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COMMERCIAL PRACTICES AND FISHERY REGULATIONS: THE UNITED STATES NORTHWEST ATLANTIC SEA SCALLOP, *PLACOPECTEN MAGELLANICUS* (GMELIN, 1791), FISHERY

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ABSTRACT Fishery regulations are based on discipline specific concepts, empirical analyses, and public comment. Supporting empirical analyses, however, often neglect commercial fishing practices. If supporting analyses do not adequately consider commercial practices, resultant regulations may fail to achieve stated objectives and impose unnecessary costs on industry. This may have been the case for the United States Atlantic sea scallop, *Placopecten magellanicus,* fishery in which empirical analyses determined a target specification of 30 meats per pound, as a maximum average value, would provide significant long-term benefits in terms of yield per recruit and the overall productivity of the resource. Targeted meat count pertained to carefully resected scallops. Industry practices, however, yield different weights and meat counts. These differences suggest that realization of the 30 MPP target count does not require commercially landed scallops to yield, on average, 30 MPP. This paper discusses the relationship between the science, commercial practices, and the determination and enforcement of fishery regulations.

KEY WORDS: commercial practices, *Placopecten magellanicus,* fishery regulation

INTRODUCTION

The sea scallop, *Placopecten magellanicus,* fishery of the United States has been managed and regulated since 1982 (New England Fishery Management Council et al. 1982). The overall objective of the Fishery Management Plan (FMP) is the maximization of the joint social and economic benefits from the harvesting and use of the sea scallop resource. The operational tool for attaining the objective has been to control the size of landed scallops (Smolowitz and Serchuk 1987). Two regulations have been used to control the size of landed scallops. First, vessels which shuck scallops at sea and land scallop meats are subject to a maximum average meat count or number of meats per pound (MPP) restriction. Second, vessels that land scallops in the shell (shell stock) are subject to a minimum shell height restriction.

The current management standards are 30 MPP and a 3.5 in. minimum shell height. A meat is defined as the retained part of the scallop adductor muscle (52 FR 1462 January 14, 1987). Enforcement policy of the Northeast Regional Office of the National Marine Fisheries Service applies a 10% tolerance for prosecuting violations. In 1987, Amendment 2 was implemented by the New England Fisheries Management Council (NEFMC); it specified that the meat count standard would be adjusted upward by 10% from October–January to account for meat weight reductions associated with spawning activity.

Under the current management and enforcement program, a vessel which lands shucked meats is considered to have nonconforming scallops if the average meat count of a sample group exceeds 33 MPP from February through September (36.3 MPP from October–January). Vessels which land shell stock are considered to have nonconforming scallops if 10% or more of the scallops in ten shell stock samples (400 scallops) have shell height smaller than 3.5 in. (52 FR 1462 January 14, 1987).

Smolowitz and Serchuk (1987) indicated several problems with controlling the average meat size being landed. First, meat count and shell size standards do not always yield equivalent results relative to age at first capture. Thus, issues about equitability arise. Second, the meat count standard poses compliance problems because it is difficult to accurately determine meat counts at sea. Third, the observed practice of mixing meats of different sizes does not prevent the exploitation of young or immature scallops.

Naidu (1984, 1987) and DuPaul and Kirkley (1987) suggested additional problems not only with controlling the average meat size but also with inadequate consideration of commercial practices in the determination of the scallop regulations. First, commercial shucking results in a loss in meat yield. Second, varying proportions of scallop meats are landed without the catch component; thus, contributing to additional losses in weight. The biological basis for selecting meat count and shell size standards, however, was based on yield per recruit analyses which utilized data from carefully resected scallops. Performance and enforcement of regulations are based, however, on the sampling of landed meats without due consideration of the loss in yield (Naidu 1987).

There is another problem, however, which both exacerbates and mitigates the problems accompanying losses associated with shucking and landing meats without the catch component. At-sea handling and stowing procedures result in both gains and losses in weight of landed meats compared to freshly harvested and shucked scallops. In partic-

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ular, scallops meats stowed for ten or more days may experience losses in weight relative to when bagged; more recently stowed meats likely experience gains in weight (DuPaul and Kirkley 1988, Wilhelm and Jobe 1987).

In contrast, Caddy and Walters (1972) found that dockside counts for iced meats, the most common landed product form, were consistently lower than at-sea or on-deck counts for freshly shucked scallops after 14 days of stowage. Meats took up enough water to reduce their specific gravity and increase their volume. More important with respect to meat count regulations was that Caddy and Walters demonstrated that the on-deck count would be considerably lower on landing (e.g., 40 MPP at sea equaled dockside count of 34 MPP).

The FMP for Atlantic sea scallops suggested that a long-term biological analysis and an economic analysis indicated a target specification of 30 MPP, as a maximum average value, would provide significant long-term benefits in terms of yield-per-recruit. The yield-per-recruit analyses, though, were based on growth relationships that used carefully resected scallops. Shucking and the loss of the catch component result in higher commercial counts than those obtained from carefully resected meats; the fishery may be achieving better yield-per-recruit than landed-meat sampling indicates (Naidu 1987). However, on-deck or at-sea counts could be higher than dockside or landed counts because of on-board handling and stowing procedures; the fishery may be achieving poorer yield-per-recruit than indicated by landed-meat samples.

