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The Use of a Volumetric Measure for Determining Sea Scallop Meat Count

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Gloucester, Massachusetts

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The Use of a Volumetric Measure for Determining Sea Scallop Meat Count

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ABSTRACT

Laboratory and field experiments were conducted to evaluate whether a volumetric measuring device could reliably provide accurate sea scallop meat count estimates at sea. A one-pound coffee can was selected as the standard volumetric sampling measure. Calibration experiments revealed that coffee-can volumes conform to manufacturing standards although slight differences in total volume exist among some brands. These differences, however, have a negligible effect on scallop meat-count measurements. Average meat-weight capacity of a coffee can filled with fresh-shucked meats is relatively constant and unaffected by the size mixture of meats within the can. Meat counts determined volumetrically appear to be highly reliable and as precise as counts obtained using weight-based procedures. Differences between at-sea and dockside counts reflect changes in meat condition that occur during handling and storage. A standardized volumetric sampling methodology is proposed along with guidelines for enabling at-sea determination of meat count relative to the current management standard. Assurance that the average meat count in a trip will conform to the management standard is highest when an effort is made to pack each and every bag as closely as possible to the management standard.

KEY WORDS: sea scallops, *Placopecten magellanicus*, meat count, volumetric measure.

INTRODUCTION

The Atlantic sea scallop, *Placopecten magellanicus*, is the most important molluscan shellfish harvested commercially in the United States. The species is sought for its large adductor muscle (the "meat") that holds the two valves of the animal together. In 1987, USA landings of sea scallop meats totaled 13,200 metric tons (29.1 million pounds) valued at 125 million dollars in ex-vessel revenue (Serchuk and Wigley 1988).

Since May 1982, the USA sea scallop fishery has been regulated by the Fishery Management Plan for the Atlantic Sea Scallop Fishery (FMP) developed by the New England Fishery Management Council (one of eight regional fishery management councils established in 1976 by the Magnuson Fishery Conservation and Management Act which extended USA fisheries jurisdiction to 200 nautical miles). The overall objective of the FMP is to "maximize over time the joint economic and social benefits from the harvesting and use of the sea scallop resource" (New England Fishery Management Council 1982). Controlling the size of scallops landed was selected as the preferred management strategy, and meat-count (number of meats per pound) and shell height standards were enacted to govern the size of scallops permissible in the landings. Current regulations require that shucked scallop meats shall not average more than 30 per pound, while scallops landed in the shell ("shellstock") must be a minimum of 89 mm in shell height. The meat-count measure *does not* preclude the landing of individual meats too small, by themselves, to meet the standard so long as the *average count* of the landed meats conforms to the standard. In fact, mixing or blending of small and large meats is a prevalent practice in the fishery. This has enabled harvesters to continue landing large quantities of small meats and still attain the average meat-count standard (Serchuk 1983, 1984; Smolowitz and Serchuk 1987).

Concern has been raised by scallop fishermen that gauging meat counts of shucked scallops at sea is both difficult and inexact, even under optimal weather conditions. Many fishermen believe that, without expensive measuring devices to determine meat weights at sea, they cannot be assured that their at-sea meat counts, when checked dockside by enforcement officials using electronic scales, will comply with the legal standard (Smolowitz and Serchuk 1988).

Present dockside enforcement procedures require that a minimum of 10 one-pound samples be taken to document a violation. The enforcement agent is not required to examine 10 bags (scallops shucked at sea are normally landed packed in 40-pound bags), although this is a common practice. From each bag selected, a sample of whole meats is drawn using a container that holds more than one pound of meat. For each sample, the number of meats per pound (MPP) is determined by weighing the sample on an electronic scale and dividing the sample weight (expressed in hundredths of pounds) by the number of meats in the sample. The average meat count for the trip is calculated as the arithmetic mean of the sample counts. A violation of the meat-count regulation is issued only if the average meat count exceeds the prevailing standard by more than 10 percent (i.e., more than 33 MPP for the 30-count standard). A penalty schedule, graduated in terms of meat count, is used in assessing the degree of non-compliance (Table 1). For example, if the average count is 35.0 MPP, 50% of the catch is forfeited and a fine of up to $10,000 may be levied.

In spite of seemingly severe penalties for slight infractions of the meat-count measure, fishermen generally strive to land scallops as close to the enforcement criterion as possible (i.e., 33 MPP: 30 MPP + 10%). The economic incentive for landing scallops averaging 33 MPP (the enforcement criterion) versus scallops averaging 30 MPP (the FMP standard) is large; many more scallops (far greater than +10%) can be legally harvested at 33 MPP than at 30 MPP. If for every 20-count scallop in the resource there

Table 1. Penalty schedule for possession of non-conforming sea scallops in the USA sea scallop fishery

Violation (MPP)	Forfeiture (%)	Fine ($000) 1st Viol.	2nd Viol.	3rd Viol.
30.1-33.0	0	Verbal Warning		
33.1-34.0	1.0-10.0	0-10	0-10	0-10
34.1-35.0	14.0-50.0	0-10	5-15	15-25
35.1-36.0	55.0-100.0	0-10	5-15	15-25[1]
36.1-39.0	100	0-10	5-15	15-25[2]
>39.0	100	5-10	10-15	15-25[3]

Forfeiture Percentages by Meat Count (to nearest 0.1 MPP)

Violation (MPP)	Forfeiture (%)	Violation (MPP)	Forfeiture (%)
33.1	1	35.1	55
33.2	2	35.2	60
33.3	3	35.3	65
33.4	4	35.4	70
33.5	5	35.5	75
33.6	6	35.6	80
33.7	7	35.7	85
33.8	8	35.8	90
33.9	9	35.9	95
34.0	10	36.0	100
34.1	14	36.1	100
34.2	18	36.2	100
34.3	22	36.3	100
34.4	26	36.4	100
34.5	30	36.5	100
34.6	34	36.6	100
34.7	38	36.7	100
34.8	42	36.8	100
34.9	46	36.9	100
35.0	50	37.0	100

[1] Plus 14-day permit sanction.
[2] Plus 30-day permit sanction.
[3] Plus 60-day permit sanction.

exists a much larger supply of 40-count animals, mixing 100 20-count scallops with 200 40-count scallops will yield 10 pounds of meat averaging 30 MPP. At 33 MPP, 100 20-count scallops can be mixed with 371 40-count animals (86% more 40-count) and yield 14.3 pounds of meat (43% more yield and revenue than at 30 MPP). The latter scenario requires that 3.7 40-count scallops be available for each 20-count scallop in the resource, an abundance pattern that often occurs in exploited scallop stocks.

Fishermen currently attempt to gauge meat counts at sea using volumetric procedures. Typically, this involves placing freshly-shucked scallop meats into an empty container (such as a frosting or coffee can), that, when full, is equated to meat count based on personal experience. This process is generally repeated throughout the trip to provide real-time estimates of the meat count of the catch. Despite these efforts, fishermen often find that their at-sea counts differ from those made dockside by enforcement authorities. Moreover, fishermen have commented that these differences do not seem to be consistent or predictable. As such, many fishermen feel that they have been placed unfairly at risk with respect to potential violation of the meat-count standard.

Previous studies evaluating volumetric methods of estimating scallop meat counts (Caddy and Radley-Walters 1972; Smolowitz and Serchuk 1987) found that volumetrically-derived counts differed by less than 10 percent with weighed meat counts. Comparison of at-sea volumetric counts with dockside counts based on weight (Smolowitz and Serchuk 1987) revealed an average difference of only five percent, with dockside MPP generally *lower* than at-sea MPP. Differences between at-sea and dockside counts were ascribed to changes in meat condition during storage in the vessel hold and to variations in filling the container when determining the volumetric count.

Although volumetric determination of meat count has been shown to be technically feasible, there is a lack of detailed information on whether a volumetric measuring device can reliably provide accurate meat counts at sea. Only limited data exist on the comparability of calibrated at-sea volumetric counts with meat counts obtained dockside using electronic scales. In this report, results are provided from laboratory and field experiments conducted to test the hypothesis that a calibrated volumetric measuring device can be successfully used as an accurate alternative to a weight-based measure of meat count. The studies involved the selection, calibration, and field testing of a standard volumetric container to determine meat counts at sea and dockside. This work was accomplished in partnership with the USA sea scallop industry as part of a Joint Industry-Government Sea Scallop Cooperative Research Program (Smolowitz and Serchuk 1987).

METHODS AND MATERIALS

SELECTION AND CALIBRATION OF VOLUMETRIC SAMPLING DEVICE

The choice of a standard volumetric device was predicated on four factors: (1) availability of the measuring device to the fishing industry; (2) expense in purchasing the device; (3) simplicity and rapidity in using the device; and (4) uniformity of manufacturing specifications of the device. The desideratum was a volumetric measure that was easily procured, widely available, inexpensive, simple to use, sturdily constructed, and fabricated to uniform specifications. All criteria were met by the one-pound container of coffee available in any supermarket (Figure 1).

Coffee cans manufactured in the United States are constructed according to voluntary standards of the Can Manufacturers Institute. The one-pound cans are of three-piece construction, nominal size of 4 1/16" diameter x 5 1/2" height (103 mm x 140 mm), with a capacity of 1,014 ml (plus or minus 20 ml). The cans, when sold with coffee, come with a plastic lid that can be pressed fit to one end after the can is opened.

To evaluate the uniformity (i.e., quality control) in volumetric capacity among coffee cans of different brands (conceivably manufactured at different facilities), an experiment was conducted in which 17 coffee cans, representing five different brands, were tested using distilled water (Table 2). Each can was tared on an electronic laboratory balance (accurate to 0.01 gm), and water added to the empty can. The first 1,000 ml was added using a 1,000-ml graduated cylinder after which a 50-ml graduated cylinder (1-ml gradations) was used to fill the can. Once filled, the weight of the can was recorded. This process was performed twice with each can. During the first time, the can was filled to the point of having a concave meniscus; during the second time, the can was filled to a convex meniscus.

A second series of experiments were conducted to test the constancy of product weight of coffee cans filled with freshly shucked scallop meats. During May 1987 to October 1988, 32 shellstock samples were obtained, on approximately a fortnightly basis, from commercial scallop vessels landing in New Bedford, Massachusetts. Each sample contained about a bushel of unculled scallops from the last tow of the trip. Samples were offloaded on the morning a vessel returned to port and immediately transported to the National Marine Fisheries Service's Woods Hole Laboratory for processing. In the laboratory, the scallops were shucked in a commercial manner and measurements taken on the shell height and adductor muscle weight (meat weight) of each individual scallop. Data were also recorded on gonad weight and sex for a concurrent study on seasonal variability in scallop meat weight and reproductive condition. After being weighed, the whole shucked meats were placed in a one-pound coffee can. The can was filled with meats until the plastic lid cover would no longer fit to the top of the can without bulging outward (i.e., the lid had to be flat when held at eye level). The number of scallop meats in every full can was recorded as was the total meat weight. Between one and three coffee-can samples were taken from each bushel of scallops. From the 32 one-bushel samples, 64 individual coffee-can weight measurements (comprising 5,291 scallop meats) were obtained.

