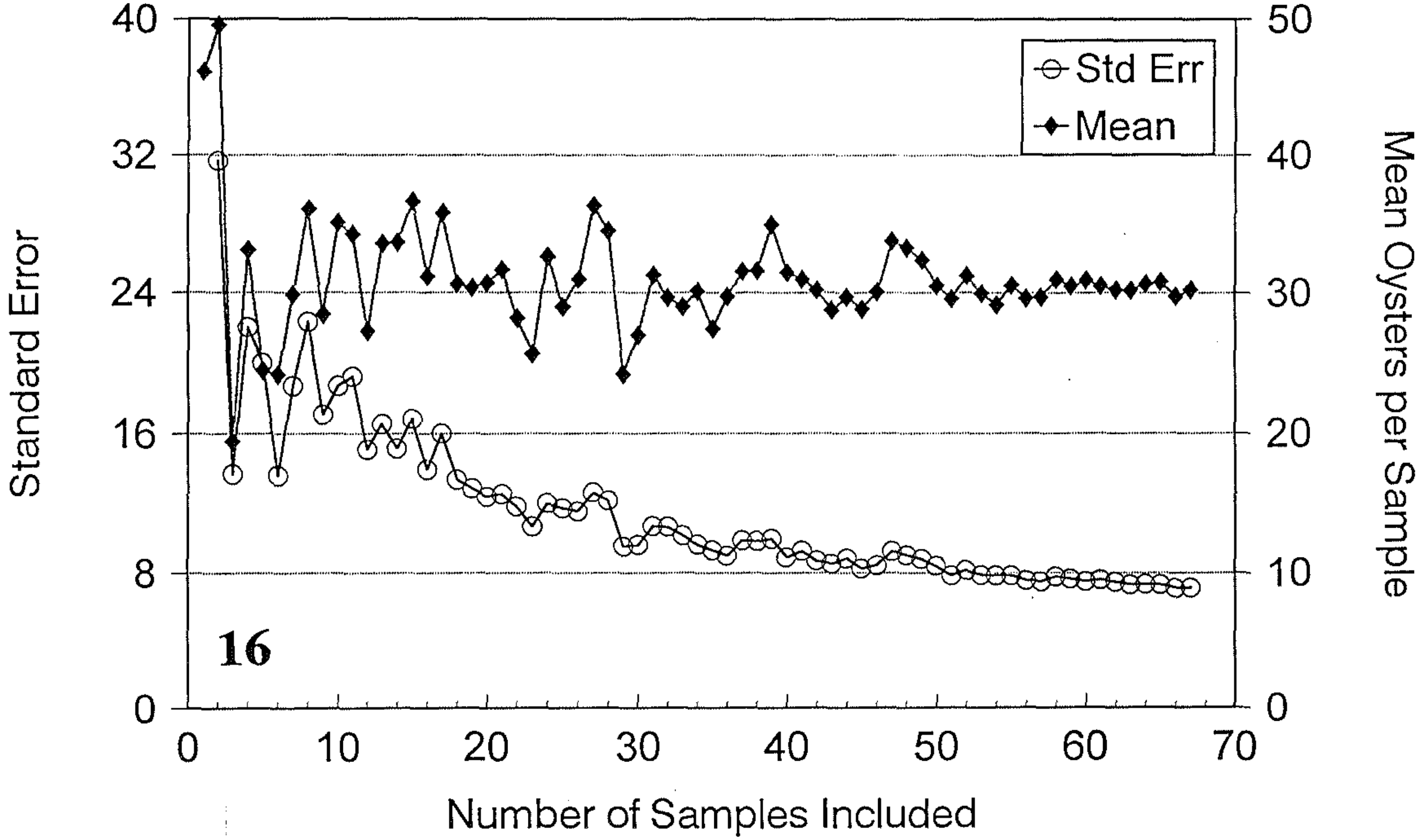


Figure 20

STATISTICAL SUMMARY FOR OFFSHORE SWASH (16)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)		190	209	283		47	14	28	39
MEAN NO. PER SQ. METER		24.5	5.7	30.2		3.7	1.2	4.0	5.6
STD.DEV.		44.6	25.8	58.2		7.0	2.5	6.5	8.4
NO. SAMPLES (n)		67	67	67		67	67	67	67
STD. ERROR (SE)		5.5	3.1	7.1		0.9	0.3	0.8	1.0
t.05 VALUE FOR n (t.05)		1.992	1.992	1.992		1.992	1.992	1.992	1.992
(SE)*(t.05) = t.05SE		10.86	6.27	14.16		1.71	0.62	1.58	2.05
UPPER 95% CONF. INTVL. FOR MEAN		35.4	12.0	44.4		5.4	1.8	5.6	7.6
LOWER 95% CONF. INTVL FOR MEAN		13.7	-0.6	16.1		1.9	0.6	2.4	3.5
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		626.51	626.51						
MEAN NO. BUSHELS PER ACRE		99	46	145					
UPPER 95% CONF. INTVL. FOR THIS MEAN		143	97	240					
LOWER 95% CONF. INTVL. FOR THIS MEAN		55	0	55					
MEAN TOTAL BUSHELS IN WHOLE ROCK		62175	28911	91086					
UPPER 95% CONF. INTVL. FOR THIS MEAN		89705	60710	150415					
LOWER 95% CONF. INTVL. FOR THIS MEAN		34644	0	34644					