The management standard and enforcement policy both refer to retained meats. The 30 MPP target in the FMP appears to be in terms of carefully resected scallops. Retained meats are of varying product forms. There are various levels of shucking losses and landed meats with and without the catch component. Gains and losses in weight vary depending on length of time scallops meats are stowed and on-board handling procedures. Thus, the management standard and enforcement policy may be inconsistent with the 30 MPP target of the FMP and unnecessarily 'rigid' or too 'inflexible' with respect to inspection of commercially landed meats. Alternatively, the target specification of 30 MPP may be achieved by landing commercial scallop meats of counts different than 30 MPP.

In this study, differences in the meat weight and meat count of carefully resected and commercially landed meats are examined. Emphasis is placed on differences resulting from shucking, loss of the catch component, and at-sea handling and stowing procedures. It is argued that the losses from commercial practices not only have implications for the management and enforcement program but also for enhancing economic returns to the fishery. Results of the study are primarily confirmatory in nature (Caddy and Walters 1972, Naidu 1984, 1987, Wilhelm and Jobe 1987). However, they are noteworthy because they are based on recently obtained data for the mid-Atlantic scallop fleet.

MATERIALS AND METHODS

As part of a cooperative research program between industry, the National Marine Fisheries Service, the New England Fisheries Management Council, and the Virginia Institute of Marine Science, shell stock samples from mid-Atlantic commercial scallop vessels were regularly obtained between April 1987–May 1988. Samples varied from 1–3 three baskets of unculled scallops, and a basket contained 140–400 scallops. The time of day, area harvested, water depth, water surface temperature, length of tow, and catch of the last tow were recorded by the captain for each sample.

Data routinely obtained from each sample included shell height and adductor muscle weight. Adductor muscles were carefully resected and included the quick and catch component. These data were similar to those used to determine the shell height and meat weight relationship utilized in the yield-per-recruit analyses of the FMP. Additional data collected on 40–120 scallops per sample included the weights of the quick and catch components. These data were used to examine differences associated with the loss of the catch component, which will be discussed later in this paper.

During April and May 1987, weights and shell heights for 67 commercially shucked scallops were obtained and used to calculate commercial counts. Corresponding carefully resected weights were obtained by removing remaining adductor muscle tissue and adding its weight to the commercial weight. These two weights and counts were used in this study to examine losses in yield resulting from commercial shucking.

In contrast to the at-sea method of Naidu (1987), all commercial and corresponding resected weights were obtained from dockside shucking of sea scallops by the captain or crew. This approach posed several problems which limit the accuracy of estimated losses because of shucking. First, there was a tendency by the captain or crew to demonstrate superior shucking capability among peers. Second, dockside conditions permitted more careful shucking than possible at sea; thereby, resulting in higher recovery than normally would be obtained at sea. Third, the 67 scallops were obtained from only 3 vessels with experienced crews; thus, the sample is inadequate for making broad conclusions about shucking related losses by the commercial fleet.

Despite the limitations, the data are useful for obtaining a conservative estimate of losses associated with commercial shucking. Estimates of losses, however, must be viewed as minimum estimates. In practice, losses would be expected to be higher than the estimates of this study.

The data were used to estimate the relationship between meat count of commercially shucked scallops and the meat count of carefully resected scallops. This permitted examination of possible losses in recovery associated with commercial shucking. In addition, a logit or binary dependent variable model was estimated and used to derive estimates of the probability that meat counts of commercially shucked scallops would exceed 33 MPP (the 30 count standard plus 10% tolerance) given corresponding counts of cleanly shucked or carefully resected scallops. The models were estimated by maximum likelihood procedures available on a micro-computer version of Statistical Software Tools (Dubin and Rivers 1986).

Examination of weight changes owing to at-sea handling and stowing procedures was based on information obtained from 3 commercial trips in August, September, and October 1987. One at-sea sample meat count was made by the vessel captain or first mate for 8–15 bags using a 1 lb. coffee can. Meats are typically packed and stowed in cloth bags. The captain was requested to carefully fill a coffee can until a plastic lid was flush with the top, take a count for 1 bag/day, and mark the bag. Three dockside counts using a coffee can were taken for each marked bag during off-loading. At-sea counts were calculated by dividing the count of the captain by 2.338 lb.; preliminary results of Smolowitz et al. (1988) suggest that a 1 lb. coffee can holds an average 2.338 pounds of meats. Dockside counts per pound were calculated by dividing the number of meats from 3 coffee can counts by the actual weight of the meats. Use of these counts requires the assumption that coffee can samples provide an accurate measure of the meat count/bag.

At-sea counts and weights were compared to the dockside counts and weights to determine possible differences resulting from at-sea handling and stowing procedures. These data were also used to estimate probabilities that dockside counts, conditional on the at-sea count and day of trip, exceeded, equalled, or were less than the at-sea count. Logit models for each of these cases were specified and estimated.

Differences in the weight and meat count between scallops with (muscle-on) and without (muscle-off) the catch component were determined by examining data from 100 trip samples obtained between April 1987–May 1988. Muscle-on and muscle-off weights were obtained for 40–120 scallops/sample for a total of 7,481 observations. Monthly counts by selected shell size intervals were calculated and used to examine the differences in the counts for muscle-on and muscle-off scallops. The meat counts (MPP) were calculated as follows:

$$MPP_i = N_i/weight_i$$

where N_i was the number of monthly observations for the ith shell size interval and weight was the total weight, in pounds, of all scallops in the ith interval.