EVALUATION OF AT-SEA VERSUS DOCKSIDE MEAT-COUNT MEASUREMENTS

Field testing and evaluation of the one-pound coffee can as a volumetric measuring device were conducted using commercial sea scallop vessels from New Bedford, Massachusetts, and Hampton Roads, Virginia. At-sea volumetric sampling was performed by scallop fishermen on 14 commercial trips made between June and December 1987 on four different vessels (Table 3).

Figure 1. Volumetric sampling devices used in determining sea scallop meat count.

Typically, the fishing vessels involved in the field work conducted their trips following normal commercial practices. Choice of fishing grounds, fishing procedures, and catch handling activities was left to the discretion of the captain (as is the norm). The crew was requested to take a volumetric sample of scallop meats during each day at sea. This entailed filling the one-pound coffee can with scallop meats taken from the washer at the end of one of the watches. The washer, a tank used for holding, mixing, and rinsing scallops prior to bagging, normally holds between 100 and 400 pounds of scallop meats by the end of a six-hour watch (only about 2.3 pounds of meat were generally needed for a volumetric sample). The number of scallops in each sample was enumerated by the crew and recorded along with a sample number. Samples were consecutively numbered to correspond with day at sea (i.e., the sample taken during the first day was labeled number one, the sample taken during the second day was labeled number

Table 2. Summary of coffee-can volumetric calibration experiments

Can #	Brand	Concave Meniscus		Convex Meniscus		Mean Values		
		Volume (ml)	Net Weight (g)	Volume (ml)	Net Weight (g)	Volume (ml)	Net Weight (g)	Vol/Wt Ratio
1	Brim	1011	1007.8	1015	1011.5	1013	1009.63	1.0033
2	Chkfulnuts	1013	1010.0	1019	1013.2	1016	1011.60	1.0043
3	Folgers	1017	1013.9	1019	1016.5	1018	1015.20	1.0028
4	Folgers	1017	1015.0	1019	1014.7	1018	1014.85	1.0031
5	Folgers	1017	1017.0	1020	1016.1	1019	1016.55	1.0019
6	Folgers	1010	1007.1	1011	1009.0	1011	1008.08	1.0024
7	Hills	1022	1020.0	1025	1022.5	1024	1021.22	1.0022
8	Hills	1017	1016.5	1018	1020.2	1018	1018.38	0.9991
9	Hills	1013	1015.4	1024	1021.8	1019	1018.62	0.9999
10	Hills	1023	1019.3	1023	1020.0	1023	1019.68	1.0033
11	Hills	1023	1021.2	1025	1023.1	1024	1022.14	1.0018
12	Maxwell	1010	1008.0	1018	1014.7	1014	1011.33	1.0026
13	Maxwell	1015	1013.2	1014	1012.4	1015	1012.82	1.0017
14	Maxwell	1010	1008.6	1016	1014.3	1013	1011.49	1.0015
15	Maxwell	1007	1006.1	1015	1012.4	1011	1009.27	1.0017
16	Maxwell	1008	1006.6	1022	1011.6	1015	1009.10	1.0058
17	Maxwell	1009	1007.2	1016	1013.1	1013	1010.16	1.0023
	Average	1014.2	1012.5	1018.8	1015.7	1016.5	1014.1	1.0023
	Std Dev	5.1905	5.1690	4.0548	4.2971	4.1870	4.5787	0.00153
	Variance	26.941	26.719	16.441	18.465	17.531	20.964	2.33E-06
	Maximum	1023	1021	1025	1023	1024	1022	1.0058
	Minimum	1007	1006	1011	1009	1011	1008	0.9991

Table 3. Summary of at-sea and dockside volumetric samples of sea scallop meats, by trip and sampling method, number of samples indicated in italics

Trip Number	Vessel Name	Landing Date	Fishing Region	Depth (fm)	Average At-Sea Vol MPP		Average Dock Vol MPP		Average Dock Wgt MPP	
					Can	SMD	Can	SMD	Can	SMD
1	*Mary Anne*	6-04-87	S. of Long Island	26	25.0	-	26.7	-	26.3	-
					10		*10*		*10*	
2	*Mary Anne*	6-21-87	S. of Long Island	27	27.1	-	26.0	-	25.9	-
					11		*22*		*22*	
3	*Mary Anne*	7-25-87	S. of Long Island	25	27.1	-	24.7	-	25.2	-
					7		*14*		*14*	
4	*Mary Anne*	8-11-87	S. of Long Island	24	26.9	-	24.6[1]	-	27.4[1]	-
					10		*20*		*20*	
5	*Mary Anne*	8-28-87	S. of Long Island	31	26.4	-	24.0[1]	-	25.9[1]	-
					8		*16*		*16*	
6	*Nordic Pride*	9-12-87	Georges Bank	36	29.0	-	26.7[1]	-	28.4[1]	-
					11		*22*		*22*	
7	*Mary Anne*	9-14-87	Georges Bank	38	25.7	-	22.7[1]	-	24.5[1]	-
					10		*20*		*20*	
8	*Carolina Breeze*	9-18-87	Mid-Atlantic	30	25.6	-	26.1	-	25.9	-
					15		*33*		*33*	
9	*Mary Anne*	10-3-87	S. of Long Island	24	26.4	-	24.7[1]	-	27.1[1]	-
					10		*20*		*20*	
10	*Carolina Breeze*	10-13-87	Mid-Atlantic	30	24.8	-	24.3	-	24.2	-
					14		*24*		*24*	
11	*Mary Anne*	10-22-87	S. of Long Island	30	26.0	-	24.7	26.8	25.3	26.6
					10		*20*	*20*	*20*	*20*
12	*Mary Anne*	11-09-87	S. of Long Island	25	-	24.5	-	24.4	-	24.7
						10		*20*		*20*
13	*Mary Anne*	11-27-87	S. of Long Island	29	26.7	27.3	26.4	26.4	26.4	26.1
					9	*9*	*18*	*18*	*18*	*18*
14	*Mary Anne*	12-17-87	S. of Long Island	30	30.0	28.4	29.0	29.6	28.7	30.1
					9	*9*	*7*	*7*	*7*	*7*
	All Trips		Average		26.57	26.77	25.24	26.23	26.10	26.26
			Number of Samples		134	28	246	65	246	65
			Number of Scallops		8339	1706	14227	3881	14227	3881
			Std Dev of MPP Samples		2.738	2.240	2.827	2.979	2.926	3.099
			Variance of MPP Samples		7.498	5.018	7.994	8.872	8.561	9.602
			Max MPP Value of Sample		33.3	29.9	32.3	32.5	32.6	33.0
			Min MPP Value of Sample		18.4	22.4	18.3	18.5	18.3	18.1

[1] Coffee cans were underfilled

two, etc). A tag with the sample number was placed on one of the 40-pound linen bags of meats made up from the washer-load of scallops from which the volumetric sample was taken. After labelling, the tagged bag was stored in the vessel hold as in normal practice.

Upon the vessel's return to port, scientific personnel were present to conduct dockside sampling during offloading. From each of the tagged bags, between one and three volumetric samples were taken using the same coffee-can sampling procedures as used by the crew at sea. In addition, the total tared meat weight of each sample was obtained with an electronic scale. From the 14 commercial trips, 134 at-sea coffee-can volumetric samples (comprising 8,339 scallops) were taken. Dockside, 246 coffee-can samples (comprising 14,227 scallops) were obtained from the tagged bags (Table 3). All sample data collected from the field study are summarized, by trip, in Appendix Table 1.

Standard protocol for filling the coffee can evolved during the experiment and was finalized as follows:

> Scallop meats were randomly picked up, a handful at a time, and counted into the coffee can. Only intact meats were used, with bits and pieces of meat discarded. No attempt was made to select meats which possessed both the "quick" and "catch" components of the adductor muscle since the small "catch" component (generally known as the 'sweet meat') is often removed during shucking or separated during washing and handling. Meats were added to the can until the can was slightly overfull. The plastic lid cover was then fitted to the top and pressed on. If the lid bulged out, meats were removed; if not, meats were added. The can was considered filled when, held at eye level with the lid on, no bulge was observed. The decision on whether a can was full was always a question of plus or minus one meat -- with the last meat or two often not randomly chosen.

At sea, using fresh-shucked scallops, it was easier to fill the coffee container by dipping it into the washer, moving the meats into the can, and then fitting the lid as described above. The meats were then counted as they were removed from the can. This procedure could not be used dockside in sampling bags of meats since the coffee can could not be pushed into the packed mass of adhered meats without causing product damage. Although concerted efforts were made to standardize the filling procedures used by both vessel crews at sea and by personnel dockside, considerable variation in filling practices occurred during the study.

Concern was raised during the developmental phase of this study that the one-pound coffee can might not be an acceptable measuring tool because it could easily be deformed. To address this potential shortcoming, a more rugged volumetric sampler was designed, the "Scallop Measuring Device" (SMD), and constructed to specifications by the Baadar North America Corporation (Figure 1). The SMD was fabricated out of stainless steel tubing with a wall thickness of 3 mm. The inside dimensions were 114 mm (height) by 107 mm (diameter), providing a volumetric capacity of 1,000 ml. The top lid of the SMD was constructed of 2-mm-thick stainless steel, perforated with 6-mm diameter holes, and could be positively seated inside the container at full 1000-ml capacity. Total weight of the SMD was 1,854 g.

Field and dockside testing of the SMD was conducted during the last four trips of the study. Twenty-eight at-sea samples (comprising 1,706 scallops) and 65 dockside samples (comprising 3,881 scallops) were obtained in the experiment.

DATA ANALYSIS

Parametric statistical procedures were used in all data analyses. Mean differences in volumetric capacity between filling methods (concave meniscus versus convex meniscus) and among brands in the coffee-can calibration experiments were evaluated by analysis of variance. Pairwise *a posteriori* comparisons of mean volumetric capacity between brands of coffee cans were performed using the T'-method (Sokal and Rohlf 1981: p. 245), which employs the studentized augmented range distribution Q' as a critical value. Determination of constancy of product weight of a filled coffee can of scallop meats was assessed from weight measurements of the 64 individual coffee-can samples taken from the one-bushel shellstock samples processed in the laboratory. The 64 samples were considered as independent from one another since the purpose in collecting these data was to assess the aggregate physical properties of a mass of shucked meats, not to estimate any biological parameters of the scallop population as a whole. To evaluate whether the total meat weight of a full coffee can might be influenced by the mix of large and small scallops in a sample, least-squares linear regressions were computed regressing: (1) coffee-can meat weight on number of meats per sample, and (2) coffee-can meat count (MPP) on number of meats per sample. Mixing effects were also assessed by regressing the standard deviation of average individual meat weight per sample on: (1) average individual meat weight per sample; and (2) average meat count (MPP) per sample. For each relationship, the regression coefficient (i.e., slope) was tested to determine if it differed significantly from zero. Comparability of meat count estimation methods (at-sea volumetric versus dockside volumetric, at-sea volumetric versus dockside weight, and dockside volumetric versus dockside weight), using both the coffee can and the SMD, was evaluated by pairwise t-tests of the average meat-count values [MPP] obtained from each method.