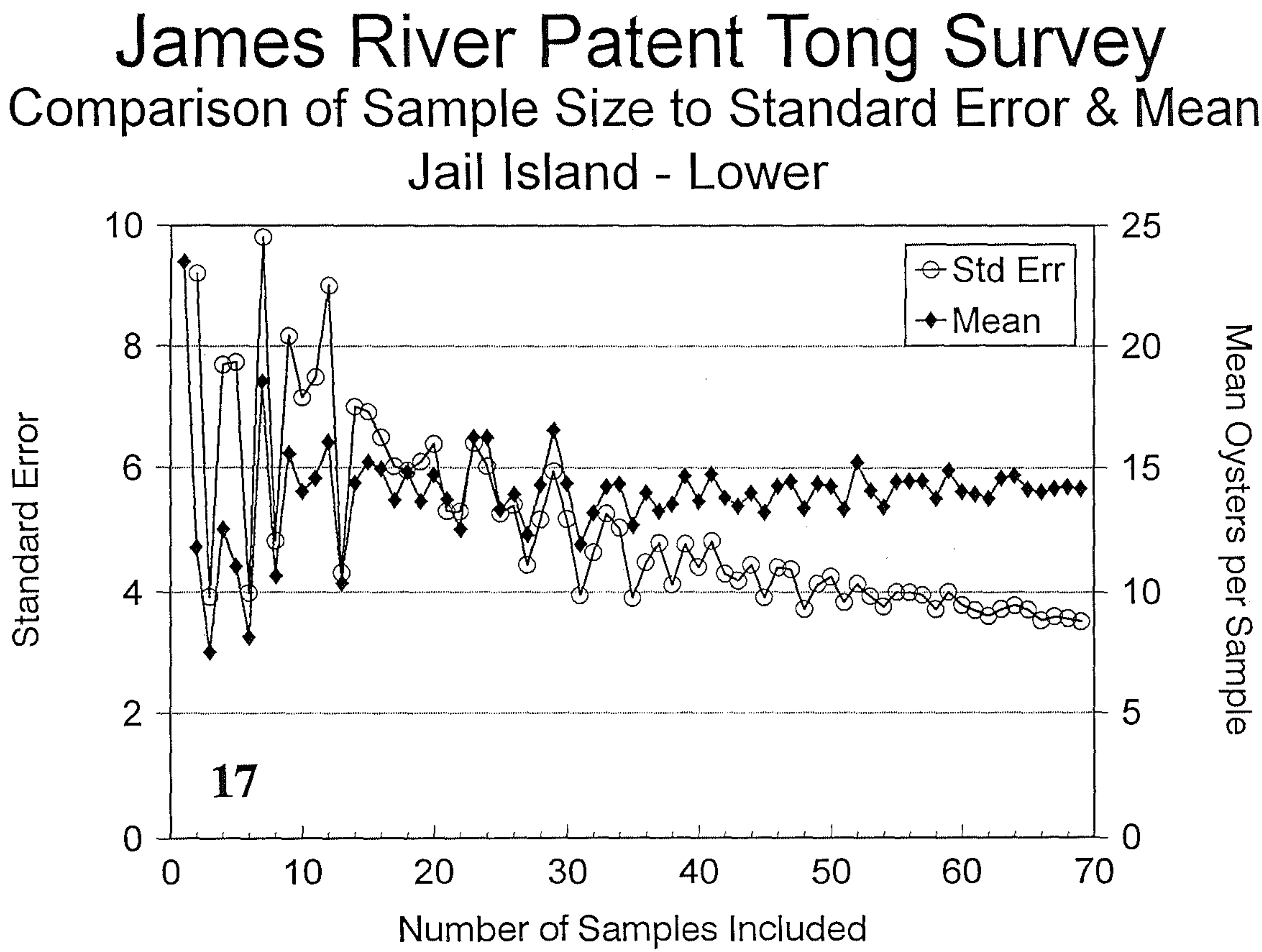

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Jail Island - Lower
Std Err
Mean
Standard Error
Mean Oysters per Sample
Number of Samples Included
10
8
6
4
2
0
25
20
15
10
5
0
0
10
20
30
40
50
60
70
17

Figure 21

STATISTICAL SUMMARY FOR LOWER JAIL ISLAND (17)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL(l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)		158	32	183		30	7	30	16
MEAN NO. PER SQ. METER		9.3	4.9	14.2		2.5	1.1	3.6	2.6
STD.DEV.		23.4	7.2	29.2		5.1	1.6	5.7	3.2
NO. SAMPLES (n)		69	69	69		69	69	69	69
STD. ERROR (SE)		2.8	0.9	3.5		0.6	0.2	0.7	0.4
t.05 VALUE FOR n (t.05)		1.994	1.994	1.994		1.994	1.994	1.994	1.994
(SE)*(t.05) = t.05SE		5.61	1.74	7.01		1.23	0.38	1.37	0.78
UPPER 95% CONF. INTVL. FOR MEAN		14.9	6.6	21.2		3.7	1.4	4.9	3.3
LOWER 95% CONF. INTVL FOR MEAN		3.6	3.2	7.1		1.3	0.7	2.2	1.8
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		628.93	628.93						
MEAN NO. BUSHELS PER ACRE		37	40	77					
UPPER 95% CONF. INTVL. FOR THIS MEAN		60	54	114					
LOWER 95% CONF. INTVL. FOR THIS MEAN		15	26	40					
MEAN TOTAL BUSHELS IN WHOLE ROCK		23571	24936	48507					
UPPER 95% CONF. INTVL. FOR THIS MEAN		37856	33768	71623					
LOWER 95% CONF. INTVL. FOR THIS MEAN		9286	16104	25390					

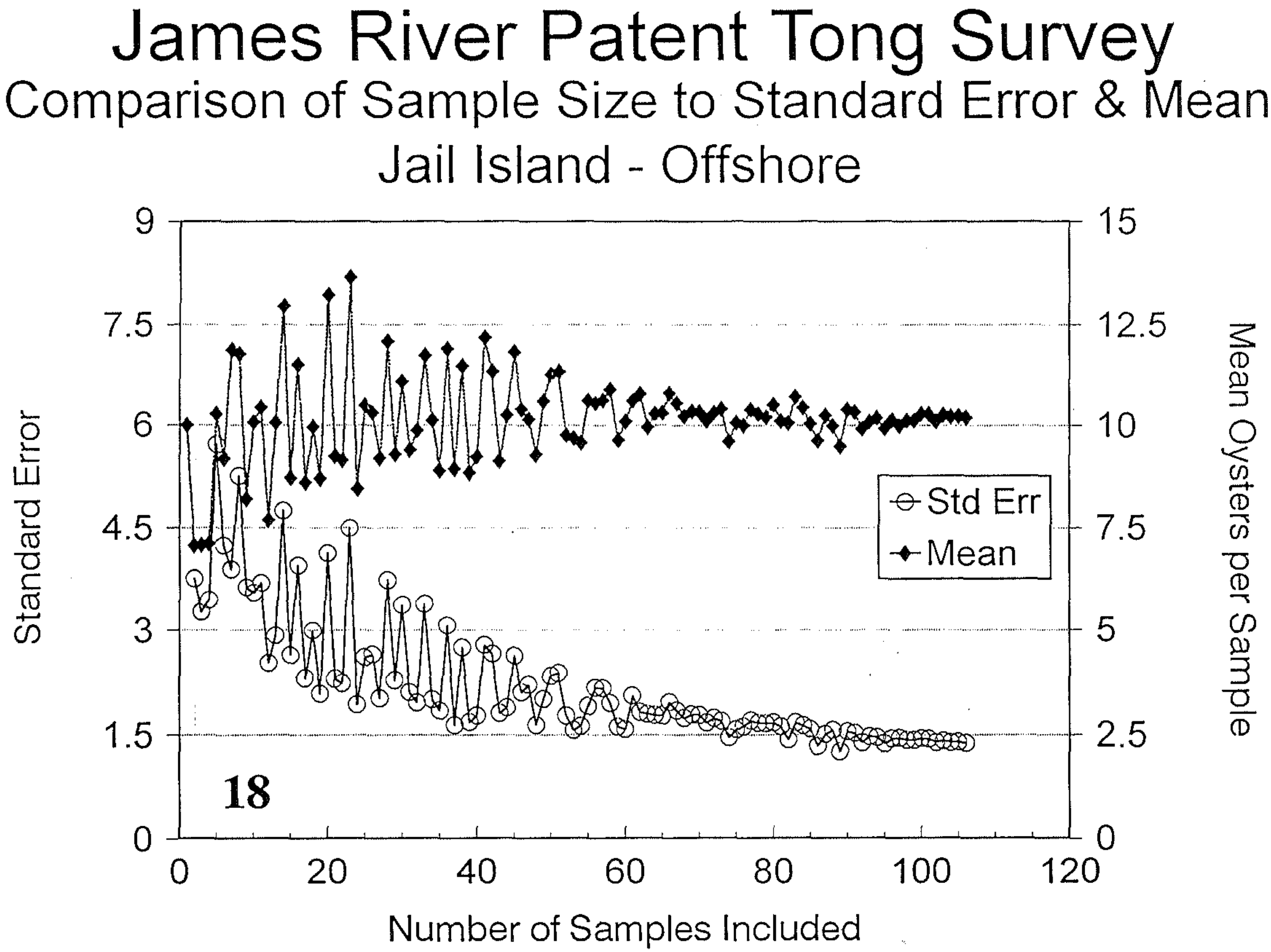
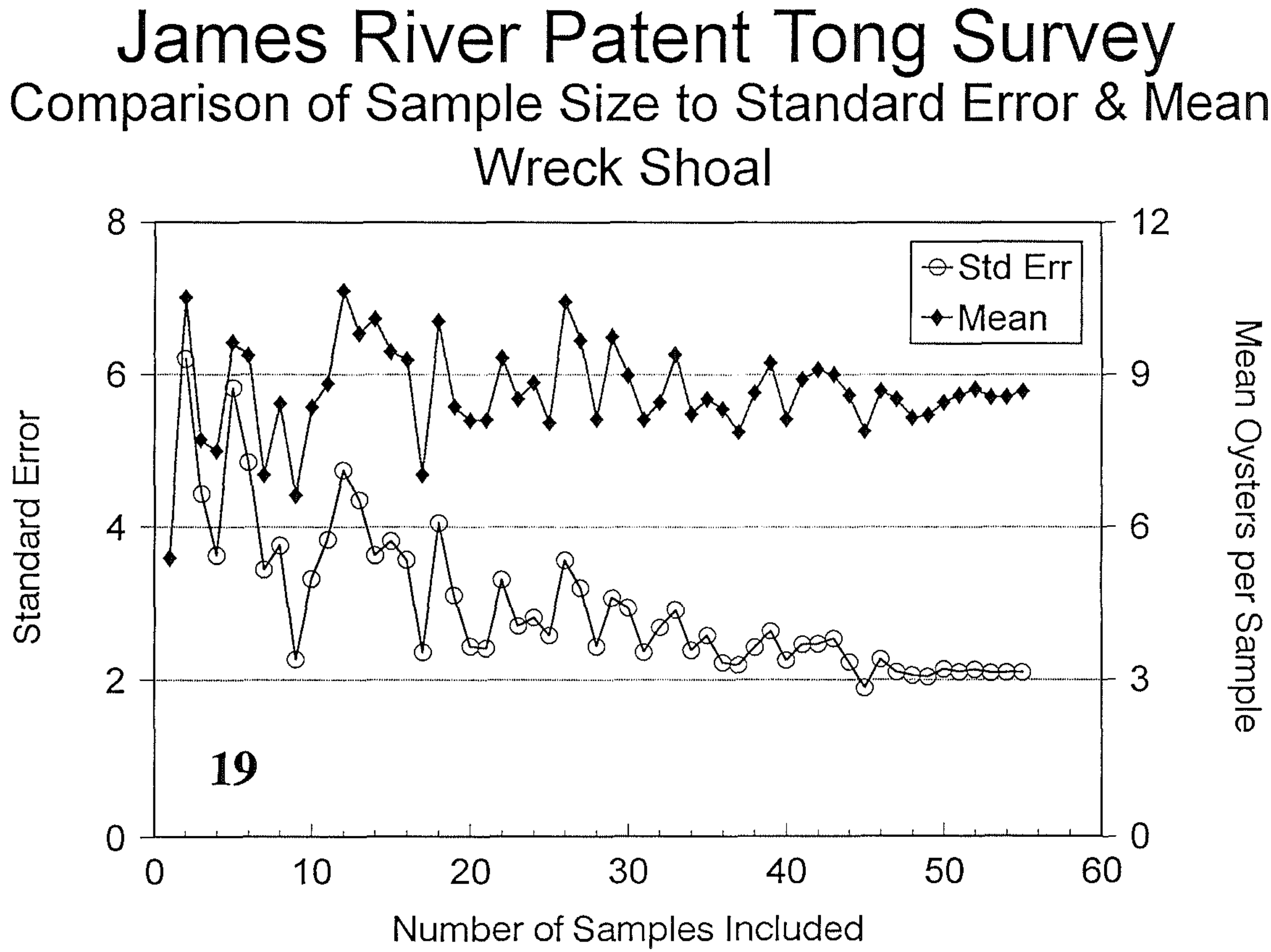

