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Efficiency of Meat Recovery from Iceland Scallops (*Chlamys islandica*) and Sea Scallops (*Placopecten magellanicus*) in the Canadian Offshore Fishery

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Abstract

The process of removing adductor muscles (meat) through manual shucking of Iceland scallops and sea scallops at sea results in loss of meat yield to the fishing industry. In the study of Iceland scallops, this loss was negatively correlated with shell size and decreased from about 30% at 60 mm (shell height) to 11% at 90 mm, with an average loss of 23%. Meat recovery was somewhat more efficient from sea scallops, but paradoxically the loss in yield increased slightly with shell size from 8% at 60 mm to 10% at 90 mm. The average loss for commercial-sized sea scallops (≥100 mm) was estimated to be 11%. In addition to such factors as experience, speed and shucking habits of the fishermen, relative efficiency of meat extraction from the shells of the two species appears to be related to shell size, tenacity of shell closure and shell morphology (curvature).

Introduction

North American consumers have a decided preference for shucked scallop meats than for scallops in the shell. Scallops cannot maintain tight shell closure for prolonged periods, and they die soon after their removal from water. They are usually shucked aboard the fishing vessels at sea and the meats are stored in ice until the vessel returns to port. After removal of the adductor muscle (meat), the shell and remaining visceral mass are discarded. The process of shucking is quite rapid, and it usually results in incomplete recovery of the meat. Efficient and full recovery of individual meats is seldom a preoccupation. Incomplete recovery of meats probably reflects a direct economic loss, but it also has important implications for assessment of the scallop stocks. While scientific advice for management, including meat counts, is based frequently on yield-per-recruit analyses using weights of biologically-dissected meats, management measures and fishery performance are nearly always based on sampling of meats at the ports of landing without due consideration of the loss in yield.

This study was undertaken to estimate the loss in yield of the adductor muscle due to rapid manual shucking of scallops at sea. Two Northwest Atlantic species of commercially-exploited scallops were examined: the sea (or giant) scallop (*Placopecten magellanicus*) and the smaller Iceland scallop (*Chlamys islandica*). This study was not meant to be a definitive treatment of the subject but rather to obtain minimum estimates of size-related loss in yield of meat for each species.

Materials and Methods

Data for approximately equal numbers of crew-shucked and biologically-dissected meats and their respective shells were obtained from commercial catches of scallops in two areas of the Northwest Atlantic. A sample of 299 Iceland scallops was taken on St. Pierre Bank (off southern Newfoundland) in November 1984 and a sample of 600 sea scallops was obtained on the northern edge of Georges Bank (eastward of Cape Cod, Massachusetts) in December 1984. Each group of scallops was divided into two equal size-specific components, one for commercial shucking of the meats and the other for biological dissection of the adductor muscles. Commercial shucking of the scallops was done at sea by an experienced fisherman who was rated by the captain as one of the best shuckers in the crew. The shucker was not forewarned about the purpose of the study. He was presented with several baskets of freshly-caught scallops and instructed to proceed routinely at his usual pace among the other shuckers. Shucked meats were retained with matching shells whose heights (mm) were determined by a scientific observer. After the commercial component of the sample was processed, the observer collected size-specific data for the biological component of the sample by recording shell height and carefully removing the complete adductor muscle from each scallop. The meats from both methods of extraction were placed individually in numbered 6-oz whirl-pak polyethylene bags and ice-chilled until precise weights (nearest 0.1 g) were determined in the laboratory. The adductor muscle in scallops consists of a large mass of striated fibers and a smaller mass of smooth fibers, commonly termed the