Table 4. Comparison of coffee-can volumetric results, by brand

Brand	Sample Size (cans)	Mean Volume (ml)	Variance Volume (ml)	95% Confidence Intervals For Mean Volume (ml)
Brim	1	1013.00	-	--
Chkfulnuts	1	1016.00	-	--
Folgers	4	1016.25	14.7500	1010.14-1022.36
Hills	5	1021.30	9.3250	1017.15-1025.09
Maxwell	6	1013.33	2.1667	1011.78-1014.88
Total	17	1016.50	4.1870	1014.35-1018.65

Pairwise Comparisons Among Brands Using T'-Method

Brands Compared	Difference in Means: Absolute	Difference in Means: Percent	Test Statistic Q'[.05]	Test Conclusion
Folgers/Hills	5.05	-0.50	5.57	NS [P>0.05]
Folgers/Maxwell	2.92	+0.29	5.57	NS [P>0.05]
Hills/Maxwell	7.97	+0.78	4.98	S [P<0.05]

RESULTS

CALIBRATION OF COFFEE-CAN VOLUMETRIC CAPACITY

The average volume of the 17 coffee cans calibrated with distilled water was 1,016.5 ml± 2.15 ml (95% confidence limits) (Table 2). Volumetric capacity of individual cans filled to a convex meniscus ranged between 1,011 and 1,025 ml, while the capacity of cans filled to a concave meniscus varied from 1,007 to 1023 ml. As expected, mean convex meniscus volume (1,019 ml) was significantly greater (P< 0.01) than mean concave meniscus volume (1,014 ml). Ratios of coffee-can volume to net coffee-can weight approximated unity (1.0) for all of the cans tested, with little variation in ratios among cans (variance = 2.3×10^{-6}). Both the mean and individual volumetric capacities (using either the convex or concave meniscus filling procedures) of the coffee cans tested in the calibration experiments were well within the manufacturing guidelines (1,014 ± 20 ml) established by the Can Manufacturers Institute. The stability in coffee-can volume/weight ratios suggests that any conclusions about volumetric capacity have equal validity with respect to weight.

Analysis of variance revealed that mean volumetric capacity differed significantly (F = 6.11; P<0.01) among brands of coffee cans. Volumetric capacity was lowest for Brim (1,013 ml) and highest for Hills Brothers (1,021 ml) (Table 4). Pairwise comparisons between brands indicated no significant difference (P>0.05) in volumetric capacity between Folgers and Hills Brothers coffee cans or between Folgers and Maxwell House cans, but a significant difference (P<0.05) was detected between Hills Brothers and Maxwell House cans. No comparisons could be made with the Brim or Chock Full of Nuts cans since only one can of each brand was used in the experiments.

The significant difference in mean volume between the Hills Brothers and Maxwell House cans was 8.0 ml (0.78%) (Table 4). At 30 MPP and 40 MPP, this corresponds to an average meat-count difference between brands of 0.23 MPP (0.78% x 30 MPP) and 0.31 MPP (0.78% x 40 MPP), respectively. For *individual cans* regardless of brand, the 95% confidence interval for volume is 1016.5 ±9.2 ml, which is ±0.90% (or ±0.27 MPP at 30 MPP).

DETERMINATION OF COFFEE-CAN MEAT-WEIGHT CAPACITY

Based on the 64 coffee-can samples of fresh-shucked scallop meats processed in the laboratory, the average tared weight of a one-pound coffee can filled with meats was 1062 g (2.342 lbs) (Table 5). Meat weights of full cans ranged between 1029 and 1112 g (2.269-2.451 lb), and encompassed sample meat counts from 12.9 to 53.5 MPP.

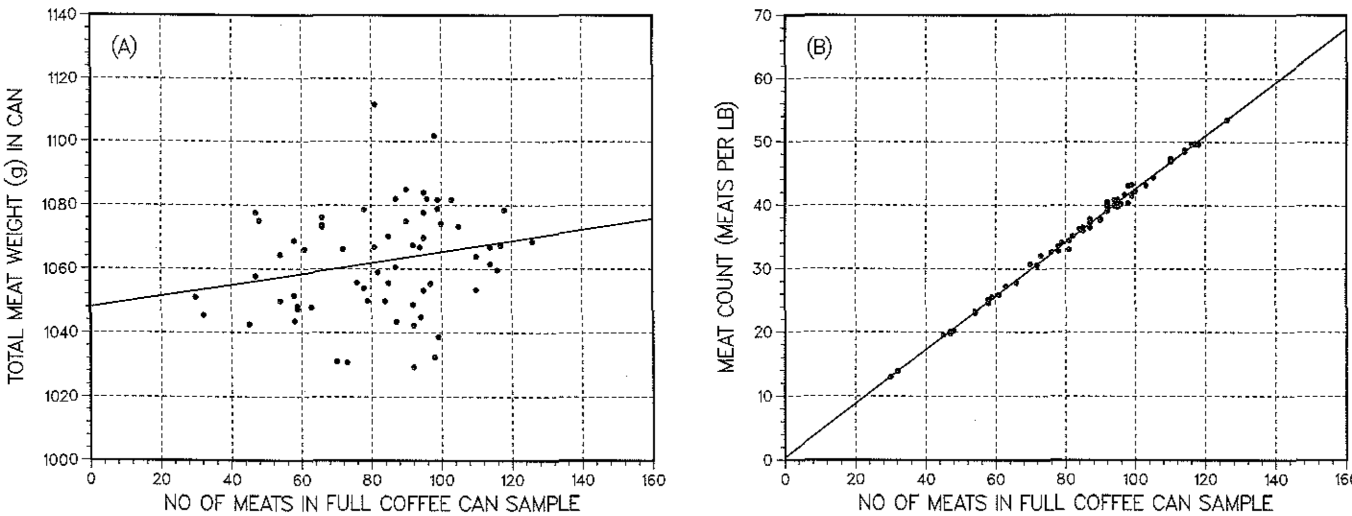

Figure 2. (A) Regression of total weight of scallop meats in one-pound coffee-can volumetric samples on number of meats per sample. (B) Regression of average meat count (MPP) in one-pound coffee-can volumetric samples on number of meats per sample.

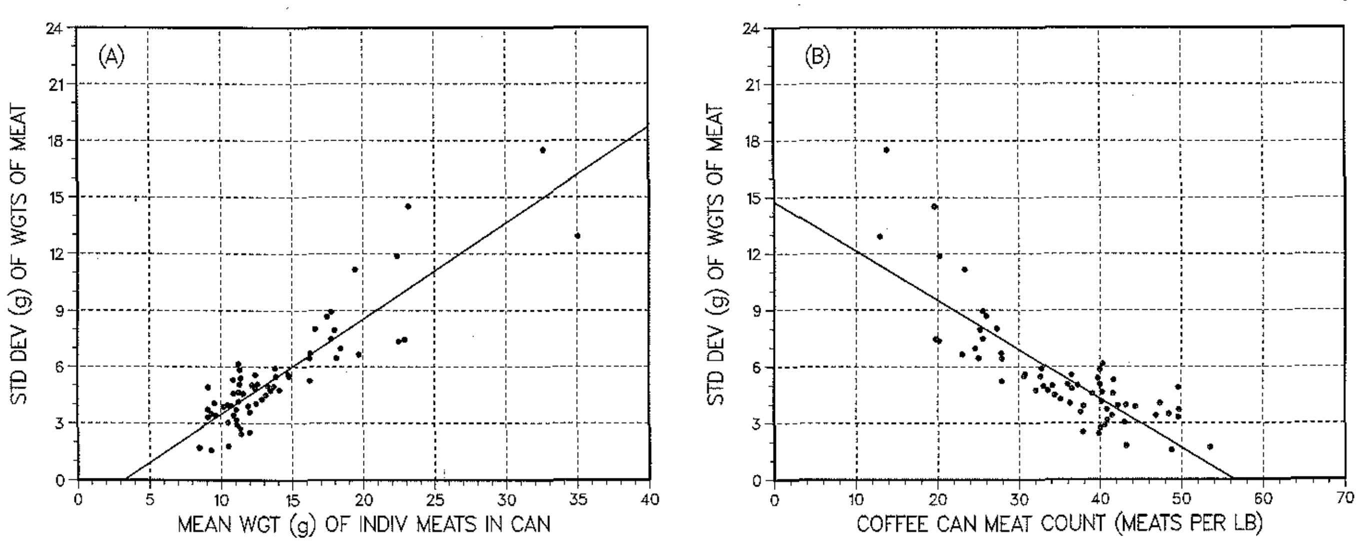

Figure 3. Regressions of standard deviation of weights of individual meats in one-pound coffee-can volumetric samples on: (A) average weight of individual meats in sample; and (B) average meat count (MPP) per sample.

Table 5. Summary of coffee-can samples of freshly shucked scallop meats, samples obtained from one-bushel shellstock samples collected by commercial scallop vessels landing in New Bedford, Massachusetts, in 1987 and 1988

Trip No	Sample No	Date of Landing	Full Can Total Meat Weight (g)	Number of Scallops	Average Weight Per Meat (g)	Variance Indiv. Meat Weight (g)	Maximum Indiv. Meat		Minimum Indiv. Meat		Avg. Meat Count (MPP)
							Weight (g)	Count (MPP)	Weight (g)	Count (MPP)	
1	1	05-16-87	1054.0	78	13.51	22.441	30.9	14.7	5.6	81.0	33.6
1	2	05-16-87	1050.0	79	13.29	24.925	33.4	13.6	4.9	92.6	34.1
1	3	05-16-87	1059.0	82	12.91	18.179	30.4	14.9	6.0	75.6	35.1
2	4	10-03-87	1064.4	54	19.71	44.454	29.6	15.3	5.6	81.0	23.0
2	5	10-03-87	1051.7	58	18.13	41.764	31.9	14.2	7.4	61.3	25.3
3	6	11-08-87	1067.5	92	11.60	20.828	24.5	18.5	6.1	74.4	39.1
3	7	11-08-87	1042.4	92	11.33	25.573	29.2	15.5	4.9	92.6	40.0
3	8	11-08-87	1060.6	87	12.19	25.238	30.3	15.0	6.6	68.7	37.2
4	9	11-19-87	1064.0	110	9.67	11.565	21.1	21.5	4.5	100.8	46.9
5	10	11-20-87	1055.6	85	12.42	23.363	31.9	14.2	5.4	84.0	36.5
5	11	11-20-87	1032.4	98	10.53	9.270	21.9	20.7	5.6	81.0	43.1
6	12	11-21-87	1059.7	116	9.14	10.969	25.4	17.9	2.7	168.0	49.7
7	13	11-21-87	1066.2	61	17.48	75.636	47.9	9.5	6.1	74.4	26.0
7	14	11-21-87	1055.7	76	13.89	30.208	35.9	12.6	6.8	66.7	32.7
8	15	11-21-87	1066.9	81	13.17	20.226	27.9	16.3	5.3	85.6	34.4
8	16	11-21-87	1049.9	84	12.50	16.400	30.3	15.0	6.4	70.9	36.3
9	17	11-24-87	1053.3	95	11.09	13.876	26.9	16.9	6.4	70.9	40.9
9	18	11-24-87	1044.9	94	11.12	10.036	31.7	14.3	5.8	78.2	40.8
10	19	11-25-87	1084.0	95	11.41	29.102	36.8	12.3	4.9	92.6	39.8
10	20	11-25-87	1038.8	99	10.49	15.678	21.5	21.1	3.9	116.3	43.2
11	21	11-25-87	1048.8	92	11.40	5.910	17.4	26.1	6.8	66.7	39.8
12	22	11-25-87	1053.5	110	9.58	16.463	27.4	16.6	5.3	85.6	47.4
13	23	11-29-87	1043.5	87	11.99	6.322	19.5	23.3	6.6	68.7	37.8
14	24	12-14-87	1074.2	100	10.74	15.461	23.3	19.5	4.8	94.5	42.2
15	25	01-13-88	1077.7	47	22.93	55.750	39.7	11.4	12.3	36.9	19.8
15	26	01-13-88	1057.7	47	22.50	54.289	38.7	11.7	8.0	56.7	20.2
16	27	02-02-88	1078.9	99	10.90	20.904	27.6	16.4	3.2	141.8	41.6
16	28	02-02-88	1073.4	105	10.22	15.064	20.8	21.8	2.8	162.0	44.4
17	29	02-19-88	1070.3	85	12.59	25.708	25.3	17.9	3.0	151.2	36.0
17	30	02-19-88	1069.8	95	11.26	21.657	29.5	15.4	3.8	119.4	40.3
17	31	02-19-88	1055.4	97	10.88	28.078	35.9	12.6	2.6	174.5	41.7
18	32	03-08-88	1067.4	117	9.12	13.810	21.5	21.1	1.8	252.0	49.7
18	33	03-08-88	1066.9	114	9.36	12.175	23.1	19.6	4.4	103.1	48.5
19	34	03-25-88	1084.9	90	12.05	12.801	22.2	20.4	3.8	119.4	37.6