James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Jail Island - Offshore
Standard Error
Mean Oysters per Sample
Number of Samples Included
Std Err
Mean
18
9
7.5
6
4.5
3
1.5
0
15
12.5
10
7.5
5
2.5
0
0
20
40
60
80
100
120

Figure 22

STATISTICAL SUMMARY FOR OFFSHORE JAIL ISLAND (18)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)		83	17	100		25	13	34	30
MEAN NO. PER SQ. METER		7.8	2.4	10.2		4.2	1.0	5.2	4.9
STD.DEV.		11.9	3.4	14.3		5.4	2.0	6.5	5.7
NO. SAMPLES (n)		105	105	105		105	105	105	105
STD. ERROR (SE)		1.2	0.3	1.4		0.5	0.2	0.6	0.6
t.05 VALUE FOR n (t.05)		2.275	2.275	2.275		2.275	2.275	2.275	2.275
(SE)*(t.05) = t.05SE		2.63	0.76	3.17		1.19	0.44	1.45	1.26
UPPER 95% CONF. INTVL. FOR MEAN		10.4	3.2	13.4		5.4	1.5	6.7	6.2
LOWER 95% CONF. INTVL FOR MEAN		5.2	1.7	7.1		3.0	0.6	3.8	3.6
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		1017.2	1017.2	1017.2					
MEAN NO. BUSHELS PER ACRE		32	20	51					
UPPER 95% CONF. INTVL. FOR THIS MEAN		42	26	68					
LOWER 95% CONF. INTVL. FOR THIS MEAN		21	14	35					
MEAN TOTAL BUSHELS IN WHOLE ROCK		32109	20151	52260					
UPPER 95% CONF. INTVL. FOR THIS MEAN		42942	26437	69379					
LOWER 95% CONF. INTVL. FOR THIS MEAN		21275	13865	35141					



James River Patent Tong Survey
Comparison of Sample Size to Standard Error & Mean
Wreck Shoal
Std Err
Mean
Standard Error
Mean Oysters per Sample
Number of Samples Included
0
2
4
6
8
0
3
6
9
12
0
10
20
30
40
50
60

19

Figure 23

STATISTICAL SUMMARY FOR WRECK SHOAL (19)

	LIVE OYSTERS				BOXES				
	SPAT	SMALL	MARKET	TOTAL SML+MKT	SPAT	SML	MKT	TOTAL SML+MKT	SHELL VOL (l)
LOW VALUE (PER SQ. METER)		0	0	0		0	0	0	0
HIGH VALUE (PER SQ. METER)		76	22	94		20	7	27	28
MEAN NO. PER SQ. METER		6.4	2.3	8.7		4.4	1.0	5.4	9.8
STD.DEV.		12.4	3.9	15.5		4.4	1.5	5.0	7.3
NO. SAMPLES (n)		55	55	55		55	55	55	55
STD. ERROR (SE)		1.7	0.5	2.1		0.6	0.2	0.7	1.0
t.05 VALUE FOR n (t.05)		2.004	2.004	2.004		2.004	2.004	2.004	2.004
(SE)*(t.05) = t.05SE		3.35	1.07	4.20		1.19	0.39	1.34	1.98
UPPER 95% CONF. INTVL. FOR MEAN		9.8	3.3	12.9		5.6	1.4	6.7	11.8
LOWER 95% CONF. INTVL FOR MEAN		3.1	1.2	4.5		3.2	0.6	4.0	7.9
CONVERS. FACTOR ACRES TO SQ. METERS		4046.9	4046.9						
ESTIMATED NO. OYSTERS IN 1 BUSHEL		1000	500						
ROCK ACREAGE		584.76	584.76						
MEAN NO. BUSHELS PER ACRE		26	18	44					
UPPER 95% CONF. INTVL. FOR THIS MEAN		40	27	66					
LOWER 95% CONF. INTVL. FOR THIS MEAN		12	10	22					
MEAN TOTAL BUSHELS IN WHOLE ROCK		15188	10671	25859					
UPPER 95% CONF. INTVL. FOR THIS MEAN		23107	15716	38823					
LOWER 95% CONF. INTVL. FOR THIS MEAN		7269	5625	12895					

General summary of population sizes

A summary of standing stock estimates for the James River is given in Table 1. The contenst of this table are distilled from the statistical summaries accompanying Figures 3 through 23. The important conversion figures to acknowledge are that of numbers of small and market oysters per bushel at 1000 and 500 respectively. These correspond to below and above two and one half inches (62.5mm) height (maximum dimension). These summaries do not include young of the year (also commonly termed spat) oysters which are very small and occupy a comparatively negligible volume.

Absolute densities of oysters are highly variable, from high values of 350, 272, 271, 222, 173 and 129 per sq. meter at Upper Horsehead, Lower Horsehead, Moon Rock, Middle Horsehead, V Rock and Point of Shoals respectively, to low values of 14, 11, 10, 9, and 5 at Lower Jail Island, Upper Jail Island, Offshoe Jail Island, Wreck Shoal, and Swash respectively. Mean estimates of standing stocks of seed (small) and market oysters are 465,356 and 258,869 bushels respectively, for a total of approximately 724,225 bushels in the surveyed section of James River. The confidence interval around these values gives upper and lower values of 318,542 and 612,169 bushels for seed (small), and 155,582 and 365,078 bushels for market oysters respectively. A limited number of individual rocks had lower estimates of zero for market oysters - these reflect analysis of data that include a large number of samples with zero market size oysters present.