In addition, shell size, adductor weight, and meat count equivalents were calculated for 1528 scallops for May 1988. These data were used to further examine differences between muscle-on and muscle-off counts. Five models were estimated and used to examine differences and to obtain more information about muscle-on and muscle-off counts.

The relationship between muscle-off (MOF) and muscle-on (MON) counts was estimated with a log-log model:

$$\log_e(MOF) = \alpha + \beta \log_e(MON) + u$$

where u is an error term assumed to be $N(O,\sigma^2)$. This model permitted estimation of muscle-off counts conditional on muscle-on counts.

Two transcendental models were used to examine the relationships between muscle-off and muscle-on counts and shell size. These models were used to estimate the meat counts for scallops of various shell sizes. The two models were of the following form:

$$\log_e(MON) = \alpha + \beta_{11} \log_e(SH) + \beta_{21} SH + u$$
$$\log_2(MOF) = \alpha + \beta_{12} \log_e(SH) + \beta_{22} SH + u$$

where SH is shell height in mm.

Two logit models were specified and estimated to determine the conditional probabilities that muscle-off counts exceeded the 30 MPP standard and the 33 MPP enforcement statute. The two logit models were as follows:

$$ZMOF30 = \alpha + \beta\, MON$$

where ZMOF30 = 1 (0 otherwise) if MOF > 30 and MON < 30;

$$ZMOF33 = \alpha + \beta\, MON$$

where ZMOF33 = 1 (0 otherwise) if MOF > 33 and MON < 33. The two models were estimated by maximum likelihood procedures available in Statistical Software Tools.

RESULTS

Commercial Shucking

Data limitations prevented a rigorous analysis as done by Naidu (1987). Sixty-seven observations obtained from 3 vessels were believed to be inadequate for making broad based conclusions. Careful dockside shucking resulted in weight losses lower than would be obtained by fishermen at sea. Estimates of losses because of commercial shucking, thus, should be viewed as minimum average losses. Losses in weight between commercially shucked and carefully resected scallops, based on the limited sample, varied between zero and 17.6% (Table 1). The average loss per individual scallop was 5.9%.

In contrast to the results of Naidu (1987), muscle tissue recovery appeared to be higher for larger scallops. The average recovery for scallops larger than 105 mm was over

TABLE 1.

Weight loss and recovery of muscle between carefully resected and commercially shucked sea scallops from the mid-Atlantic region, April thru May 1987.

Shell Height (mm)	Weight loss Minimum	Weight loss Average	Weight loss Maximum	Average Recovery
	Percent			
80–85	2.6	6.9	13.5	93.1
86–90	0.0	7.4	17.7	92.6
91–95	0.0	5.1	14.8	96.9
96–100	0.0	5.0	12.4	95.0
101–105	1.3	7.0	16.8	93.0
106–110	0.0	1.1	2.8	99.0
111–120	0.0	2.1	4.2	97.9

TABLE 2.

Estimated meats counts per pound (453.6 grams) for commercially shucked scallops conditional on meat counts for carefully resected scallops, April thru May 1987.

Meat Counts/lb Carefully Resected	Meat Counts/lb Commercially Shucked
25.0	26.4
26.0	27.5
27.0	28.6
28.0	29.7
29.0	30.8
30.0	32.0
31.0	33.0
32.0	34.2
33.0	35.4

97%; the average recovery for scallops smaller than 106 mm was below 95%. These results should not be interpreted as contradictions to the results of Naidu in which lower recovery was observed for larger scallops. The sample size of Naidu was considerably larger and the shuckers and experimental conditions were different.

The relationship between the meat counts of commercially shucked (CS) and carefully resected scallops (CR) was estimated by ordinary least squares. The estimated equation and results were as follows:

$$CS = .86\ CR^{1.06} \qquad R^2 = .98$$
$$(2.60)(63.40)$$

where CS and CR are meat counts for commercially shucked and carefully resected scallops; numbers in parentheses are the t-statistics. Estimated meat counts for commercially shucked scallops conditional on carefully resected meat counts are presented in Table 2.

As indicated in Table 2, the average count of commercially shucked scallops was 6.4% higher than the count of carefully resected scallops yielding 25–33 MPP. Differences in the meat count estimated by the regression model increased as the meat count of carefully resected scallops increased; however, this may have been a result of the specified relationship between the two meat counts. Power functions such as the standard weight-length relationship or those in Naidu (1987) and this study tend to underestimate (overestimate) for values of regressors which are lower (higher) than the mean value of the regressor.

Parameter estimates and statistical results for the logit model were as follows:

$$CMPP = -214.6 + 6.9\ CR$$
$$(2.4) \quad (2.6)$$

where CMPP was assigned the value 1 (0 otherwise) if meat counts of commercially shucked scallops exceeded 33. Estimation was accomplished by maximum likelihood procedures and data were limited to observations in which carefully resected counts were less than 33. Estimation of a similar model for 30 MPP was attempted, but convergence of the log-likelihood function could not be achieved. The 33 MPP model correctly predicted 94.4% of the observations.