Table 5. (Cont.)

Trip No	Sample No	Date of Landing	Full Can Total Meat Weight (g)	Number of Scallops	Average Weight Per Meat (g)	Variance Indiv. Meat Weight (g)	Maximum Indiv. Meat		Minimum Indiv. Meat		Avg. Meat Count (MPP)
							Weight (g)	Count (MPP)	Weight (g)	Count (MPP)	
19	35	03-25-88	1075.0	90	11.94	15.258	24.3	18.7	4.7	96.5	38.0
20	36	04-10-88	1073.7	66	16.27	27.495	29.6	15.3	6.9	65.7	27.9
20	37	04-10-88	1082.0	87	12.44	31.047	32.1	14.1	3.7	122.6	36.5
21	38	05-02-88	1081.7	99	10.93	11.637	28.5	15.9	5.9	76.9	41.5
21	39	05-02-88	1081.7	103	10.50	3.219	16.9	26.8	6.4	70.9	43.2
21	40	05-02-88	1082.1	96	11.27	17.256	32.7	13.9	6.5	69.8	40.2
22	41	05-10-88	1061.6	114	9.31	2.440	14.1	32.2	5.9	76.9	48.7
22	42	05-10-88	1068.6	126	8.48	2.900	15.2	29.8	4.0	113.4	53.5
23	43	05-16-88	1111.7	81	13.72	24.405	32.4	14.0	7.3	62.1	33.0
23	44	05-16-88	1078.7	78	13.83	35.176	39.6	11.5	1.4	324.0	32.8
24	45	06-18-88	1075.1	48	22.40	141.222	55.7	8.1	8.5	53.4	20.3
24	46	06-18-88	1048.1	63	16.64	64.516	61.6	7.4	7.2	63.0	27.3
25	47	06-30-88	1076.1	66	16.30	45.195	37.5	12.1	2.1	216.0	27.8
25	48	06-30-88	1077.7	95	11.34	34.150	26.0	17.4	1.6	283.5	40.0
26	49	07-04-88	1043.7	58	17.99	63.427	55.5	8.2	7.6	59.7	25.2
26	50	07-04-88	1049.9	54	19.44	124.954	57.7	7.9	7.9	57.4	23.3
26	51	07-04-88	1042.6	45	23.17	210.653	63.5	7.1	9.1	49.8	19.6
27	52	07-12-88	1066.9	94	11.35	7.492	21.4	21.2	6.0	75.6	40.0
27	53	07-12-88	1029.3	92	11.19	8.380	22.0	20.6	3.1	146.3	40.5
28	54	07-22-88	1047.4	59	17.75	56.162	52.3	8.7	9.0	50.4	25.6
28	55	07-22-88	1068.9	58	18.43	48.806	40.4	11.2	6.9	65.7	24.6
28	56	07-22-88	1048.3	59	17.77	80.144	59.4	7.4	3.9	116.3	25.5
29	57	08-08-88	1031.1	70	14.73	31.454	48.6	9.3	8.4	54.0	30.8
29	58	08-08-88	1030.8	73	14.12	22.713	34.0	13.3	7.6	61.3	32.1
30	59	08-26-88	1051.1	30	35.04	166.797	59.4	7.6	12.1	37.5	12.9
30	60	08-26-88	1045.4	32	32.67	306.674	60.2	7.5	10.4	43.6	13.9
31	61	09-13-88	1073.2	66	16.26	41.680	39.4	11.5	8.6	52.7	27.9
31	62	09-13-88	1066.3	72	14.81	30.183	32.2	14.1	8.2	55.3	30.6
32	63	10-18-88	1101.7	98	11.24	37.885	28.9	15.7	4.2	108.0	40.3
32	64	10-18-88	1078.6	118	9.14	24.010	23.3	19.5	3.9	116.3	49.6
Average			1062.38	82.67							
No. of samples			64	64							
Std. dev.			16.7407	21.96							
Variance			280.252	482.3							
SE of mean			2.093	2.745							
Max value			111.7	126							
Min value			1029.3	30							

Table 6. Regression analyses evaluating the influence of mixing of large and small scallop meats on the average meat weight of a full coffee-can volumetric sample

Parameter	Estimate	Standard Error	T Value	Probability Level
(A) Full coffee-can meat weight (Y) on number of meats per can (X)				
Intercept	1047.95	8.0563	130.08	0.000
Slope	0.1745	0.0942	1.85	0.069
R=0.229; R^2=0.052				
(B) Full coffee-can meat count (MPP) (Y) on number of meats per can (X)				
Intercept	0.3736	0.2771	1.35	0.183
Slope	0.4222	0.0032	130.25	0.000
R=0.998	R^2=0.996			
(C) Full coffee-can meat count (MPP) (Y) on number of meats per can (X) (Regression through the origin)				
Slope	0.4265	0.0008	512.84	0.000
R=0.999; R^2=0.999				
(D) Standard deviation of weights of meats in full coffee can (Y) on average weight per meat in can (X)				
Intercept	-1.63	0.5020	-3.24	0.002
Slope	0.5088	0.0335	15.18	0.000
R=0.888; R^2=0.789				
(E) Standard deviation of weights of meats in full coffee can (Y) on meat count (MPP) per can (X)				
Intercept	14.77	0.8296	17.81	0.000
Slope	-0.2616	0.0228	-11.50	0.000
R=-0.825; R^2=0.681				

The size mixture of scallop meats within a coffee-can sample did not affect the average meat-weight capacity of a full can. Regression analysis indicated no significant relationship between total coffee-can meat weight and number of scallops (P=0.07) (Table 6; Figure 2A). Both mean weight per individual meat and sample meat count were significantly correlated (P<0.001) with individual scallop meat-weight variability (Table 6: regressions [d] and [e]) (Figure 3) indicating that coffee-can samples with low meat counts (i.e., high mean weight per meat) had a greater mixture of different-sized scallop meats than did samples with high meat counts.

The relationship between number of meats per full coffee can and coffee-can meat count was highly significant (P<0.001; r=0.99) (Table 6; Figure 2B), indicating that the number of meats in a filled can is an accurate predictor of meat count. Since the intercept of the regression was not statistically different from zero (P = 0.18, Table 6), it was possible to estimate meat count from number of meats per can using the calibration equation (Y = 0.427X) obtained by regression through the origin (Table 6: regression [c]).

Because the one-pound coffee-can volumetric measure packed equally well regardless of meat size, volumetric sampling data obtained from the at-sea experiments (in which fresh-shucked meat-weight capacity was expressed as number of meats per coffee can) were converted to MPP by multiplying by 0.427. This facilitated comparison of at-sea volumetric data with data from both dockside volumetric sampling and dockside weight-based sampling.

The average meat-weight capacity of a one-pound coffee can filled with scallop meats in dockside condition was significantly lower (P<0.01) than the capacity of a one-

Table 7. Summary statistics on meat-weight capacity of one-pound coffee-can volumetric samples filled with scallop meats in fresh-shucked and dockside condition

	Fresh-Shucked Scallop Meats			Dockside Scallop Meats		
	Coffee Can Meat Weight		Meats per[1] Sample	Coffee Can Meat Weight		Meats per[1] Sample
	(g)	(lb)	(MPS)	(g)	(lb)	(MPS)
Average	1062.38	2.342	70.26	1039.20	2.291	68.73
Std deviation	16.741	0.037	1.11	21.541	0.047	1.42
No. of samples	64	64		148[2]	148[2]	
For a single can:						
95% conf. interval (±)	33.45	0.074	2.21	42.57	0.094	2.82
Lower limit	1028.9	2.268	68.05	996.6	2.197	65.91
Upper limit	1095.8	2.416	72.48	1081.8	2.385	71.55
For the average of all cans:						
95% conf. interval(±)	4.18	0.009	0.28	3.50	0.008	0.23
Lower limit	1058.2	2.333	69.99	1035.7	2.283	68.50
Upper limit	1066.6	2.351	70.54	1042.7	2.299	68.96

[1] Assuming 30 meats per pound.

[2] Only 148 of the 246 dockside samples (Table 3) were used. Dockside samples from trips 4-7 and trip 9 were excluded from the analysis since these coffee-can samples were not completely filled with meats. In these samples, the plastic coffee can lid cover was not used in determining when a can was full of meats.

pound can filled with fresh-shucked meats (Table 7). Tared mean weight for a full can of dockside meats was 1039 g (2.291 lb) ±3.5 g (0.008 lb) (95% confidence interval), 23 grams less (-2.2%) than a full can of fresh shucked scallops. At 30 MPP, the average difference between a volumetric sample of dockside meats and a volumetric sample of fresh-shucked meats is -1.53 meats per sample (MPS).

Confidence limits on the meat-weight capacity of coffee cans filled with meats in fresh-shucked and dockside condition are presented in Table 7. For a single can of fresh product (i.e., shucked at sea), 95% of all cans will hold between 1029 and 1096 g of meat. When measured dockside, 95% of all coffee cans will hold between 997 and 1082 g of scallops. One can be 95% certain that the average weight of a can filled with fresh-shucked meats will be between 1058 and 1067 g, while the average weight of a coffee can filled with meats in dockside condition will fall between 1036 and 1043 g.

The scallop samples measured dockside in this study were shucked at sea from 1 to 16 days prior to vessel landing, packed in linen bags placed on ice, and were cold when unloaded in port. At dockside, the meats tended to be drier, stickier, and more rigid than when freshly shucked.