Substantial seed (small) oyster resources are present in a number of locations: Upper Deep Water Shoal, the components of Horsehead Rock, V Rock, Point of Shoals, Cross Rock, and the large areas of Swash and Jail Island. The bulk of market oysters are located on the same rocks.

In the Rappahannock River standing stock estimates were made for Carters Rock, Ross's Rock, Bowlers Rock, Long Rock, and Sharps Rock (inshore). These are all very small rocks and of limited commercial importance. The estimated seed oysters resources on these were 126, 637, 36, 78, and 13 bushels respectively. The estimated market oyster resources on these were 69, 371, 79, 202 and 0 bushels respectively. Only Ross's Rock supported any commercial activity in the public oyster season of 1993-94.

Table 1

JAMES RIVER OYSTER ROCKS
Standing Stock Estimates
BUSHELS OF OYSTERS IN ROCK ACREAGE SAMPLED
Fall 1993

OYSTER ROCK		ACRES SAMPLED	SEED OYSTERS			MARKET OYSTERS			SEED & MARKET COMBINED		
Chart No.	Name		MEAN ESTIMATE	Lower Mean Estimate	Upper Mean Estimate	MEAN ESTIMATE	Lower Mean Estimate	Upper Mean Estimate	MEAN ESTIMATE	Lower Mean Estimate	Upper Mean Estimate
1	Upper Deep Water Shoal	233.92	***46,472***	31,692	61,252	***37,579***	25,918	49,240	***84,051***	57,610	110,492
2	Lower Deep Water Shoal	19.93	***798***	508	1,089	***1,371***	969	1,773	***2,170***	1,477	2,862
3	Upper Horsehead	3.009	***3,588***	429	6,747	***1,348***	101	2,594	***4,936***	530	9,341
4	Middle Horsehead	19.465	***16,877***	11,671	22,083	***1,158***	521	1,795	***18,035***	12,192	23,878
5	Lower Horsehead	19.467	***19,963***	15,439	24,487	***2,954***	1,179	4,729	***22,917***	16,619	29,216
6	Moon Rock	3.95	***3,948***	1,744	6,152	***791***	223	1,360	***4,740***	1,967	7,512
7	V Rock	72.053	***45,950***	39,780	52,120	***11,842***	9,777	13,906	***57,792***	49,557	66,026
8	Point of Shoals	131.71	***55,906***	42,919	68,893	***25,463***	19,309	31,617	***81,369***	62,229	100,509
9	Cross Rock	36.688	***11,151***	7,050	15,252	***2,329***	1,685	2,972	***13,480***	8,735	18,224
10	Shanty Rock	3.58	***471***	32	909	***65***	0	160	***536***	32	1,069
11	Dry Lumps	5.93	***360***	142	578	***40***	0	90	***400***	142	667
12	Mulberry Point	86.85	***6,436***	2,973	9,899	***3,937***	2,240	5,633	***10,372***	5,213	15,532
13	Swash	165	***2,355***	657	4,052	***1,687***	385	2,989	***4,042***	1,042	7,042
14	Upper Jail Island	611.8	***13,560***	7,497	19,624	***27,578***	11,818	43,337	***41,138***	19,315	62,961
15	Swash-Swash Mud Slough	1244.9	***104,703***	83,669	125,738	***56,092***	45,838	66,346	***160,795***	129,507	192,084
16	Offshore Swash	626.51	***62,175***	34,644	89,705	***28,911***	0	60,710	***91,086***	34,644	150,415
17	Lower Jail Island	628.93	***23,571***	9,286	37,856	***24,936***	16,104	33,768	***48,507***	25,390	71,623
18	Offshore Jail Island	1017.2	***31,884***	21,141	42,626	***20,117***	13,890	26,343	***52,000***	35,030	68,970
19	Wreck Shoal	584.76	***15,188***	7,269	23,107	***10,671***	5,625	15,716	***25,859***	12,895	38,823
TOTALS		5515.652	***465,356***	318,542	612,169	***258,869***	155,582	365,078	***724,225***	474,124	977,247

Size distribution data and implications for interpretation of general summary

Size distribution data, by numbers of individual oysters present within each 5 mm height size class interval, for all 19 areas sampled is illustrated in Figure 24. For convenience this is displayed as six graphics. Again, young of the year (spat) oysters are not included in this illustration. The dominant feature of all plots is the rapid decrease in number of individuals in all locations above the 60-65 mm (mid point 63 mm on Figure 24) size class. This corresponds closely with the two and one half inch (62.5 mm) minimum size for market oyster harvest, suggesting efficient harvesting above the size limit. Despite this individual of over 100 mm maximum dimension were found in very limited numbers in the majority of locations. The size distribution data illustrate that the increase in minimum size for market oyster exploitation to three inches (76 mm) for the 1994-1995 public oyster season may result in some hardship to watermen in that large numbers of individuals were at or below 60 mm in the Fall of 1993, and would have to grow substantially through the spring and summer of 1994 to attain a 76 mm size and become available to the fishery in the Fall of 1994.

When size distribution data by individual numbers is replotted by either biomass or potential contribution to egg production other facets of stock management are implicated. A sample of 111 oysters of sizes varying from 30 to 95 mm height was collected from the James River on May 13, 1994 and used to generate conversion functions of height to live weight and dry tissue weight. The relationships generated by MINITAB analysis are:

$$\text{live weight (g)} = 0.0064642 \times \text{height}^{2.1095}$$

$$\text{dry tissue weight (g)} = 0.000423 \times \text{height}^{1.7475}$$

In turn these can be related to fecundity by the relationship:

$$\text{fecundity (millions of eggs)} = 39.06 \times \text{dry tissue weight}^{2.36}$$

These conversions are illustrated for data from Lower and Upper Deep Water Shoal in Figure 25. In the instance of both live and dry tissue weight the mode moves above the 60-65 mm size class, illustrating the importance of the numerically smaller size classes in the ecologically important processes of filtration and benthic-pelagic coupling. The fecundity issue is critical, in that the basis for setting minimum harvest size is to maximize reproductive output prior to harvest (although this is somewhat questionable in the James River where, until the 1994-1995 season, seed harvest procedures allowed removal of essentially all oysters from the majority of public oyster ground). When considering contribution to egg production 76 and 65% of production for Lower and Upper Horsehead is in the 60-65 mm size class and above. Harvesting these size classes. despite their numerical inferiority to smaller size classes, can clearly have major impact on egg production. Note that these percentages are calculated giving equal weighting to sex ration with increasing size. Although a matter of debate in the literature the positions vary from unity of ratio with size to a predominance of females with larger size classes. If the latter were the case then the 76 and 65% values are conservative estimates!. An increase of minimum size to 76 mm decreases these values considerably: 48 and 32% of estimated egg production comes from individuals in the 75-80 mm size interval and larger in the two locations. Increasing the minimum size limit for market oysters from two and one half to three inches (62.5 to 76 mm) effectively doubles the available egg production from the resource.