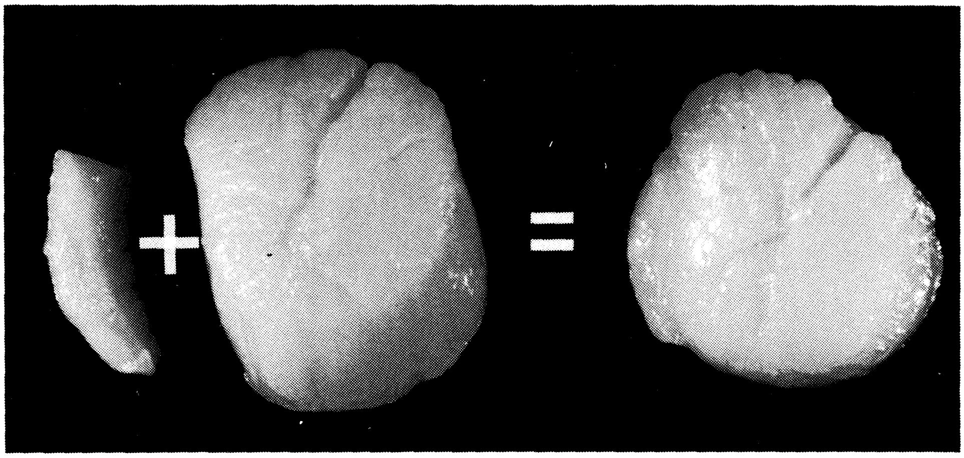

Fig. 1. The adductor muscle of the sea scallop and its "quick" and "catch" components.

"quick" and "catch" components respectively. These components were weighed separately for sea scallops and their combined weight represented the meat weight of each scallop (Fig. 1).

Shell-height and meat-weight data for each shucking method and for each species were logarithmically-transformed (base 10) and the parameters of least-squares regression lines were computed. Average meat yields for selected shell heights were derived from the regressions, and the differences between these yields at corresponding scallop sizes for the biological and commercial data were taken as estimates of the loss in meat yield during the commercial shucking process. Slopes of the regression lines were compared by analysis of covariance.

Results

For each scallop species, shell-height compositions of the biological and commercial components of the sample were quite similar, and the mean shell heights did not differ significantly ($P>0.05$). Difference in the relative sizes of the two species in commercial catches is clearly evident from the shell-height means and ranges (Table 1). Plots of the individual records of log weight (g) against log shell height (mm SH) indicated that the shell height-meat weight relationships for both species and both types of shucking could be represented adequately by log-log least squares straight lines (Fig. 2), the correlation coefficients of which were quite high (r = 0.91–0.96).

Iceland scallops

The difference between the slopes of the log-log regression lines which represent the biological and commercial yields of meat by shell height from Iceland scallops (Fig. 2A) was significant ($P<0.05$), with the slope for the former being higher than that for the latter.

TABLE 1. Number and size of Iceland scallops from St. Pierre Bank and sea scallops from Georges Bank for comparison of yields by biological and commercial shucking methods.

Species	Type of sample	No. of scallops	Shell height (mm) Range	Mean	SD
Iceland scallop	Biological	150	46-95	73.8	9.5
	Commercial	149	58-94	72.0	7.6
Sea scallop	Biological	300	73-146	103.9	14.3
	Commercial	300	75-144	103.0	15.5

Relative to the biological yields, the meat loss due to commercial shucking decreased with size of scallops (Table 2). Over the size range of scallops that are commonly retained commercially, meat loss decreased from 69% at 60 mm SH to 11% at 90 mm SH. In terms of number of scallops to produce 500 g of meat, an additional 54 commercially-shucked scallops at 60 mm SH and 5 at 90 mm SH are required than would be necessary if complete meats were extracted.

Sea scallops

Comparison of the log-log regressions of meat weight on shell height for sea scallops (Fig. 2B) indicated similar slopes ($P>0.05$) but significantly different elevations ($P<0.05$). Paradoxically, percent recovery of muscle tissue decreased slightly with shell size (Table 2), from 91% at 80 mm SH to 88% at 140 mm SH. Examination of the two contributing portions of the adductor muscle (Table 3) showed that incomplete recovery of the larger "quick" component accounted for most of the loss in yield. Difference in adjusted mean weights between biologically-dissected and commercially-extracted adductor muscles was significant for the "quick" component and for the combined components ($P<0.01$) and significant ($P<0.05$) for the "catch" component of the adductor muscle (Table 4). Approximately three times as much muscle tissue (by weight) was lost from the larger "quick" component, which on the average makes up about 92% of the total