COMPARISON OF AT-SEA VERSUS DOCKSIDE MEAT-COUNT MEASUREMENTS

Pairwise evaluation of average meat-count values from eight different sets of at-sea versus dockside meat-count estimation methods (Table 8) indicated no significant difference ($P>0.05$) in average MPP between any of the comparisons except in two of the 16 tests of at-sea volumetric coffee-can MPP versus dockside volumetric coffee-can MPP, and in two of the 26 tests of at-sea volumetric coffee-can MPP versus dockside weight coffee-can MPP. Overall, the average meat count in dockside volumetric and weight samples was lower than that in samples taken at sea by 0.63 MPP (-2.1% at 30 MPP) and 0.46 MPP (-1.5% at 30 MPP), respectively. Pairwise comparisons of meat count between various *dockside* volumetric and weight measurement methods showed no significant differences ($P>0.05$) in average MPP (Table 8).

To quantify the magnitude of the average difference in MPP between at-sea and dockside measurements that might normally be expected in the USA fishery, a subset of the volumetric sampling data was analyzed, consisting of samples from trips lasting between 8 and 12 days and in

Table 8. Comparison of differences in average meat count (MPP) and meat-count variances among various at-sea and dockside meat-count estimation methods

Measurement Method: Method 1	vs. Method 2	Number of Paired Comparisons	Average Difference in MPP	Average Difference in Variance of MPP	No. of Paired Comparisons of Avg. MPP Sig. at P<0.05 (Paired T-tests): #	%	Average Diff. in MPP	No. of paired Comparisons of Variance in MPP Sig. at P<0.05 (F-tests): #	%	Average Diff. in Variance
Sea vs Sea										
Sea Vol Can	Sea Vol SMD	2	0.76	-0.04	1	50	1.87	0		
Sea vs Dock										
Sea vol can	Dock vol can	16	0.63	0.77	2	13	1.98	3	19	-1.47
Sea vol can	Dock wgt can	26	0.46	-1.51	2	8	1.97	11	42	-3.38
Sea vol can	Dock vol SMD	5	0.21	-6.16	0			4	80	-6.45
Sea vol can	Dock wgt SMD	5	-0.01	-7.18	0			4	80	-7.09
Sea vol SMD	Dock vol can	3	0.17	-7.67	0			2	67	-8.94
Sea vol SMD	Dock wgt can	3	0.21	-8.39	0			3	100	-8.39
Sea vol SMD	Dock vol SMD	5	0.29	-1.94	0			1	20	-6.58
Sea vol SMD	Dock wgt SMD	5	-0.08	-2.80	0			1	20	-9.13
Dock vs Dock										
Dock vol can	Dock vol can Repl[1]	10	-0.64	0.16	0			0		
Dock vol can	Dock wgt can	36	0.00	-0.10	0			0		
Dock vol can	Dock vol SMD	9	-0.71	1.46	0			0		
Dock vol can	Dock wgt SMD	9	-0.86	0.61	0			0		
Dock wgt can	Dock wgt can Repl	15	-0.37	-0.50	0			0		
Dock wgt can	Dock wgt SMD	9	-0.61	1.58	0			0		
Dock vol SMD	Dock wgt can	9	0.46	-2.43	0			0		
Dock vol SMD	Dock vol SMD Repl	3	-0.52	-0.92	0			0		
Dock vol SMD	Dock wgt SMD	13	-0.27	-0.81	0			0		
Dock wgt SMD	Dock wgt SMD Repl	3	-0.59	-0.15	0			0		

[1] Repl=Comparison of replicate samples.

which no daily samples were missing. The average at-sea meat count from these trips was 26.72 MPP, equivalent to an average weight per scallop meat of 16.98 g. When these same bags of meat were measured dockside both volumetrically and by weight, average meat counts of 25.71 MPP (17.64 g per meat) and 25.88 MPP (17.53 g per meat) were obtained, respectively. Hence, the average meat count from volumetric samples taken at sea was 3.93% higher than the corresponding dockside volumetric count, and 3.25% higher than the dockside average based on weight. The latter difference represents the net effects of swelling and loss of sweet meats. The volumetric difference, in addition, reflects packing changes effected by variations in meat condition.

The Scallop Measuring Device (SMD) was calibrated using 65 dockside weight samples (Table 3) and had an average meat-weight capacity of 1032.4 g (2.276 lb) ± 5.1 g (95% confidence interval). Meat-weight capacity of the SMD was not significantly different ($P>0.05$) from the capacity of a one-pound coffee can filled with dockside meats. Where more than two sets of paired comparisons were able to be performed, no significant differences were detected in the average meat count obtained with the SMD and any of the other at-sea or dockside MPP measurement methods (Table 8).

RELIABILITY OF THE ONE-POUND COFFEE-CAN VOLUMETRIC SAMPLING TECHNIQUE

In addition to testing the hypothesis that a calibrated volumetric measuring device can be used as an accurate alternative for a weight-based measure of meat count, data from the field samples were also used to evaluate the reliability of the sampling process itself. Replicate coffee-can samples (from the same bag of meats) were taken in dockside sampling of 11 of the 14 commercial scallop trips. Excluding those dockside samples in which coffee cans were underfilled (from trips 4-7 and 9: see Tables 3 and 7), the data set allowed 10 independent tests of volumetric sampling reliability (Table 8). Fifteen tests of weight-based sampling reliability were performed using all of the replicate data (including the underfilled cans) since both weight and count were known in all cases (Table 8). In none of the tests (volumetric or weight) was a significant difference ($P<0.05$) in MPP variance detected between replicate samples. For all volumetric samples, the average difference in meat count between replicates was 0.64 MPP, while the average difference in variance between the first and a repeat sample was 0.16 MPP. For weight-based samples, the differences were 0.37 MPP and 0.50 MPP, respectively. Experiment-wide, within-bag MPP variance was 2.54 MPP while between-bag MPP variance was 7.36 MPP.

DISCUSSION

Field and laboratory tests indicate that a one-pound coffee-can container can successfully be used as a volumetric measuring device to determine sea scallop meat counts accurately at sea. Although statistically significant differences in volumetric capacity exist among various brands of coffee cans, these differences are small compared to other sources of variability when measuring meat count volumetrically. The resolution of the volumetric technique is roughly 0.5 scallop meats (e.g., the addition or removal of the last meat to obtain a full can divided by the meat-weight capacity of a full can). This resolution is about twice as large as the most extreme differences in volume among individual coffee cans irrespective of brand. Average meat-weight capacity of one-pound coffee cans filled with fresh-shucked meats is relatively constant and unaffected by mixing of different-sized scallop meats. Nonetheless, if the coffee-can technique is adopted in measuring meat counts at sea, it is recommended that fishermen avoid reliance on a *single* coffee can. By rotating meat count measurements among *three* or more cans, fishermen can reduce the already tiny risk of obtaining a biased meat count which might result from slight differences in individual coffee can volumes. The two key factors in deriving accurate meat counts at-sea using the coffee can method are: (1) proper packing of the measuring device, and (2) taking an adequate number of samples during a trip.

The recommended procedure for taking a volumetric sample at sea is as follows:

1. At the end of the watch, just before bagging, thoroughly mix the meats in the washer.

2. Drain the washer. Then, fill the coffee can with whole meats (discarding bits and pieces), either manually or by carefully scooping with the can, so that the meats overflow the can. Press down on the scallops so a slightly mounded overfill is achieved.

3. Affix the plastic coffee-can lid on the can and hold the can at eye level. The cover should bulge out. Remove the cover, eliminate one scallop meat, and repeat the process.

4. When the cover is flat at eye level, the can is properly filled.

5. Count the scallops in the can, and multiply the total by 0.427 to obtain the sample meat count (MPP) (or use Appendix Table 2 which equates the number of meats in a full coffee can to meat count).

Table 9. Number of one-pound coffee-can volumetric samples required to be taken during a trip to achieve a given degree of confidence that the average meat count for a trip will not exceed 30 meats per pound (30 MPP) by a given meat-count erro.

Meat-Count Error (MPP)	Degree of Confidence				
	75.0	**90.0**	**95.0**	**99.0**	**99.9**
0.5	39	137	226	451	796
1.0	10	35	58	116	199
1.5	5	17	27	53	93
2.0	3	10	16	32	54
2.5	3	7	11	22	36
3.0	2	5	9	16	28
3.5	2	5	7	13	22
4.0	2	4	6	11	18
4.5	2	4	5	9	15
5.0	2	3	5	8	13

The number of coffee-can samples to be taken on a trip depends on the level of assurance that is desired in knowing the "true" average meat count for a trip. Based on the data acquired from the 134 at-sea volumetric coffee-can samples taken during the field studies (Table 3), a chart of recommended sample sizes was developed to provide guidance for at-sea sampling using the one-pound coffee-can technique (Table 9). Sample sizes were calculated using the largest meat-count variance observed from a single trip during the study (20.85 MPP per coffee can: *Carolina Breeze* - Appendix Table 1). This approach is conservative in that the number of samples and size of meat-count error is overestimated and the degree of confidence underestimated. On 11 of the 13 trips in which at-sea coffee-can samples were taken in 1987, the trip meat-count variance was less than 4.5 MPP. In this regard, the sample size chart reflects more extreme mixing of meats than would generally be expected in the fishery. This is analagous to designing a structure to withstand a 50-year storm, an infrequent but predictable event.

The following example illustrates how the sample size chart might be used. If one wished to estimate, with 99.9% certainty, the true average meat count of a trip within 3 MPP, 28 samples would need to be taken randomly throughout a trip. If the average meat count determined from the 28 samples was 30.0 MPP, there is only one chance in 1000 that the average meat count for all scallops shucked during a trip will exceed 33.0 MMP (i.e., the present enforcement criterion). Only nine samples would be needed for the same meat count error (3 MPP) at the 95% confidence level. To estimate the true average trip count within a smaller meat-count interval (i.e., <3 MPP), more intensive sampling is required; for example, to be 95% confident of the trip meat count being within 1 MPP, 58 coffee-can samples would have to be taken. Given the present USA enforcement tolerance of 10% in MPP, a scallop fisherman might take between 16 and 32 samples per trip to be 99% assured that the average meat count for a trip fell within the tolerance interval. More precision almost always requires more samples, but diminishing returns quickly ensue (i.e., reducing the meat-count error from 3 MPP to 2 MPP generally requires doubling the number of samples, while reducing the error from 2 MPP to 1 MPP requires more than triple the number of samples).

The sample size table is only meaningful when an effort is made during a scallop trip *to pack each and every bag* to comply with the present 30 MPP management standard, **not** the 33.0 MPP enforcement criterion. Indeed if, after taking 796 samples on a trip the estimated meat count is 32.5 MPP, the probability of this count exceeding 33.0 MPP when sampled by the dockside enforcement procedure is about **50%**, not **0.1%** (i.e., the probability value listed in Table 9 for *deviating from 30 MPP* when the meat-count error is 0.5 MPP and 796 samples are taken). This seeming discrepancy is a result of the difference in precision between the 796 samples taken at sea and the 10 enforcement samples taken dockside. The enforcement procedure with its smaller sample size simply cannot determine the average meat count within 0.5 MPP.