Figure 24: Size class distribution

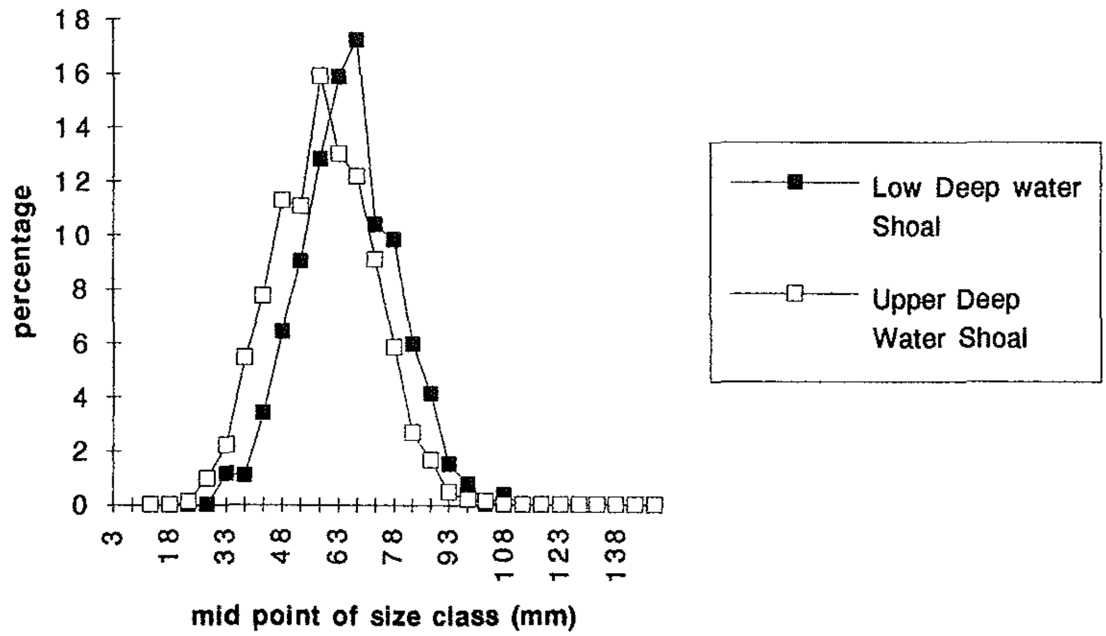


Figure 24: Size class distribution

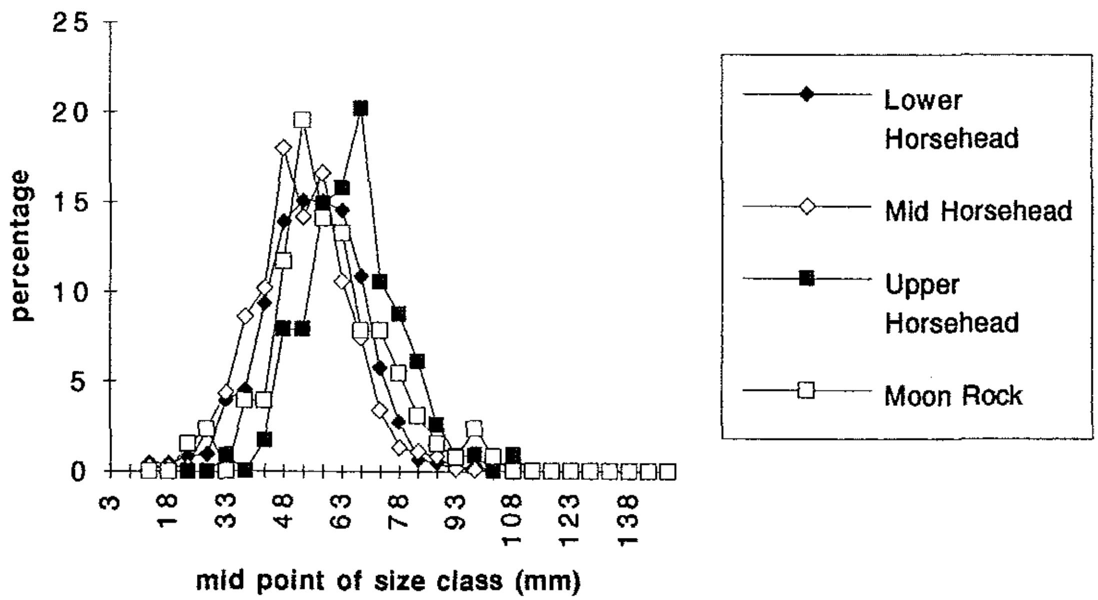


Figure 24: Size class distribution

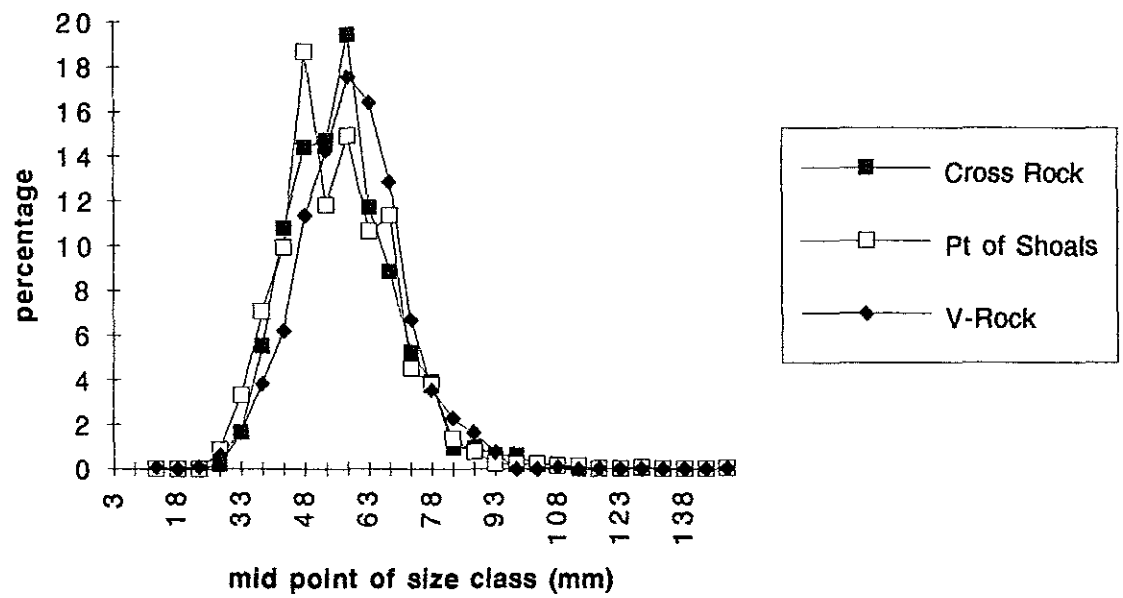


Figure 24: Size class distribution

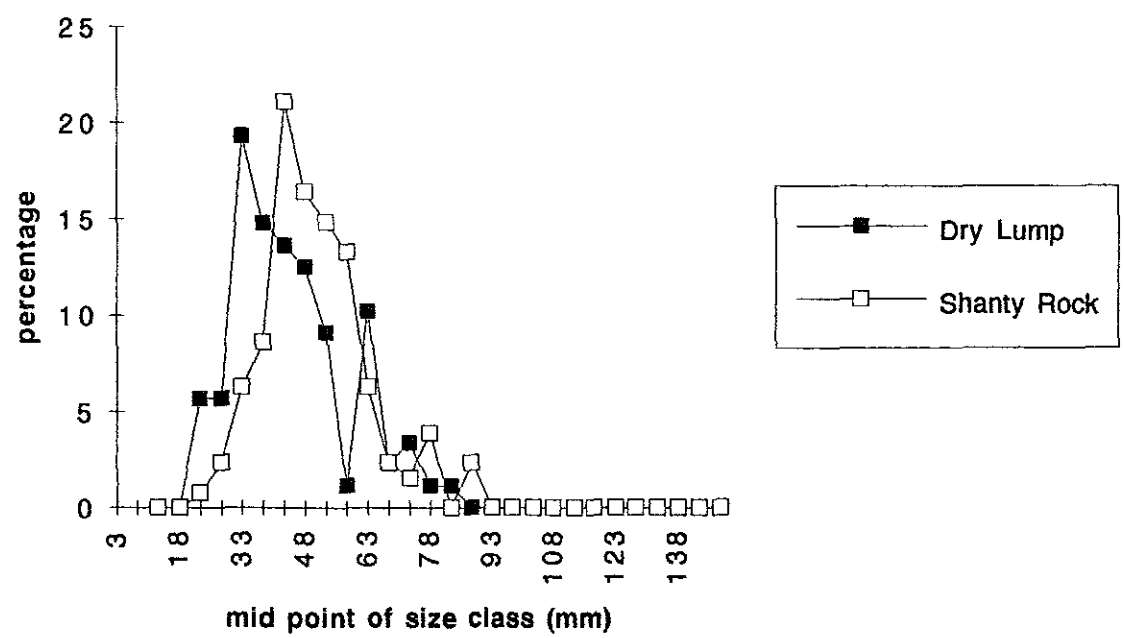


Figure 24: Size class distribution

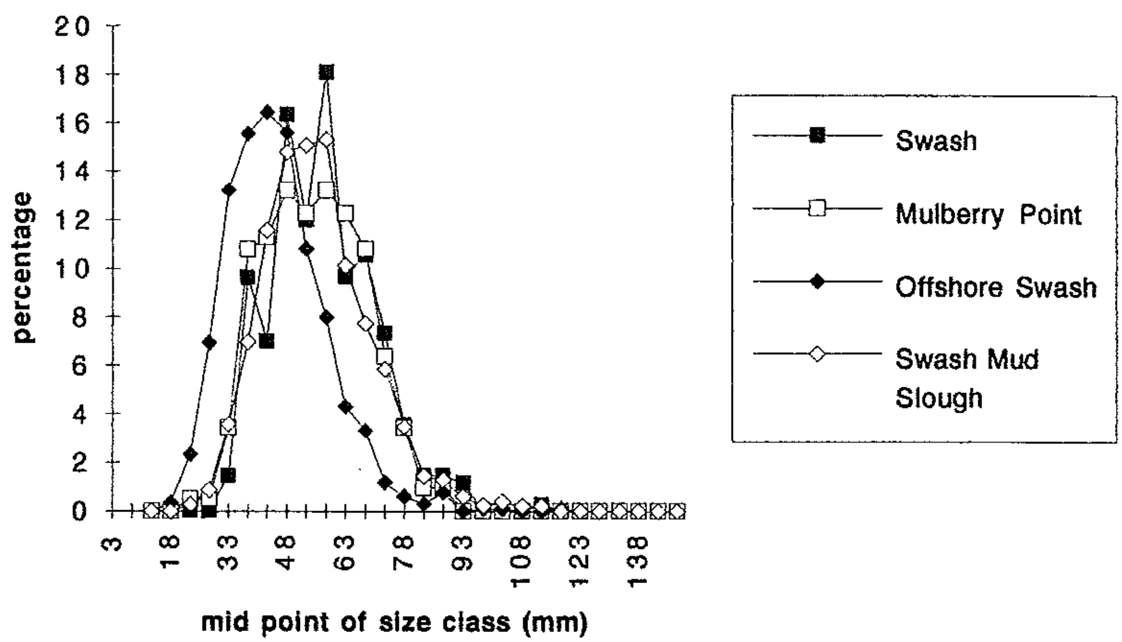


Figure 24: Size class distribution

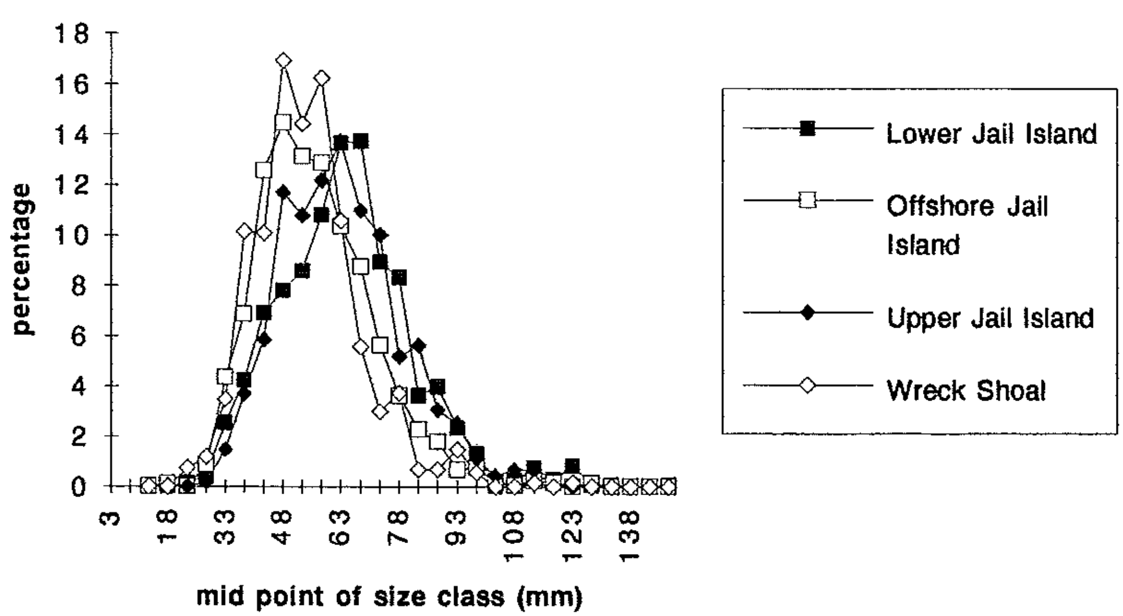
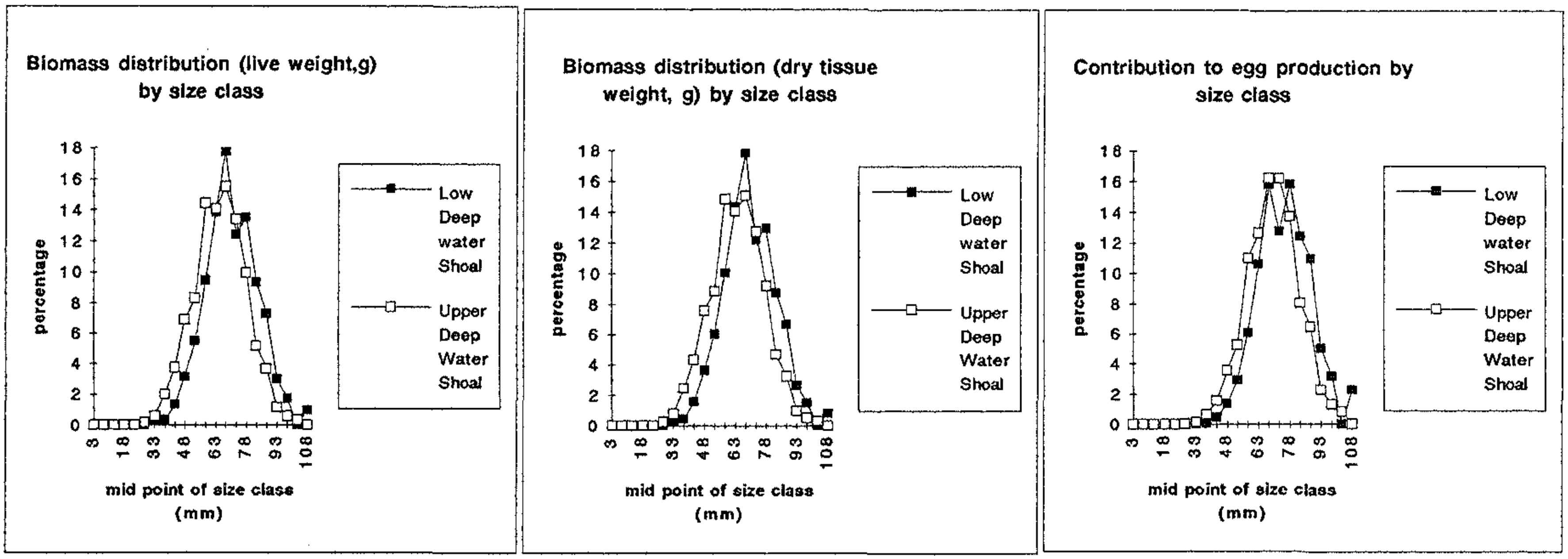


Figure 25: Comparison of biomass distribution by live and dry tissue weights, and egg production by size class interval



Fishery Dependent Methods

Barber and Mann (1991), supported by Chesapeake Bay Stock Assessment Committee (CBSAC) funds, employed Leslie - DeLury analysis of commercial fishery data (daily and weekly boat count data to estimate effort, landing data to estimate catch, both data sets collected and provided by the VMRC) to estimate recent decline in standing stock of oysters in the James River. A secondary objective of the current study was to compare, where possible, fishery independent and fishery dependent estimates of standing stock.