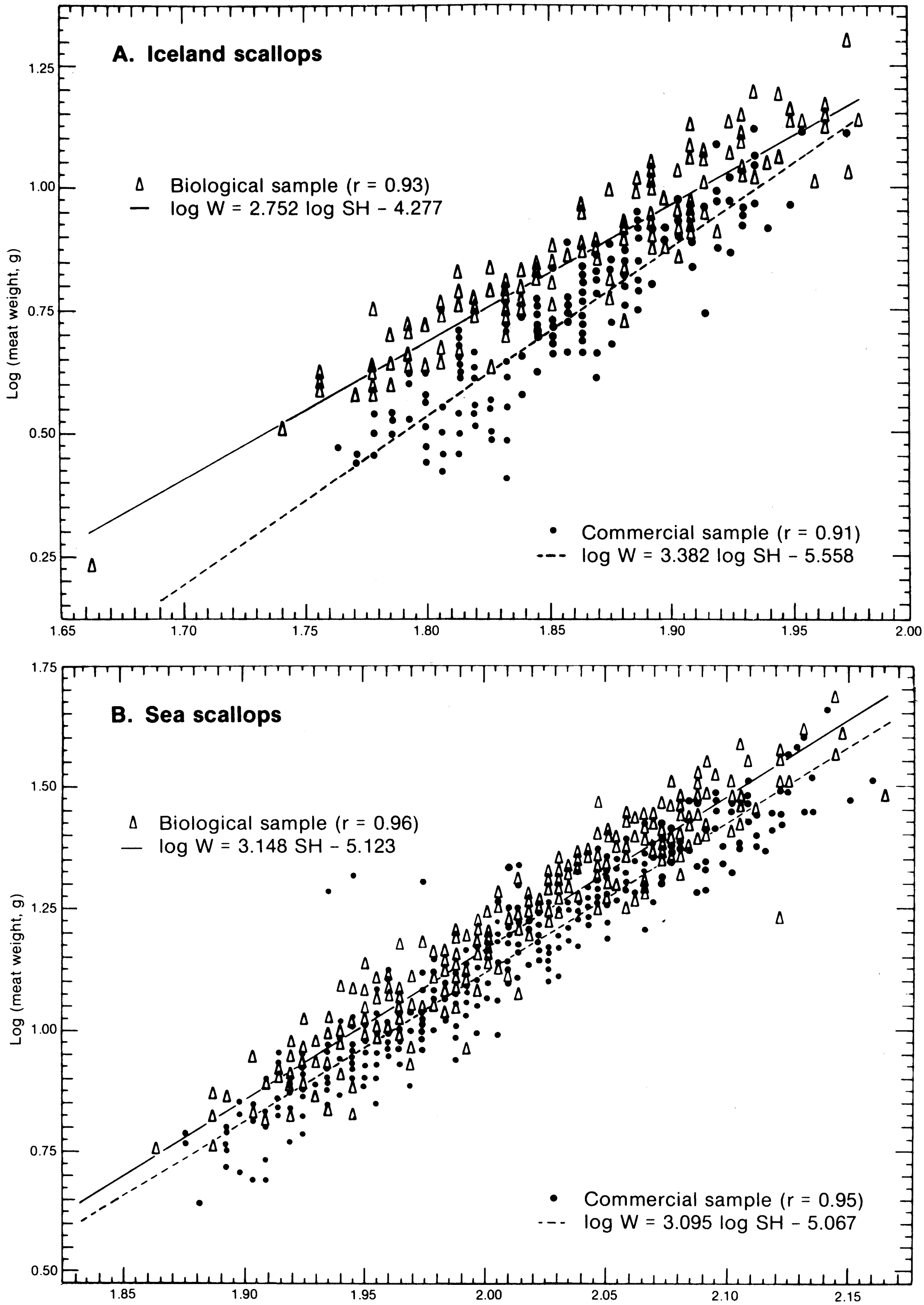

Fig. 2. Shell height-meat weight relationships for the biological and commercial components of (**A**) Iceland scallops from St. Pierre Bank and (**B**) sea scallops from Georges Bank (W = meat weight; SH = shell height; r = coefficient of correlation).

TABLE 2. Average biological and commercial yields of meat from the shell height-meat weight regressions, together with mean counts per 500 g, for Iceland scallops from St. Pierre Bank and sea scallops from Georges Bank.