Probabilities that commercially shucked meats given equivalent carefully resected counts are in Table 3. Results indicate that, on average, meat counts of commercially shucked scallops will be less than 33 MPP (30 MPP standard plus 10% tolerance) for equivalent carefully resected counts <31. The probability that commercial counts >33 MPP is quite high for carefully resected counts of ≥ 31.

At-sea Handling and Stowing Procedures

Comparison of at-sea sample counts to dockside sample counts indicated the likelihood of differences (Table 4). The differences in the two counts may be partially due to sampling error or particular at-sea practices. Alternatively, one at-sea and 3 dockside counts may not provide an accurate estimate of the at-sea and dockside counts. These factors should be considered when reviewing the data in Table 4.

Examination of the data in Table 4 indicate a rather consistent time-dependent relationship between the at-sea and dockside counts. In general, the at-sea meat counts for scallops from the beginning of a trip appeared to be lower than the dockside counts; the at-sea counts for scallops harvested and stowed between the sixth and fifteenth day of a trip tended to be higher than the dockside counts.

Probabilities that the dockside count exceeded, equaled, or was less than the at-sea count were estimated by the cumulative logistic distribution function derived from the following logit models:

$$Y = 3.39 - 5.01\ MIX - .38\ DAY + .53\ DUMDAY$$
$$(2.54) \quad (2.40) \qquad (2.72) \qquad (2.54)$$

TABLE 3.

Estimated probabilities of commercially shucked meats exceeding 33 MPP conditional on meat counts of carefully resected scallops.

Carefully Resected Counts	Probability of Exceeding 33 MPP
25.0	0.0
26.0	0.0
27.0	0.0
28.0	0.0
29.0	0.0
30.0	0.0
31.0	.7
32.0	1.0

where Y = 1 (0 otherwise) if dockside count was higher than the at-sea count, MIX is a dummy variable assigned the value 1 (0 otherwise) if the sample consisted of meats of many sizes, DAY was the day of the trip, and DUMDAY equalled the product of the variables DAY and MIX; and

$$Y = -3.62 + 3.84\ MIX + .23\ DAY - .34\ DUMDAY$$
$$\quad\ (2.28)\quad (2.89)\qquad (2.65)\qquad (2.62)$$

where Y = 1 (0 otherwise) if the at-sea count was within the mathematical range of observed dockside counts. The model for dockside count being less than at-sea count is equivalent to the model for dockside count exceeding at-sea count but with the signs of the parameters being reversed (− for +). Dummy variables were set to 1 only for the 3rd trip in which the 3 dockside counts and sizes of individual meats widely varied (e.g., 10–80 count meats). The models correctly predicted 76.6 and 76.5% of the observations, respectively.

The estimated cumulative logistic distribution function for the logit distribution was used to estimate the probabilities with minimum mixing of different sized meats (Table 5). Mixing of different sizes of meats is a common practice which has complicated enhancing yield per recruit. However, visual examination of the 3rd sample indicated extreme variability in the size of individual meats. This level of variation was not visually observed in the other two samples or previously observed landings. The probability that the dockside count exceeded (was lower than) the at-sea count was lower (higher) for scallops taken during the end of a trip. The probability that the two counts were equal increased for scallops taken during the latter part of a trip.

Loss of Catch Component

The percentage difference in meat count/month for carefully resected scallops with and without the catch component are presented in Table 6 for 5 arbitrary shell size intervals. Larger differences were observed for all size ranges in October and November 1987; smaller differences were observed for April, May, and August 1987. Temporal and size related variation did not appear to characterize the differences. A statistical examination of the differences, however, was not conducted since the differences would likely be biased because of spatial, temporal, and environmental

TABLE 4.

At-sea and dockside sample counts for three commercial trips in the mid-Atlantic region.

Day of Trip	Trip 1		Trip 2		Trip 3	
	At-Sea[1]	Dock.[2]	At-Sea	Dock.	At-Sea[3]	Dock.[3]
1	24.38	28.69	18.39	22.11	20.10	21.95
2	25.24	28.55	23.52	25.36	28.66	25.04
3	28.23	31.01	25.23	26.86	20.10	21.83
4	20.96	23.62	24.38	29.27	——[4]	——
5	26.52	29.71	29.94	26.69	19.25	22.19
6	27.41	24.78	——	——	——	——
7	27.80	26.23	——	——	——	——
8	25.66	24.63	——	——	——	——
9	25.24	28.98	24.80	24.53	——	——
10	29.51	31.74	26.95	23.70	25.66	28.51
11	21.81	20.89	24.38	23.86	30.80	25.07
12	26.09	25.50	33.36	27.75	——	——
13	21.39	20.09	——	——	——	——
14	27.80	24.63	24.81	24.32	25.66	23.87
15	29.94	28.93	29.08	22.95	20.10	24.86

[1] At-sea count taken for day of trip.
[2] Dock. is the dockside count taken at end of trip.
[3] The meats for trip 3 were extremely variable in size.
[4] —— indicates no data available.

TABLE 5.