Fishery-dependent estimates quantify only that portion of the resource harvested as a part of commercial activity and systematically exclude smaller animals that also contribute to gamete production. They are also susceptible to errors from under-reporting of catch. An excellent review of the limitations of Leslie-DeLury application to invertebrate fisheries is given by Breen (1992). Leslie-DeLury analysis becomes less sensitive as stocks become very low or if there is not a marked decrease in catch per unit effort over a fishing season. Both situations are likely to occur in application to the Virginia oyster fishery, and are complicated by variable, low or no effort towards the end of the fishing season as watermen turn to other resources. Finally, any method based on regression analysis must comply to certain statistical prerequisites, including normal distribution of data. This may not always be the case in data obtained from commercial fishing operations. Despite these limitations, fishery dependent estimates of standing stock have been the only estimates available to the Virginia Marine Resource Commission.

Tables 3 and 4 provide summaries, taken from V.M.R. C. records, of seed and market oyster catches, by month, for the public fishery for the seasons from 1982-1983 through 1994-1994. To illustrate trends in seasonal totals the values are plotted in Figure 26. The period of 1982-1983 through 1988-1989 are characterized by an initial focus on the market oyster fishery, with an accompanying decline, subsequently followed by an increasing harvest of seed oysters in the 1986-1987 through 1988-1989 period. Note that the focus on market oysters is historically unprecedented in this location. Previously sub sets of the data of Tables 3 and 4 were used to generate Leslie-DeLury estimates of standing stock of market oysters, and the data given limited distribution (including the proposal which lead to the current fishery independent assessment). These estimates are given in Table 5. They suggest a rapidly diminishing resource, and values that are well below those suggested by the fishery independent estimates given earlier in this report. The immediate question to present is why? The answer to this question is that the analysis is probably flawed!

Leslie-DeLury analysis relies on decreases in catch per unit effort over time to estimate initial values of standing stock. The data as used for effort do not distinguish between effort devoted to market oyster harvest and that devoted to seed oyster harvest. On any particular boat at any time in the period described by Table 5 attention may have been devoted to market oysters or seed oysters in isolation, or to the peculiar (to this River, and again a product of the regulations allowing both seed and market oyster harvest from the same location) activity of "two piling" - retaining both seed and market oysters as separate catches for inspection purposes on the same vessel. Short term variability in relative effort devoted to each resource, suggested by catch landing data in Tables 3 and 4, will complicate the estimation of effort. Although "two piling" was not a common practice (market oyster prices dictating more efficient use of limited space) such activity also influenced effort data on each resource. To rectify the problem and repeat the analysis would probably require that all oyster tax records provided from individual harvesters be re-examined and a new database generated which consistently distinguishes, if possible, between the two catches. In the interim period the continued use of summary data that does not distinguish effort between the two resources should not be used to generate fishery independent estimates of standing stock.

Table 2: James River Seed and Market Oyster Harvest: 1982-1983 through 1993-1994.

HARVEST SEASON

SEED OYSTERS

	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	TOTAL
82/83	83,282	72595	57,144	29,264	24,245	47,418	51,110	56,599	23,536	445,193
83/84	68,774	68414	32,939	15,043	35,605	15,947	53,375	33,961	22,076	346,134
84/85	72,463	54,338	38,744	25,277	28,649	50,801	71,595	54,119	13,881	409,867
85/86	61,420	48,731	32,908	32,240	16,920	36,238	27,745	20,301	0	276,503
86/87	39,092	34,193	14619	3,839	3,375	18,215	41,088	47,985	0	202,406
87/88	20,592	16,281	11,634	1,017	17,585	29,548	15,949	21,847	0	134,453
88/89	13,827	1,948	3,934	675	797	1,281	4,757	14,084	0	41,303
89/90	7,523	8,817	3,137	4,915	6,062	6,266	7,633	7,031	0	51,383
90/91	624	1,475	2,476	4,670	16,130	8,539	16,476	4,620	0	55,010
91/92	1,996	1,320	3,842	17,109	16,052	10,020	2,011	1,187		53,537
92/93	1,896	757	3,135	18,927	18,142	38,824	925			76,606
93/94	31917	49897	38870	7810	3060	5150	4847			141551

MARKET OYSTERS

	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	
82/83	2,039	4,684	2,384	2,004	1,182	386	1,003	1,493	956	16,131
83/84	6,833	8,339	3,423	9,492	3,423	3,420	6,018	6,171	1,632	48,746
84/85	370	6,912	1,694	1,904	1,259	1,243	2,452	3,087	1,555	21,467
85/86	2,196	706	0	4,516	3,893	3,882	3,145	10,418	0	28,756
86/87	62,675	62,212	70,346	50,139	52,823	21,958	15,867	6,764	0	342,784
87/88	65,268	57,052	46,343	36,965	31,433	28,029	17,235	15,449	0	297,774
88/89	43,113	25,225	22,876	15,220	10,997	14,590	7,461	7,474	0	146,956
89/90	11,699	10,658	7,235	13,873	6,587	7,745	6,157	4,588	0	68,542
90/91	7,747	8,126	6,350	4,582	3,487	3,461	4,269	5,384	0	43,406
91/92	4,709	3,651	4,326	2,404	2,373	2,719	3,088	2,314		25,584
92/93	3,584	1,987	2,774	2,161	1,117	2,117	2,153	334		16,227
93/94	1448	2464	2077	403	135	285	236			7048

Table 3: James River Boat Days (Effort) and Catch / Day: 1982-1983 through 1993-1994

HARVEST
SEASON
BOAT DAYS

	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	TOTAL
82/83	1,142	1,225	895	704	564	692	769	834	262	7,087
83/84	1,260	1,305	674	710	809	646	961	786	382	7,533
84/85	1,392	1,045	1,112	331	532	866	975	1,024	260	7,537
85/86	1,078	731	668	626	557	636	730	599	0	5,625
86/87	2,408	2,518	2,752	1,966	2,222	1,158	1,432	1,298	0	15,754
87/88	3,628	3,021	2,939	2,216	3,081	3,042	1,423	1,775	0	21,305
88/89	3,355	2,139	2,360	1,554	1,193	1,340	1,099	987	0	14,027
89/90	1,758	1,362	1,019	1,840	1,075	1,154	899	703	0	9,810
90/91	892	967	1,003	831	825	578	828	774	0	6,698
91/92	682	488	500	600	534	561	458	176		4,032
92/93	294	291	274	306	333	833	165	202		2,698