The importance of packing each and every bag to the meat-count standard can best be explained by example. Suppose that a fisherman could ascertain the meat count with 100% accuracy and packed each bag with 30-meat-count scallops. Assuming no changes in meat condition and 100% accuracy in determining the meat count by dockside enforcement procedures, an enforcement check of 10 bags shoreside would yield a 30-MPP trip average. Now let us suppose that the fisherman packed half his bags with just

20-count scallops and the other half with just 40-count scallops and there were 200 bags total. Even though the true trip meat count average is 30 MPP, by only sampling 10 bags dockside there is a 17% probability (based on the binomial distribution) of enforcement officials obtaining an average meat count exceeding 33 MPP for the trip.

The sampling guide indicates that, by taking as few as 3 to 6 coffee-can samples per day (essentially sampling each washer load of scallops to insure that the meat count of the washer complies with the management standard before the meats are bagged), fishermen at sea can determine with high assurance whether their trip meat count will conform with the legal count when evaluated dockside by enforcement officials.

PRECISION OF DOCKSIDE ENFORCEMENT SAMPLING

The within- and between-bag variances (2.54 MPP and 7.36 MPP, respectively) obtained from the weight-based dockside samples can be used to assess the precision of dockside sampling procedures used by enforcement officials. After adjusting for the difference in sample weight between a full coffee can measured dockside (2.291 lb) and the one-pound samples taken during enforcement sampling, the within-bag variance of enforcement samples was predicted to be 5.82 MPP with an expected standard error of the mean of 1.70 MPP. Analysis of actual enforcement sampling data[1] from six trips sampled between July and November 1986 (in which replicate samples were taken from each of the bags checked) gave results virtually identical to those expected; within-bag variance was 5.23 MPP with a standard error of the mean of 1.61 MPP. In contrast, the between-bag variance from the enforcement samples was 33.36 MPP with a standard error of the mean of 1.83 MPP (determined for a sample size of 10 enforcement samples per trip).

Meat-count determinations made either volumetrically using coffee-can samples, or by weight using electronic scales, thus appear to be highly reliable and of about equal precision. In both methods, within-sample variance in MPP is not a significant source of error in estimating the average meat count of a trip.

AT-SEA VERSUS DOCKSIDE MEAT-COUNT COMPARISONS

As in previous studies (Caddy and Radley-Walters 1972; Smolowitz and Serchuk 1987), results from the present study indicate that meat counts of scallops measured at sea are usually higher than those obtained when the same batches of scallops are remeasured dockside. Water weight gain by the meats, through absorption of melted freshwater ice during storage in the hold of a vessel, has been identified as a principal factor producing this phenomenon. Caddy and Radley-Walters (1972) reported that the average uptake of water by meats held on ice between 9 and 14 days was 17%. As a result, scallop meats that measured 40 MPP as fresh-shucked product would measure 34 MPP shoreside. Laboratory experiments on weight changes in scallop meats during fresh storage (Wilhelm and Jobe, unpublished MS) revealed that meats stored on ice absorbed water for the first six days, reaching a maximum weight gain of 12%. From the seventh day onward, however, meats began losing weight and continued to do so until the study was terminated after 15 days of storage. At that time, the average weight of a meat was 7.5% lower than at the beginning of the experiment. By comparison, scallop meats soaked in fresh water for three days showed an average weight gain of 37%, but lost weight after removal from soaking and were below their original weight by the eighth day of storage.

Virtually all scallops shucked at sea are stored on ice to preserve product quality. For a scallop trip of 10 fishing days (i.e., about the average trip length in the USA fishery) assuming equal daily catches, the difference between meat counts taken at sea and those taken dockside would be approximately 7% based on the laboratory results. An at-sea meat count of 30 MPP would measure 28.0 MPP dockside, while a 35.3 MPP average at sea would measure 33.0 MPP at landing.

Loss of sweet meats during packing and bagging of scallops at sea may explain the apparent disparity in percentage meat-weight gain (at-sea versus dockside) observed in the field samples (3.25 - 3.93%) versus that noted in the laboratory. Naidu (1984) found that the sweet-meat component of the adductor muscle accounted for 7 to 9% of the total adductor muscle weight, and that about half (52%) of the scallop meats landed in the St. Pierre, Newfoundland, sea scallop fishery lacked the sweet meat. Separation of the sweet meat can occur during shucking and handling, but more frequently, the sweet meat becomes detached when the scallops are washed prior to bagging (Naidu 1987). If most of the loss of sweet meats occurs during washing, the percentage difference in MPP between at-sea versus dockside counts will depend on whether the at-sea count was taken before or after the meats were washed. At-sea meat counts determined from volumetric samples *taken before washing* (with sweet meats intact) will be lower than sample meat counts *taken after washing* (reflecting some loss of sweet meats and assuming that detached sweet meats are not included in the volumetric sample). The laboratory estimates of the weight gained by meats due to water absorption during storage were based on intact adductor muscles. Hence, laboratory and field results of *percentage* meat-weight gain are only strictly comparable for at-sea samples taken after washing since any reductions in adductor muscle weight from sweet meat loss in at-sea samples taken before washing are not accounted for in the laboratory evaluations.

[1] Confidential data from enforcement actions.

This issue can be examined from another perspective. If the specific gravity of a fresh-shucked scallop meat (1.064 from Caddy and Radley-Walters 1972) is multiplied by the average weight of distilled water held by a one-pound coffee can (1014.1 g - Table 2), the expected total product weight of a full can of scallop meats would be 1079.0 grams. The average weight of a full can of fresh-shucked meats obtained from the shellstock samples provided by commercial fishermen in the present study was 1,062 grams (Table 7), a 17-g difference or 1.6%. This difference represents imperfect packing of meats (i.e., interstitial spaces between individual meats). The 0.7% disparity between the dockside volumetric and dockside weight sampling estimates of MPP relative to at-sea MPP determinations (+3.93% volumetric versus +3.25% weight) is thus likely to reflect packing error. As such, the net dockside packing error would be about **2.3%** (1.6% + 0.7%).

The net dockside packing error reflects changes in product condition (density and volume) and changes in product integrity (e.g., any loss of sweet meats) between sampling at sea and sampling dockside. The percentage difference in average total weight between one-pound coffee-can samples of fresh-shucked and dockside meats taken during the present study was **2.2%** (1062 versus 1039 g - Table 7), suggesting that the expected differences in at-sea versus dockside counts are indeed realized in practice. In essence, dockside samples underestimate the true meat count of scallops packed at sea, thereby providing fishermen with an additional tolerance in complying with the meat-count standard.

CONCLUSIONS

This study confirms that a volumetric system for measuring meat counts at sea can be compatible with the shoreside sampling operations currently in place in the USA scallop fishery. Meat counts determined from volumetric sampling appear to be as accurate and precise as those determined by weight measurements. In this context, one might be tempted to consider replacing the weight-based dockside system of enforcement sampling with a volumetric system. The advantage in doing this would be that at-sea and dockside meat-count estimation procedures would be identical, providing some sense of equitability to fishermen in assessing at-sea compliance with the meat-count standard. However, to implement a volumetric measuring system dockside would require the development of a **legally defensible** sampling technique for filling the volumetric container. This problem is more difficult to address dockside than at sea, due to the condition of the meats at landing, but conceptually it is solvable. While dockside sampling with a volumetric measure might be more time-consuming than by using electronic scales, it could provide more flexibility since enforcement officials would be able to conduct inspections virtually anywhere.

By the same token, the use of electronic scales in dockside enforcement operations is rather straightforward and provides an accurate and objective means for determining meat counts. There is no *a priori* reason to switch from a system that has already proven to be legally defensible in court. Moreover, there are many enforcement systems in society where compliance is evaluated using a different procedure than that used by those being regulated (e.g., radar enforcement of automobile speeding limits versus speedometer readings used by vehicle operators).

The fundamental issue regarding the ability of fishermen to comply with meat-count regulation is more complex than ascertaining the MPP of individual samples or the trip as a whole, regardless of which method of meat-count determination is used. The real problem confronting fishermen is the mathematics of optimizing fishing practices (primarily in deciding on which beds to fish) with the time remaining in the trip so that earnings are maximized with a "legal" catch. More frequently than not, this optimization procedure involves taking large catches of small scallops (high meat count) to mix with larger-sized meats (low meat count) obtained from less dense beds located in different fishing areas. By its nature, this practice does not lend itself to insuring that all bags placed in the hold are consistent with the average meat-count standard (i.e., currently 30 MPP). To comply with the standard, fishermen thus not only have to know how to use an at-sea meat count measuring device (volumetric or otherwise), but also how to pack the catch so that bags with meats of different counts will average out to the legal count when a subsample of bags is checked dockside. In general, given the present enforcement sampling regimen, this can only be achieved by packing individual bags as close to the management standard as possible so that between-bag variability in meat count is minimized.

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Appendix Table 1. Summary of at-sea and dockside volumetric samples of sea scallop meats, by sampling method