Estimated probabilities of dockside counts exceeding (>) equalling (=), or being less than (<) at-sea counts.[1]

Day of Trip	Estimated Probability Dock. > At-Sea	Dock. = At-Sea	Dock. < At-Sea
1	.95	.03	.05
2	.93	.04	.07
3	.90	.05	.10
4	.85	.06	.15
5	.80	.08	.20
6	.73	.10	.27
7	.65	.12	.35
8	.56	.15	.44
9	.46	.18	.54
10	.37	.22	.63
11	.29	.26	.71
12	.21	.31	.79
13	.16	.36	.84
14	.11	.42	.89
15	.08	.48	.92

[1] Estimates based on minimum mixing of meat sizes; MIX and DUMDAY variables assigned value of zero. Dock. indicates dockside count.

differences (i.e., aggregation bias). It also should be remembered that the difference between 33–33.1 MPP is .3%; enforcement does not statistically test for differences.

There was a clear pattern of size related differences for May 1988; the reasons for this pattern are not known. Over the entire data set of 7,481 observations, the average count for scallops without the catch component was 9.8% higher than the count for scallops with the catch component. This percentage should be considered a maximum value when applied to evaluating commercial counts since meats are landed with and without the catch component.

The estimated double-log model relating muscle-off (MOF) count to muscle-on (MON) count in May 1988 was

$$MOF = 1.058\ MON^{1.01} \quad (14.81)\ (86.72) \quad R^2 = .998$$

where numbers in parentheses are the t-statistics. An examination of the differences between conditional muscle-off counts and observed muscle-on counts indicated larger differences for higher count or smaller size scallops (Table 7). This was consistent with the observed differences in May 1988. This also, however, could be a result of the mathematical form of the model; estimated differences would increase for values of the regressor larger than the mean. Differences were not statistically examined, but it is doubtful that they would be statistically significant.

Estimates of the two transcendental models relating muscle-on and muscle-off counts to shell size (SH) were as follows:

$$MON = \exp^{22.91}\ SH^{-4.46}\ \exp^{.0092SH} \quad (97.70)\ (80.98)\ (35.28) \quad R^2 = .85$$

$$MOF = \exp^{23.21}\ SH^{-4.51}\ \exp^{.0094SH} \quad (96.93)\ (80.16)\ (35.17) \quad R^2 = .85$$

where numbers in parentheses are the t-statistics. Comparison of the estimated parameters indicated similarity between the coefficients. However, a likelihood-ratio-test of the equality of the parameters for the two models failed to accept the null hypothesis that all parameters were equal (chi-squared equaled 98.17).

Examination of expected muscle-on and muscle-off counts conditional on shell size also indicated larger differences for smaller size or higher count scallops (Table 8). The differences were not subjected to statistical validation. Moreover, estimated differences could be exaggerated be-

TABLE 6.

Percentage difference in counts for scallops with and without the catch component, April 1987–May 1988.[1]

Month	Percentage Difference in Mean Count for Selected Shell Size Intervals <89	89–101	102–114	115–126	≥127
April	8.75	8.11	10.76	—[2]	—
May	9.52	10.02	9.60	9.66	—
June	9.14	9.33	9.17	8.67	9.12
August	9.23	8.33	8.37	11.90	8.34
September	10.23	9.68	10.50	9.74	8.97
October	10.56	10.10	10.01	10.37	9.75
November	12.04	10.09	9.66	10.08	10.30
December	9.58	9.43	8.90	9.27	9.71
January	9.78	9.59	9.39	9.88	9.22
February	9.36	9.75	10.31	9.65	9.39
March	9.83	9.46	9.32	9.55	9.80
April	9.81	8.91	9.15	9.06	8.90
May	10.45	9.53	8.89	8.76	8.68

[1] Muscle-off data not available July 1987.
[2] Muscle-off data not available for size range.

TABLE 7.

Estimated muscle-off counts conditional on observed muscle-on counts, May 1988.

Muscle-on Count	Estimated Muscle-off Count	Percentage Difference
25	27.4	9.4
26	28.5	9.5
27	29.6	9.6
28	30.7	9.6
29	31.8	9.6
30	32.9	9.7
31	34.0	9.7
32	35.1	9.8
33	36.2	9.8
34	37.3	9.8
35	38.5	9.9

cause of the functional form. In contrast to the previous models, the meat-count and shell-height model tends to overestimate (underestimate) differences for regressors with values smaller (larger) than the mean.

Estimated counts for muscle-on scallops between 80 and 100 mm, a size range frequently harvested by scallop dredges, were between 60.4–26.9 MPP. Estimated counts for muscle-off scallops of the same size were between 66.7–29.4 MPP. The difference ranged from 10.4% for 80 mm scallops to 9.5% for 100 mm scallops.

Estimates of the two logit models used to estimate the probability of muscle-off scallops exceeding 30 and 33 MPP given muscle-on counts were, respectively:

$$\begin{aligned} ZMOF30 &= -125.3 \;\; +4.6\ MON \\ &\quad\;\; (5.8) \;\;\; (5.8) \\ ZMOF33 &= \;\; -61.0 + 2.0\ MON \\ &\quad\;\; (7.9) \;\;\; (7.9) \end{aligned}$$

where ZMOF30 and ZMOF33 equal 1 (0 otherwise) if muscle-off counts exceed 30 and 33 MPP. The models correctly predicted 98.3 and 97.7% of the observations for May 1988. All parameters were statistically significant. Estimates of the probabilities are presented in Table 9.

TABLE 8.

Conditional estimates of muscle-on and muscle-off counts for selected shell sizes, May 1988.