CATCH/DAY

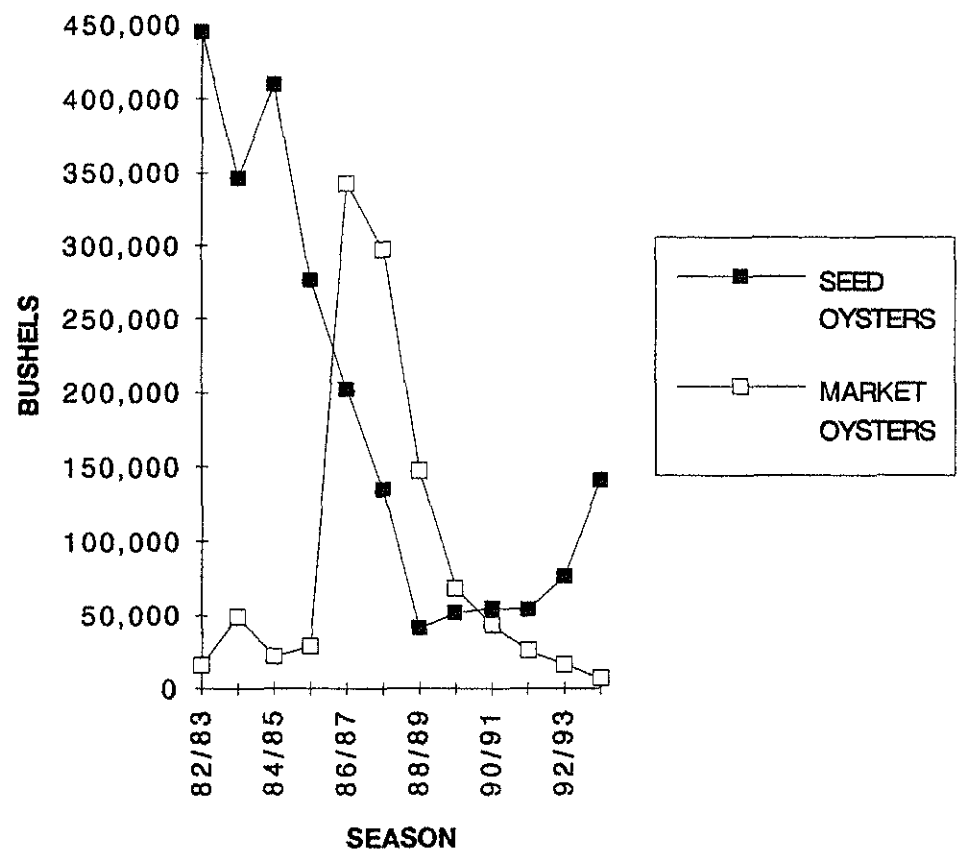
	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	TOTAL
82/83	75	63	67	44	45	69	68	70	94	65
83/84	60	59	54	35	48	30	62	51	62	52
84/85	52	59	37	82	56	60	76	56	59	57
85/86	59	68	49	59	37	63	42	51	0	54
86/87	42	38	31	28	25	35	40	42	0	35
87/88	24	24	20	17	16	19	23	21	0	20
88/89	17	13	11	10	10	12	11	22	0	13
89/90	11	14	10	10	12	12	15	17	0	12
90/91	9	10	9	11	23	21	25	13	0	15
91/92	10	10	11	31	34	20	11	20		20
92/93	19	9	22	69	58	42	19			34

Table 5. Previously generated estimates of standing stock of oysters (bushels) in James River, estimated using Leslie-DeLury from partial (October-December) and full (October-May) season commercial fishery data. The notation ns indicates no significant estimate available from regression analysis. We now suggest that this analysis is compromised by the lack of separation of estimates of effort in the seed and market oyster fisheries, and that these data should be viewed with caution.

Year	October-December	October -May
1986-1987	1,093,000	618,000
1987-1988	840,500	ns
1988-1989	429,000	ns
1989-1990	234,000	265,750
1990-1991	78,400	95,350

SEASON	SEED OYSTERS	MARKET OYSTERS
82/83	445193	16131
83/84	346134	48746
84/85	409867	21467
85/86	276503	28756
86/87	202406	342784
87/88	134453	297774
88/89	41303	146956
89/90	51383	68542
90/91	55010	43406
91/92	53537	25584
92/93	76606	16227
93/94	141551	7048

FIGURE 26: OYSTER PRODUCTION BY SEASON: 1982/3 THROUGH 1993/4



Literature cited

Barber, B. J. and R. Mann. 1991. Estimation of Standing Stock of Oysters in the James River, Virginia, Using Commercial Fishing Records. Virginia Institute of Marine Science, Special Report in Applied Marine Science and Ocean Engineering, No 310.

Breen, P. A. 1992. A review of models used for stock assessment in abalone fisheries. pp 253-275 in: Abalone of the World: Biology, Fisheries and Culture. S. A. Shepherd, M. J. Tegner, S. A. Guzman del Proo (Eds.). Fishing News Books, Blackwell Scientific, 608p.

Bros, W. E. and B. C. Cowell. 1987. A technique for optimizing sample size (replication). J. Exp. Mar. Biol. Ecol. 114: 63-71.

Chai, A-L, M. Homer, C-F. Tsai and P. Goulletquer. 1992. Evaluation of oyster sampling efficiency of patent tongs and an oyster dredge. North American Journal of Fisheries Management 12: 825-832.

Cox. C. 1988. Seasonal changes in the fecundity of oysters Crassostrea virginica (Gmelin) from four oyster reefs in the James River, Virginia. M.A. thesis, College of William and Mary, Williamsburg, VA.

Cox, C. and R. Mann. 1992. Fecundity of oysters, Crassostrea virginica (Gmelin), in the James River, Virginia, U.S.A. J. Shellfish Res. 11(1): 47-52.

Hargis, W. J. Jr. and D. S. Haven. 1988. The imperilled oyster industry of Virginia. VIMS Special Report NUmber 290 in Applied Marine Science and Ocean Engineering. 130p.

Haven, D. S., W. J. Hargis, Jr. and P Kendall. 1981. The present and potential productivity of the Baylor Grounds in Virginia. Va. Inst. Mar. Sci., Spec. Rep. Appl. Mar. Sci. Ocean. Eng. No. 243: 1-154.

Haven, D. S. and J. P. Whitcomb. 1983. The Origin and Extent of Oyster Reefs in the James River, Virginia. J. Shellfish Res. 3(2):141-151

Haven, D. S. and J. P. Whitcomb. 1989. The Location and Topography of oyster reefs in the Rappahannock River Estuary, Virginia. J. Shellfish Res. 8:105-116

Morales-Alamo, R. and R. Mann. 1990. Recruitment and growth of oysters on shell planted at four monthly intervals in the Lower Potomac River, Maryland. J. Shellfish Res. 9(1): 165-172).

Rheinhardt, R. D. and R. Mann. 1990. Development of epibenthic fouling communities on a natural oyster bed in the James River, Virginia. Biofouling: 2: 13-25.

Conclusions and Recommendations

The James River will remain the only substantial source of both seed and market oysters for the public fishery for the immediate future. The resource in the Rappahannock will remain of minor importance to the total fishery production. The James River market oyster harvest for the 1993-94 public season of 5,173 bushels represents approximately 2.2% of the estimated standing stock; however, the seed harvest of 72,470 bushels for the same period represents approximately 15.6% of the estimated standing stock. These are the first ever fishery independent estimates, so long term comparisons of harvest versus standing stock are not possible, although such levels of exploitation appear reasonable at this time. There is considerable spatial variability in oyster density, and harvesting will probably continue to focus on those areas with high density such as Horsehead, Moon Rock, V Rock and Point of Shoals. The seed resource is still substantial, but its utilization will probably be controlled by factors other than availability to the watermen. Lease holding planters are reluctant to purchase seed oysters that may have already been exposed to disease. While mortalities associated with disease are limited in the upper part of the James as sampled oysters may contract infective particles. When transferred to higher salinity grow out sites infected oysters essentially participate in a race between the progressing disease and growth to market size. The financial consequences to the planter of disease related loss in this instance has prompted caution in seed sales. Seed prices, when buyers are present, are variable, but often suppressed.

The recent increase in minimum size of market oysters may suppress landings in the 1994-1995 season depending on the growth of smaller size classes in the spring and summer of 1994. The majority of oysters were below the former size limit during the Fall 1993 sampling, and consistently good growth would be required to make them abundant for the 19945-1995 public season. From an ecological perspective the increase in minimum size is to be applauded. calculations based upon observed size class distribution data illustrate the important contribution of the numerically limited market oysters to total biomass, and hence benthic pelagic coupling. More importantly, accompanying calculations suggest that the modest increase in minimum size will double the available egg production from remaining oysters - a clear bonus in a long term plan to rebuild the resource.

The nature of fishery dependent data records is such that they do not adequately distinguish between market and seed oyster fishing activity, and changes in emphasis from one to the other cause major variability in catch per unit effort data. In turn this compromises the value of standing stock estimates obtained by Leslie-DeLury analysis. We suggest they not be used until fishery records can be re-examined for possible generation of a new database. Fishery independent estimates appear to provide a much more stable method of stock estimate for management purposes.