Measurement Method	Sample #	At-Sea Sample Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Average	Variance	No. of Obs
6/4/87																				
Sea vol can MPS		62	62	53	56	55	51	62	63	60	62							58.60	19.60	10
Dock vol can MPS		60	64	50	56	56	68	66	65	66	60							61.10	32.99	10
Dock wgt can LBS		2.33	2.30	2.36	2.36	2.30	2.35	2.29	2.34	2.31	2.32							2.33	0.0007	10
Sea vol can MPP		26.5	26.5	22.6	23.9	23.5	21.8	26.5	26.9	25.6	26.5							25.02	3.57	10
Dock vol can MPP		26.2	27.9	21.8	24.4	24.4	29.7	28.8	28.4	28.8	26.2							26.67	6.29	10
Dock wgt can MPP		25.8	27.8	21.2	23.7	24.3	28.9	28.8	27.8	28.6	25.9							26.28	6.67	10
6/21/87																				
Sea vol can MPS	-	63	64	62	65	68	63	67	59	61	65	62						63.55	6.87	11
Dock vol can MPS	1	64	60	56	61	55	57	62	65	56	58	55						59.00	13.00	11
Dock vol can MPS	2	59	62	57	63	56	62	63	63	61	56	59						60.09	7.89	11
Dock wgt can lbs	1	2.30	2.38	2.39	2.30	2.33	2.31	2.25	2.26	2.30	2.22	2.32						2.30	0.0024	11
Dock wgt can lbs	2	2.33	2.34	2.36	2.34	2.32	2.25	2.28	2.30	2.22	2.31	2.18						2.29	0.0031	11
Sea vol can MPP		26.9	27.3	26.5	27.8	29.0	26.9	28.6	25.2	26.0	27.8	26.5						27.13	1.25	11
Dock vol can MPP	1	27.9	26.2	24.4	26.6	24.0	24.9	27.1	28.4	24.4	25.3	24.0						25.75	2.48	11
Dock vol can MPP	2	25.8	27.1	24.9	27.5	24.4	27.1	27.5	27.5	26.6	24.4	25.8						26.23	1.50	11
Dock wgt can MPP	1	27.8	25.2	23.5	26.5	23.6	24.7	27.6	28.8	24.3	26.1	23.7						25.62	3.43	11
Dock wgt can MPP	2	25.3	26.5	24.2	26.9	24.1	27.6	27.6	27.4	27.5	24.2	27.1						26.22	2.13	11
7/25/87																				
Sea vol can MPS		59	65	65	67	65	65				59							63.57	10.29	7
Dock vol can MPS	1	51	62	60	56	61	54				50							56.29	23.57	7
Dock vol can MPS	2	60	64	62	54	57	55				47							57.00	32.67	7
Dock wgt can lbs	1	2.30	2.30	2.30	2.30	2.30	2.18				2.18							2.27	0.0034	7
Dock wgt can lbs	2	2.30	2.30	2.24	2.18	2.24	2.11				2.30							2.24	0.005	7
Sea vol can MPP		25.2	27.8	27.8	28.6	27.8	27.8				25.2							27.14	1.88	11
Dock vol can MPP	1	22.3	27.1	26.2	24.4	26.6	23.6				21.8							24.57	4.49	7
Dock vol can MPP	2	26.2	27.9	27.1	23.6	24.9	24.0				20.5							24.88	6.22	7
Dock wgt can MPP	1	22.2	27.0	26.1	24.3	26.5	24.8				22.9							24.83	3.31	7
Dock wgt can MPP	2	26.1	27.8	27.7	24.8	25.4	26.1				20.4							25.47	6.17	7
8/11/87																				
Sea vol can MPS		62	61	64	68	63	62	60	65	62	63							63.00	5.11	10
Dock vol can MPS	1*	51	67	58	56	57	55	65	50	56	56							58.10	22.77	10
Dock vol can MPS	2*	44	59	53	60	58	56	57	51	53	57							54.80	22.62	10
Dock wgt can lbs	1*	2.03	2.09	2.04	1.93	2.04	2.09	2.11	2.04	1.97	2.11							2.05	0.0035	10
Dock wgt can lbs	2*	2.07	2.15	2.06	2.07	2.01	2.06	2.13	2.02	2.09	2.09							2.07	0.0019	10
Sea vol can MPP		26.5	26.0	27.3	29.0	26.9	26.5	25.6	27.8	26.5	26.9							26.90	0.93	10
Dock vol can MPP	1*	22.3	29.2	25.3	24.4	24.9	24.0	28.4	26.2	24.4	24.4							25.36	4.34	10
Dock vol can MPP	2*	19.2	25.8	23.1	26.2	25.3	24.4	24.9	22.3	23.1	24.9							23.92	4.31	10
Dock wgt can MPP	1*	25.1	32.1	28.4	29.0	27.9	26.3	30.8	29.4	28.4	26.5							28.41	4.37	10
Dock wgt can MPP	2*	21.3	27.4	25.7	29.0	28.9	27.2	26.8	25.2	25.4	27.3							26.41	4.96	10

*** Coffee cans were underfilled**

Measurement Method	Sample #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Average	Variance	No. of Obs
		At-Sea Sample Number																		
8/28/87																				
Sea vol can MPS		64	63	64	59	62	59	61	62									61.75	3.93	8
Dock vol can MPS	1*	56	54	61	50	55	50	60	60									55.75	19.07	8
Dock vol can MPS	2*	56	52	55	48	61	53	55	55									54.38	13.70	8
Dock wgt can lbs	1*	2.23	2.15	2.09	2.14	2.03	2.06	2.18	2.07									2.12	0.0046	8
Dock wgt can lbs	2*	2.25	2.04	2.16	2.28	2.03	2.11	2.11	2.13									2.14	0.0080	8
Sea vol can MPP		27.3	26.9	27.3	25.2	26.5	25.2	26.0	26.5									26.37	0.72	8
Dock vol can MPP	1*	24.4	23.6	26.6	21.8	24.0	21.8	26.2	26.2									24.33	3.63	8
Dock vol can MPP	2*	24.4	22.7	24.0	21.0	26.6	23.1	24.0	24.0									23.73	2.61	8
Dock wgt can MPP	1*	25.1	25.1	29.2	23.4	27.1	24.3	27.5	29.0									26.33	4.74	8
Dock wgt can MPP	2*	24.9	25.5	25.5	21.1	30.0	25.1	26.1	25.8									25.49	5.92	8
9/12/87																				
Sea vol can MPS		60	73	71	73	68	69	63	70	70	59	70						67.82	24.16	11
Dock vol can MPS	1*	51	66	63	65	55	55	56	70	63	61	60						60.45	32.47	11
Dock vol can MPS	2*	54	70	56	66	53	66	58	66	63	63	65						61.82	31.96	11
Dock wgt can lbs	1*	2.13	2.18	2.12	2.14	2.17	2.21	2.13	2.18	2.18	2.11	2.19						2.16	0.0011	11
Dock wgt can lbs	2*	2.21	2.16	2.11	2.15	2.14	2.24	2.11	2.14	2.15	2.16	2.13						2.15	0.0015	11
Sea vol can MPP		25.6	31.2	30.3	31.2	29.0	29.5	26.9	29.9	29.9	25.2	29.9						28.96	4.41	11
Dock vol can MPP	1*	22.3	28.8	27.5	28.4	24.0	24.0	24.4	30.6	27.5	26.6	26.2						26.39	6.19	11
Dock vol can MPP	2*	23.6	30.6	24.4	28.8	23.1	28.8	25.6	28.8	27.5	27.5	28.4						26.98	6.09	11
Dock wgt can MPP	1*	23.9	30.3	29.7	30.4	25.3	24.9	26.3	32.1	28.9	28.9	27.4						28.01	6.88	11
Dock wgt can MPP	2*	24.4	32.4	26.5	30.7	24.8	29.5	27.5	30.8	29.3	29.2	30.5						28.69	6.66	11
9/14/87																				
Sea vol can MPS		60	64	61	63	57	60	61	63	59	55							60.30	7.79	10
Dock vol can MPS	1*	56	54	53	57	44	44	58	57	47	43							51.30	37.34	10
Dock vol can MPS	2*	56	58	54	61	47	44	54	60	47	44							52.50	42.28	10
Dock wgt can lbs	1*	2.12	2.05	2.11	2.02	2.08	2.16	2.11	2.20	2.14	2.18							2.12	0.0032	10
Dock wgt can lbs	2*	2.17	2.06	2.07	2.09	2.06	2.14	2.11	2.15	2.18	2.19							2.12	0.0026	10
Sea vol can MPP		25.6	27.3	26.0	26.9	24.3	25.6	26.0	26.9	25.2	23.5							25.75	1.42	10
Dock vol can MPP	1*	24.4	23.6	23.1	24.9	19.2	19.2	25.3	24.9	20.5	18.8							22.39	7.12	10
Dock vol can MPP	2*	24.4	25.3	23.6	26.6	20.5	19.2	23.6	26.2	20.5	19.2							22.92	8.05	10
Dock wgt can MPP	1*	26.4	26.3	25.1	28.2	21.2	20.4	27.5	25.9	22.0	19.7							24.27	9.90	10
Dock wgt can MPP	2*	25.8	28.2	26.1	29.2	22.8	20.6	25.6	27.9	21.6	20.1							24.78	10.89	10
9/18/87																				
Sea vol can MPS		43	55	59	57	70	62	45	53	58	63	57	78	74	58	68		60.00	93.71	15
Dock vol can MPS	1	54	55	63	65	69				57	55	61	59		57	49		58.55	31.87	11
Dock vol can MPS	2	50	64	60	67	64				55	55	63	67		62	54		60.09	32.89	11
Dock vol can MPS	3	51	58	65	72	67				56	54	74	66		50	54		60.64	71.85	11
Dock wgt can lbs	1	2.36	2.35	2.33	2.32	2.33				2.28	2.31	2.29	2.31		2.32	2.29		2.32	0.0006	11
Dock wgt can lbs	2	2.33	2.27	2.33	2.33	2.34				2.28	2.29	2.27	2.30		2.32	2.26		2.30	0.0009	11
Dock wgt can lbs	3	2.32	2.36	2.32	2.32	2.30				2.29	2.32	2.30	2.31		2.31	2.29		2.31	0.0004	11

*** Coffee cans were underfilled.**

Measurement .Method	Sample #	At-Sea Sample Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Average	Variance	No. of Obs
9/18/87																				
Sea vol can MPP		18.4	23.5	25.2	24.3	29.9	26.5	19.2	22.6	24.8	26.9	24.3	33.3	31.6	24.8	29.0		25.62	17.09	15
Dock vol can MPP	1	23.6	24.0	27.5	28.4	30.1				24.9	24.0	26.6	25.8		24.9	21.4		25.55	6.07	11
Dock vol can MPP	2	21.8	27.9	26.2	29.2	27.9				24.0	24.0	27.5	29.2		27.1	23.6		26.23	6.27	11
Dock vol can MPP	3	22.3	25.3	28.4	31.4	29.2				24.4	23.6	32.3	28.8		21.8	23.6		26.47	13.69	11
Dock wgt can MPP	1	22.9	23.4	27.0	28.0	29.6				25.0	23.8	26.6	25.5		24.6	21.4		25.26	5.84	11
Dock wgt can MPP	2	21.5	28.2	25.8	28.8	27.4				24.1	24.0	27.8	29.1		26.7	23.9		26.10	6.01	11
Dock wgt can MPP	3	22.0	24.6	28.0	31.0	29.1				24.5	23.3	32.2	28.6		21.6	23.6		26.22	13.62	11
10/3/87																				
Sea vol can MPS		63	66	62	65	63	65	64	56	58	56							61.80	14.18	10
Dock vol can MPS	1*	61	63	54	57	54	56	55	46	52	62							56.00	26.22	10
Dock vol can MPS	2*	62	62	58	60	50	57	60	46	54	61							57.00	29.33	10
Dock wgt can lbs	1*	2.07	2.04	1.97	2.04	2.08	2.09	2.11	2.10	2.10	2.24							2.08	0.0047	10
Dock wgt can lbs	2*	2.02	2.08	2.09	2.02	2.09	2.07	2.12	2.08	2.09	2.21							2.09	0.0028	10
Sea vol can MPP		26.9	28.2	26.5	27.8	26.9	27.8	27.3	23.9	24.8	23.9							26.39	2.58	10
Dock vol can MPP	1*	26.6	27.5	23.6	24.9	23.6	24.4	24.0	20.1	22.7	27.1							24.44	5.00	10
Dock vol can MPP	2*	27.1	27.1	25.3	26.2	21.8	24.9	26.2	20.1	23.6	26.6							24.88	5.59	10
Dock wgt can MPP	1*	29.5	30.9	27.4	27.9	26.0	26.8	26.1	21.9	24.8	27.7							26.89	6.17	10
Dock wgt can MPP	2*	30.7	29.8	27.8	29.7	23.9	27.5	28.3	22.1	25.8	27.6							27.33	7.26	10
10/13/87																				
Sea vol can MPS		47	67	47	70	45		69		60	60	72	45	72	60	47	52	58.07	114.38	14
Dock vol can MPS	1	44	60	45		49					67	52			49	63		53.63	74.27	8
Dock vol can MPS	2	53	53	53		55					68	68			55	50		56.88	49.55	8
Dock vol can MPS	3	54	59	52		50					62	53			60	61		56.38	21.41	8
Dock wgt can lbs	1	2.27	2.29	2.27		2.29					2.31	2.31			2.30	2.34		2.30	0.0005	8
Dock wgt can lbs	2	2.28	2.28	2.30		2.31					2.31	2.31			2.30	2.33		2.30	0.0003	8
Dock wgt can lbs	3	2.33	2.30	2.30		2.34					2.29	2.28			2.27	2.33		2.31	0.0007	8
Sea vol can MPP		20.1	28.6	20.1	29.9	19.2		29.5		25.6	25.6	30.7	19.2	30.7	25.6	20.1	22.2	24.80	20.85	14
Dock vol can MPP	1	19.2	26.2	19.6		21.4					29.2	22.7			21.4	27.5		23.41	14.15	8
Dock vol can MPP	2	23.1	23.1	23.1		24.0					29.7	29.7			24.0	21.8		24.83	9.44	8
Dock vol can MPP	3	23.6	25.8	22.7		21.8					27.1	23.1			26.2	26.6		24.61	4.08	8
Dock wgt can MPP	1	19.4	26.2	19.8		21.4					29.0	22.5			21.3	26.9		23.32	12.82	8
Dock wgt can MPP	2	23.2	23.2	23.0		23.8					29.4	29.4			23.9	21.5		24.70	9.11	8
Dock wgt can MPP	3	23.2	25.7	22.6		21.4					27.1	23.2			26.4	26.2		24.47	4.46	8
10/22/87																				
Sea vol can MPS		66	61	65	63	61	52	63	64	59	56							61.00	18.67	10
Dock vol can MPS	1	58	57	60	52	51	42	59	65	51	63							55.80	46.84	10
Dock vol can MPS	2	65	55	66	52	58	45	62	63	48	59							57.30	51.57	10
Dock vol SMD MPS	1	69	57	70	58	67	45	66	56	55	58							60.10	60.99	10
Dock vol SMD MPS	2	70	65	69	61	54	42	69	62	62	63							61.70	70.68	10
Dock wgt can lbs	1	2.22	2.21	2.20	2.24	2.29	2.29	2.20	2.28	2.23	2.31							2.25	0.0017	10
Dock wgt can lbs	2	2.27	2.15	2.12	2.24	2.26	2.23	2.22	2.24	2.32	2.32							2.24	0.0041	10
Dock SMD wgt lbs	1	2.23	2.29	2.29	2.27	2.24	2.33	2.31	2.30	2.33	2.35							2.29	0.0015	10
Dock SMD wgt lbs	2	2.30	2.28	2.32	2.25	2.24	2.32	2.27	2.24	2.29	2.35							2.29	0.0014	10