Shell Size (mm)	Estimated Meat Counts Conditional on Shell Size: Muscle-on	Muscle-off	Percentage Difference
80	60.4	66.7	10.4
85	48.3	53.2	10.2
90	39.2	43.1	10.0
95	32.2	35.4	9.7
100	26.9	29.4	9.5
105	22.6	24.7	9.3
110	19.3	21.0	9.2

As indicated in Table 9, the probability that muscle-off counts exceeded 30 MPP was quite high for muscle-on counts of 28 MPP; for muscle-on counts higher than 28 MPP, the probability that muscle-off counts exceeded 30 MPP was one. The probability that muscle-off counts exceeded 33 MPP given muscle-on counts <30 was quite low; for muscle-on counts >32, the probability that muscle-off counts exceeded 33 was one. The probability that muscle-off counts exceeded 33 given muscle-on counts of 30.5 and 31 was between .68–.85.

DISCUSSION

Naidu (1987, p. 136) suggested a possible inconsistency between meat weight data used for providing scientific advice and landed meat weights: "Also, the meat count regulations for the scallop fisheries are based on yield-per-recruit analyses, which utilize data from biologically-dissected meats. Fishery performance and enforcement, on the other hand, are based on the sampling of landed meats (i.e., the fishery is achieving better yield than landed meat sampling would indicate)." Naidu also suggested a potential bias in estimating age compositions using commercial meat weight data.

Yield-per-recruit analyses of the United States Northwest Atlantic scallop fishery were based, in part, on weight-length relationships which utilized data from carefully resected scallops. The target specification of 30 MPP in the FMP refers to carefully resected scallops. The management standard of 30 MPP and enforcement procedures, however, apply to landed meats regardless of product form. That is, there is no legal or allowable tolerance for meats which are poorly shucked or do not have a catch component. The 10% enforcement tolerance is applied to com-

TABLE 9.

Conditional probabilities of muscle-off counts exceeding 30 and 33 MPP given muscle-on counts, May 1988.

Muscle-on Count	Probability of Exceeding 30 and 33 MPP: 30 MPP	33 MPP
26.5	0.02	0.00
27.0	0.17	0.00
27.5	0.67	0.01
28.0	0.95	0.01
28.5	1.00	0.04
29.0	1.00	0.09
29.5	1.00	0.22
30.0	1.00	0.44
30.5	1.00	0.68
31.0	1.00	0.85
31.5	1.00	0.94
32.0	1.00	1.00

pensate for at-sea measuring difficulties (Smolowitz and Serchuk 1987). Differences between commercially shucked meats and carefully resected meats suggest an inconsistency between the meat weight data used in the biological analyses in support of the plan and the corresponding meats actually landed by fishermen and subject to enforcement. Alternatively, commercial counts different than the carefully resected target count of 30 MPP may be sufficient for realizing long-term benefits in terms of yield-per-recruit.

In the commercial sector, live scallops are landed on deck. The scallops are then culled by either visual observation or by the criteria that the size of the shell must be at least equal to the palm size of the hand of the individual culling the scallops. Crew members rapidly remove the meats from the shell with a shucking knife; speed and complete removal of the meat are primary concerns. Meats are shucked into small buckets. During a watch or work shift or at the end of a watch, the scallop meats are dumped into a large stainless steel bin, washed with sea water, sampled for meat count by using a coffee can or 1-pint cake frosting container, placed in cloth bags, chilled, and stowed with ice in the hold. At the end of a trip, which varies between 9–18 days, the bags of scallop meats are off-loaded at the dock.

Thus, commercial practices offer several sources through which landed weights and meat counts could vary from carefully resected weights and counts. Naidu (1987) demonstrated losses resulting from shucking; results presented in this study provide documentation of minimum losses resulting from shucking. Naidu (1984) also documented differences between muscle-on and muscle-off weights and counts; this study indicates there are substantial differences between muscle-on and muscle-off counts. Last, results of this study demonstrate that weight and meat counts may vary as a result of at-sea handling and stowing practices; that is, dockside meat counts may be higher or lower than the meat counts obtained during bagging of the scallop meats.

Commercial Shucking

Results in this study suggested that carefully resected scallops yielding 30 MPP in April and May 1987 yielded 32 MPP when commercially shucked. Using Naidu's (1987) results, scallops yielding ~30 MPP would, on average, yield 34 MPP when commercially shucked. Previous results in DuPaul and Kirkley (1987), however, obtained results identical to Naidu's when meat counts were estimated using weight-length relationships. The difference of 2 MPP, although small in value, is quite important in terms of the target specification and the management and enforcement program.

Naidu's results suggest that scallopers would be in violation of the 30 count standard plus 10% tolerance while satisfying the target specification. Results in this study indicate that scallopers would not be in violation while satisfying the target specification. However, both results suggest that the fishery may be achieving better yield-per-recruit than commercially landed meats would indicate. In addition, both results suggest that enforcement of the standard may be overly restrictive with respect to achieving the target specification of 30 MPP.

The loss in yield resulting from shucking also presents a serious economic problem. Data available from the National Marine Fisheries Service indicates that mid-Atlantic scallop dredge vessels between 51–150 gross registered tons landed 108,000 lb. of meat/vessel in 1987; the average revenue per vessel was $432,634. Average losses of 5–10% in weight because of shucking represents an economic loss between $22,770 and $48,070/vessel.

Unfortunately, the potential for increasing yield by alternative shucking procedures is limited by the necessity to shuck a large quantity of scallops over a short period of time. Hiring more experienced labor would increase the yield but may not be feasible because of possible increased cost. Shucking scallops more slowly might increase the yield but may not be feasible because of increased labor requirements. The economic ramifications of more carefully shucking scallops have not been examined. However, the most likely source of improved yields will be more experienced crews.

Differences in the two counts further raises the issue of whether or not the current regulations or commercial practices should be changed. Unfortunately, information necessary to address this issue is limited. Changing the current 10% tolerance would better reflect commercial practices but would also likely result in increased fishing mortality on smaller scallops. Increasing the culling size of scallops would reduce the likelihood of exceeding the 30 MPP standard but would be accompanied, at least in the short run, by reduced landings and revenues. The most likely change would be for industry to change commercial practices. More careful shucking results in substantial economic gain regardless of the type of regulation.

At-sea Handling and Stowing Procedures

At-sea handling and stowing procedures were found to result in both gains and losses. Washing, soaking, and stowing on ice tends to increase the weight and decrease the count. However, the length of time scallops are stowed also affects the weight and count. Weight loss and higher dockside counts were found to characterize scallop meats which were held in the hold between 10–15 days; weight gain and lower dockside counts tended to occur for scallops stowed <10 days.

Improvements in the at-sea handling and stowing procedures are possible. However, studies to determine improved procedures have only recently been initiated. Short-run options for improving the yield include packing bags of less weight and making shorter trips. Thus far, industry appears to have been receptive only to packing bags of less weight; the benefits of adopting other methods have not been determined.

There appears to be little practical basis for modifying the current regulation or enforcement procedures to account for differences resulting from at-sea handling and stowing procedures. First, mid-Atlantic vessels appear to take longer trips than vessels from other regions, and there is no rational basis, except increased efficiency and quality, to amend the regulation because one sector of the fleet chooses to take longer trips. Increased technical efficiency and improved quality should be pursued, but data necessary for determining the economic benefits are not available. Alternatively, restricting trips to no more than 10–12 days might improve the quality and landed weight of meats, but might result in more frequent trips and higher total annual operating costs. Second, it would be difficult to determine enforcement procedures compatible with weight gain and loss. Last, gains and losses appear to be variable and conditional on season, temperature abuse of the product, and the reproductive cycle. These problems appear to preclude amending the regulations or changing the enforcement procedures to reflect at-sea handling and stowing procedures.

Loss of Catch Component

Fishery researchers derived the 30 MPP target utilizing scientifically dissected muscle-on scallops (Serchuk et al. 1982). Enforcement and the management standard, though, are predicated on commercially landed scallop meats. Thus, the meat count standard and enforcement procedures are inconsistent with the 30 MPP target specification derived by researchers. Simply, fishery researchers determined that a target count of 30 MPP, based on carefully resected scallops with the catch component attached, would make a substantial contribution towards achievement of the objective of the FMP. In actuality, realization of the target count can be accomplished with different commercially landed scallop meat counts.

In the Code of Federal Regulations, Part 650, Atlantic Scallop Fishery, a scallop meat is defined to be the retained part of the scallop adductor muscle (Federal Register 1987). The meat count means the number of scallop meats required to make one pound. Given this definition, the meats to be sampled or inspected appear to be at the discretion of the inspecting officer. In practice, the enforcement officer usually considers any scallop meat which appears to have been cleanly cut regardless of whether or not the catch component is attached.

The enforcement agent takes one pound samples at random from the total amount of scallops in possession. The sample need not be taken dockside but this appears to be the preferred point of inspection. In addition, the person in possession of the scallops may request as many as ten samples be examined as a sample group. A sample group fails to comply with the standard if the averaged meat count for the entire sample group exceeds the standard.

Presently, this occurs if the count exceeds 30 MPP between February and September or 33 between October–January. If the count exceeds 33 MPP between February 1–September 30 or 36.3 MPP between October 1–January 31, the captain or vessel owner is subject to a citation, fine, and forfeiture of catch.

Results presented in the paper indicated that the loss of the catch component in more than 50% of the commercially landed and bagged meats could result in the inadvertent violation of the meat count standard. This would be particularly true if the catch component separated in the bag after at-sea counts were made. The average count for muscle-off scallops over all months and shell sizes was 9.79% higher than the corresponding muscle-on count. Thus, muscle-on scallops yielding counts of 30.06 MPP, which is in excess of the standard but well below the 10% tolerance, could yield muscle-off counts greater than 33 MPP.

Similarly in May 1988, the results indicated a higher probability of being in violation of the 30 MPP standard for muscle-on counts >29 MPP if the scallops were landed without the catch component (Table 10). A muscle-on count of 30.09 MPP yielded, on average, a muscle-off count of 33 MPP.

Improving the commercial yield or count, however, by landing muscle-on scallops appears to be limited. First, not all fisherman are cognizant of the potential losses evident by their discarding the catch component. Second, the loss of the catch component does not always result in reduced dockside weight since the detached catch components are occasionally bagged with the quick component. More important, a large volume of product must be processed over a short period of time; this severely restricts the landing of muscle-on scallops.