*** Coffee cans were underfilled.**

Measurement Method	Sample #	At-Sea Sample Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Average	Variance	No. of Obs
10/22/87																				
Sea vol can MPP		28.2	26.0	27.8	26.9	26.0	22.2	26.9	27.3	25.2	23.9							26.05	3.40	10
Dock vol can MPP	1	25.3	24.9	26.2	22.7	22.3	18.3	25.8	28.4	22.3	27.5							24.36	8.92	10
Dock vol can MPP	2	28.4	24.0	28.8	22.7	25.3	19.6	27.1	27.5	21.0	25.8							25.01	9.82	10
Dock wgt can MPP	1	26.1	25.8	27.3	23.2	22.3	18.3	26.8	28.5	22.9	27.3							24.85	9.68	10
Dock wgt can MPP	2	28.6	25.6	31.1	23.2	25.7	20.2	27.9	28.1	20.7	25.4							25.66	12.31	10
Dock vol SMD MPP	1	30.3	25.0	30.8	25.5	29.4	19.8	29.0	24.6	24.2	25.5							26.41	11.77	10
Dock vol SMD MPP	2	30.8	28.6	30.3	26.8	23.7	18.5	30.3	27.2	27.2	27.7							27.11	13.64	10
Dock wgt SMD MPP	1	30.9	24.9	30.6	25.6	29.9	19.3	28.6	24.3	23.6	24.7							26.24	13.66	10
Dock wgt SMD MPP	2	30.4	28.5	29.7	27.1	24.1	18.1	30.4	27.7	27.1	26.8							27.00	13.46	10
11/9/87																				
Sea vol SMD MPS		62	56	61	52	51	56	54	53	59	60							56.40	15.38	10
Dock vol SMD MPS	1	60	53	58	51	54	54	51	54	57	59							55.10	10.32	10
Dock vol SMD MPS	2	62	51	60	56	50	56	54	56	57	58							56.00	13.56	10
Dock SMD wgt lbs	1	2.15	2.24	2.23	2.21	2.30	2.22	2.28	2.32	2.30	2.31							2.26	0.0030	10
Dock SMD wgt lbs	2	2.24	2.26	2.19	2.22	2.26	2.23	2.26	2.21	2.26	2.33							2.25	0.0015	10
Sea vol SMD MPP		27.2	24.6	26.8	22.8	22.4	24.6	23.7	23.3	25.9	26.4							24.78	2.97	10
Dock vol SMD MPP	1	26.4	23.3	25.5	22.4	23.7	23.7	22.4	23.7	25.0	25.9							24.21	1.99	10
Dock vol SMD MPP	2	27.2	22.4	26.4	24.6	22.0	24.6	23.7	24.6	25.0	25.5							24.60	2.62	10
Dock wgt SMD MPP	1	27.9	23.7	26.0	23.1	23.5	24.3	22.4	23.3	24.8	25.5							24.44	2.76	10
Dock wgt SMD MPP	2	27.7	22.6	27.4	25.2	22.1	25.1	23.9	25.3	25.2	24.9							24.95	3.17	10
11/27/87																				
Sea vol can MPS		64	65	62	66	64	58	64	62	58								62.56	8.28	9
Sea vol SMD MPS		66	67	60	62	62	56	68	61	58								62.22	16.69	9
Dock vol can MPS	1	65	70	54	61	65	50	66	57	48								59.56	59.28	9
Dock vol can MPS	2	66	69	65	68	60	53	70	50	50								61.22	67.69	9
Dock vol SMD MPS	1	60	63	55	63	60	57	61	67	49								59.44	27.53	9
Dock vol SMD MPS	2	61	65	55	63	66	57	68	58	52								60.56	29.28	9
Dock wgt can lbs	1	2.23	2.29	2.27	2.27	2.28	2.27	2.28	2.23	2.32								2.27	0.0008	9
Dock wgt can lbs	2	2.25	2.29	2.33	2.30	2.34	2.29	2.33	2.27	2.29								2.30	0.0009	9
Dock SMD wgt lbs	1	2.24	2.27	2.30	2.34	2.25	2.35	2.36	2.31	2.30								2.30	0.0018	9
Dock SMD wgt lbs	2	2.27	2.33	2.31	2.27	2.29	2.28	2.31	2.32	2.31								2.30	0.0005	9
Sea vol can MPP		27.3	27.8	26.5	28.2	27.3	24.8	27.3	26.5	24.8								26.71	1.51	9
Sea vol SMD MPP		29.0	29.4	26.4	27.2	27.2	24.6	29.9	26.8	25.5								27.34	3.22	9
Dock vol can MPP	1	28.4	30.6	23.6	26.6	28.4	21.8	28.8	24.9	21.0								26.00	11.29	9
Dock vol can MPP	2	28.8	30.1	28.4	29.7	26.2	23.1	30.6	21.8	21.8								26.72	12.90	9
Dock vol SMD MPP	1	26.4	27.7	24.2	27.7	26.4	25.0	26.8	29.4	21.5								26.12	5.31	9
Dock vol SMD MPP	2	26.8	28.6	24.2	27.7	29.0	25.0	29.9	25.5	22.8								26.61	5.65	9
Dock wgt can MPP	1	29.1	30.6	23.8	26.9	28.5	22.0	28.9	25.6	20.7								26.23	11.89	9
Dock wgt can MPP	2	29.3	30.1	27.9	29.6	25.6	23.1	30.0	22.0	21.8								26.62	12.34	9
Dock wgt SMD MPP	1	26.8	27.8	23.9	26.9	26.7	24.3	25.8	29.0	21.3								25.83	5.40	9
Dock wgt SMD MPP	2	26.9	27.9	23.8	27.8	28.8	25.0	29.4	25.0	22.5								26.34	5.64	9

Measurement Method	At-Sea Sample Number																Average	Variance	No. of Obs
Sample #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
12/14/87																			
Sea vol can MPS	71	64	72	70	73	75	74	71	62								70.22	19.44	9
Sea vol SMD MPS	68	60	66	64	65	67	68	65	59								64.67	10.50	9
Dock vol can MPS		57		73	73	69	67	66	60								66.43	37.29	7
Dock vol SMD MPS		54		69	74	68	71	72	64								67.43	45.29	7
Dock wgt can lbs		2.35		2.24	2.33	2.29	2.32	2.31	2.37								2.32	0.0018	7
Dock SMD wgt lbs		2.31		2.29	2.24	2.24	2.19	2.21	2.21								2.24	0.0019	7
Sea vol can MPP	30.3	27.3	30.7	29.9	31.2	32.0	31.6	30.3	26.5								29.98	3.55	9
Sea vol SMD MPP	29.9	26.4	29.0	28.1	28.6	29.4	29.9	28.6	25.9								28.41	2.03	9
Dock vol can MPP		24.9		31.9	31.9	30.1	29.2	28.8	26.2								29.00	7.10	7
Dock vol SMD MPP		23.7		30.3	32.5	29.9	31.2	31.6	28.1								29.63	8.74	7
Dock wgt can MPP		24.3		32.6	31.3	30.1	28.9	28.6	25.3								28.72	9.22	7
Dock wgt SMD MPP		23.4		30.1	33.0	30.4	32.4	32.6	29.0								30.12	11.12	7

Appendix Table 2. Conversion chart for a one-pound coffee-can volumetric sample (fresh-shucked meats only).

No. of Meats in Full Can	Meat Count (MPP)	No. of Meats in Full Can	Meat Count (MPP)	No. of Meats in Full Can	Meat Count (MPP)
31	13.2	61	26.0	91	38.9
32	13.7	62	26.5	92	39.3
33	14.1	63	26.9	93	39.7
34	14.5	64	27.3	94	40.1
35	14.9	65	27.8	95	40.6
36	15.4	66	28.2	96	41.0
37	15.8	67	28.6	97	41.4
38	16.2	68	29.0	98	41.8
39	16.7	69	29.5	99	42.3
40	17.1	70	29.9	100	42.7
41	17.5	71	30.3	101	43.1
42	17.9	72	30.7	102	43.6
43	18.4	73	31.2	103	44.0
44	18.8	74	31.6	104	44.4
45	19.2	75	32.0	105	44.8
46	19.6	76	32.5	106	45.3
47	20.1	77	32.9	107	45.7
48	20.5	78	33.3	108	46.1
49	20.9	79	33.7	109	46.5
50	21.3	80	34.2	110	47.0
51	21.8	81	34.6	111	47.4
52	22.2	82	35.0	112	47.8
53	22.6	83	35.4	113	48.2
54	23.1	84	35.9	114	48.7
55	23.5	85	36.3	115	49.1
56	23.9	86	36.7	116	49.5
57	24.3	87	37.1	117	50.0
58	24.8	88	37.6	118	50.4
59	25.2	89	38.0	119	50.8
60	25.6	90	38.4	120	51.2

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