A final condition is the frequent at-sea mixing of recently shucked scallops with scallops meats which have already been bagged. Fishermen note the need to do this to stay within the 30 MPP standard. This appears to be a common practice and is believed to result in the separation of the catch and quick components of bagged meats. Quantitative research, however, does not appear to have determined the processing stage primarily responsible for the separation of the two components. Separation of the catch component has been observed during shucking, washing, and subsequent mixing of the meats (Personal observation, DuPaul and Kirkley 1988).

Amending the regulation and enforcement procedures to account for the loss of the catch component appears to be more practical than altering commercial practices. As shown in Tables 6–8, the percentage difference in muscle-on and muscle-off counts appear to be more stable and predictable than differences that are due to shucking and at-sea practices. Moreover, enforcement agents can determine whether or not a scallop meat contains a catch component.

TABLE 10.

Comparison of meat count restriction, meat count violation, and additional ten- and five-percent tolerances in the meat count standard.[1]

Date of Violation	Meat Count at Time of Violation		Meat Count Restriction with Additional Tolerance[3]	
	Legal[2]	Actual	Ten-percent	Five-percent
2/24/87	30.00	34.00	36.00	34.50
6/5/87	30.00	33.47	36.00	34.50
6/6/87	30.00	41.21	36.00	34.50
6/18/87	30.00	34.20	36.00	34.50
6/18/87	30.00	33.60	36.00	34.50
6/22/87	30.00	38.00	36.00	34.50
8/26/87	30.00	34.39	36.00	34.50
10/22/87[4]	30.00	37.90	39.60	37.95
10/23/87	30.00	33.30	39.60	37.95
10/29/87	30.00	33.90	39.60	37.95
11/15/87	30.00	35.60	39.60	37.95
11/20/87	33.00	43.80	39.60	37.95
11/20/87	33.00	40.28	39.60	37.95
11/20/87	33.00	40.30	39.60	37.95

[1] Trips in which violations occurred and penalties were assessed as reported in the January through July issues of Commercial fisheries News.
[2] Legal refers to the count permitted by the regulation. A violation occurs when the average meat count exceeds the legal count plus the 10% tolerance (i.e., 33 and 36.3 MPP). Actual is the count of the trip which resulted in a violation. Meat count with additional tolrance is based on 1988 amendment which increases the standard to 33 between October 1–January 31.
[3] Meat count restriction with additional tolerance equals meat count standard plus current 10% tolerance and additional tolerances of 5–10%.
[4] Seasonal adjustment plus 10% tolerance allowing 36.3 MPP before issuing a citation was in place between November 18 and January 31, 1987. Currently, the adjustment and 10% tolerance applies between October–January.

Based on the stable nature of the change and the ability of enforcement agents to determine the count, it would appear possible to amend the regulation to allow for the loss of the catch component.

The results of this study indicated an average difference of 9.8% between the counts of scallops with and without the catch component; an allowance of 5% to compensate for the loss of the catch component, thus, would not be unreasonable. An enforcement agent should be able to adjust the weight of muscle-off scallops by 5% to obtain the meat count for the scallops being inspected. This type of adjustment would made the regulation more consistent with commercial practices and help industry without increasing juvenile mortality. The 30 MPP standard and target specification would remain unchanged; only enforcement procedures would be changed.

Data on 14 violations that occurred in 1987 are presented in Table 10. It is not known whether or not the published violations included muscle-on or muscle-off scallops, but given that 50% or more of commercially landed scallops contain no catch component, it is likely that the counts included some muscle-off scallop meats. The data are used to illustrate how a change in enforcement policy in the form of increased tolerance to allow for the loss of the catch component might benefit the scallop industry, in terms of reduced violations, without compromising the target specification of 30 MPP.

Of the 14 violations in which penalties were assessed, 57.1% or 8 out of 14 may not have been in violation if the 30 MPP standard allowed a 10% tolerance for the loss of the catch component. The trip of October 22, 1987 may not have been in violation if the seasonal adjustment had been in effect during October 1987 and the standard reflected the loss of the catch component. If only a 5% tolerance had been added to the existing 10% tolerance and seasonal adjustment, 9 of the 14 violations presented in Table 10 may not have occurred.

Although results of this study suggest that it is possible to change enforcement procedures to better reflect commercial practices, a more important issue in need of attention is whether or not an average meat count regulation is fundamentally flawed. Naidu (1984) and Serchuk (1983, 1984) indicated that an average meat count regulation facilitates mixing of small and large meats; thus, the regulations do not have the desired effect of protecting young scallops and enhancing yield per recruit. Results of Shumway and Schick (1987) and DuPaul and Kirkley (1987) demonstrate considerable spatial and temporal variation in meat counts for given shell sizes. This creates an equitability issue in which vessels fishing different areas will have to harvest different size scallops in order to comply with a meat count standard. Alternatively, vessels will deplete those areas having large concentrations of scallops yielding 30 or less MPP.

The above mentioned problems and the results of this study indicate serious problems with the average meat count regulation and its enforcement. The meat count regulation does not adequately protect young or immature scallops. It poses compliance problems for industry. The meat count regulation does not yield the same results as a minimum shell size relative to age at first capture. Enforcement does not provide adequate consideration of commercial practices. Concluding on a positive note, however, the New England Fisheries Management Council and industry are currently investigating alternative types of regulations which should mitigate the problems addressed in this study.

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