Shell height (mm)	Average meat yields (g) Biol.	Comm.	Percent loss	Meat counts per 500 g Biol.	Comm.
Iceland scallops					
50	2.48	1.53	38.3	202	327
60	4.10	2.83	31.0	122	177
70	6.26	4.77	23.8	80	105
80	9.05	7.49	17.2	55	67
90	12.50	11.15	10.8	40	45
Sea scallops					
70	4.83	4.40	8.9	104	114
80	7.36	6.66	9.5	68	75
90	10.66	9.58	10.1	47	52
100	14.86	13.28	10.6	34	38
110	20.05	17.84	11.0	25	28
120	26.37	23.35	11.5	19	21
130	33.93	29.92	11.8	15	17
140	42.84	37.64	12.1	12	13
150	53.22	46.59	12.5	10	11

TABLE 3. Biological and commercial yields, based on regressions of meat weight on shell height, for quick and catch components of adductor muscle in sea scallops from Georges Bank.

Shell height (mm)	Quick muscle yield (g) Biol.	Comm.	Percent loss	Catch muscle yield (g) Biol.	Comm.	Percent loss
70	4.41	3.98	9.8	0.42	0.42	0.0
80	6.74	6.05	10.2	0.61	0.60	1.6
90	9.81	8.75	10.8	0.84	0.82	2.4
100	13.71	12.17	11.2	1.12	1.08	3.6
110	18.57	16.41	11.6	1.46	1.40	4.1
120	24.50	21.55	12.0	1.85	1.77	4.3
130	31.60	27.69	12.4	2.31	2.19	5.2
140	40.01	34.92	12.7	2.83	2.67	5.7
150	49.83	43.34	13.0	3.41	3.21	5.9

weight of the adductor muscle, than from the "catch" component. Less than 4% of the "catch" component was lost during commercial shucking.

Discussion

The adductor muscle in scallops is located centrally between the valves and usually makes up about 10% of the total scallop weight. The "quick" and "catch" components of this muscle, consisting of striated and smooth fibers respectively, have different functions. The larger "quick" muscle is responsible for rapid adductions which are usually associated with swimming, whereas the smaller "catch" component (commonly referred to in the fishing industry as the "bit") is responsible for prolonged and sustained contraction (tonus). At present, there is no attempt by shuckers to leave the "bit" attached to the shell, as was practised a few years ago during the fishery for Iceland scallops in the northeastern Gulf of St. Lawrence (Naidu *et al.*, MS 1982). Frequently, however, the "bits" become separated when the meats are being washed (Naidu, MS 1984).

TABLE 4. Comparison of adjusted mean weights of adductor muscles in Iceland scallops from St. Pierre Bank and sea scallops from Georges Bank.

Species	Muscle	Mean meat weight (g) Biol.	Comm.	Loss	Percent recovery
Sea scallop	Quick	14.79	13.12	1.67	88.7
	Catch	1.19	1.15	0.04	96.6
	Total	15.98	14.27	1.71	89.3
Iceland scallop	Total	6.92	5.35	1.57	77.3

The three stages in the dextral process of shucking sea scallops was described by MacPhail (1954) as follows:

a) The scallop is held in the left hand with the hinge in the palm and the left shell toward the shucker (Fig. 3A). The shucking knife, held in the right hand, is inserted forward and upward along the inner face of the flat shell, being entered just above the right-hand corner of the hinge. The blade is then forced backward and downward and toward the operator in a semi-circular motion so as to sever the attachments of meat (muscle) and rim (viscera) from the flat valve.

b) In the next step (Fig. 3B), the point of the knife is hooked downward and away from the operator under the thick muscular mantle edge. The thumb is then pressed against the shell, thus clamping the mantle edge between it and the knife. By lifting upward and toward the operator, the shell and the whole of the rim come away leaving only the meat attached to the cupped valve in the left hand.

c) The meat is then scraped off into the shucking pail (Fig. 3C).

Although Haynes (1966) did not provide essential data, he estimated that scallop shuckers leave 2–10% of the meat attached to the shell. His attempt to duplicate the commercial method of shucking resulted in an estimated loss in yield of about 3%. The process of commercial shucking is such that a fractional loss (difference between potential and realized yield) is not surprising. Variation in efficiency of meat extraction may arise from many causes which can be classified into two types (accidental and systematic). The accidental types are essentially forms of "personal error"

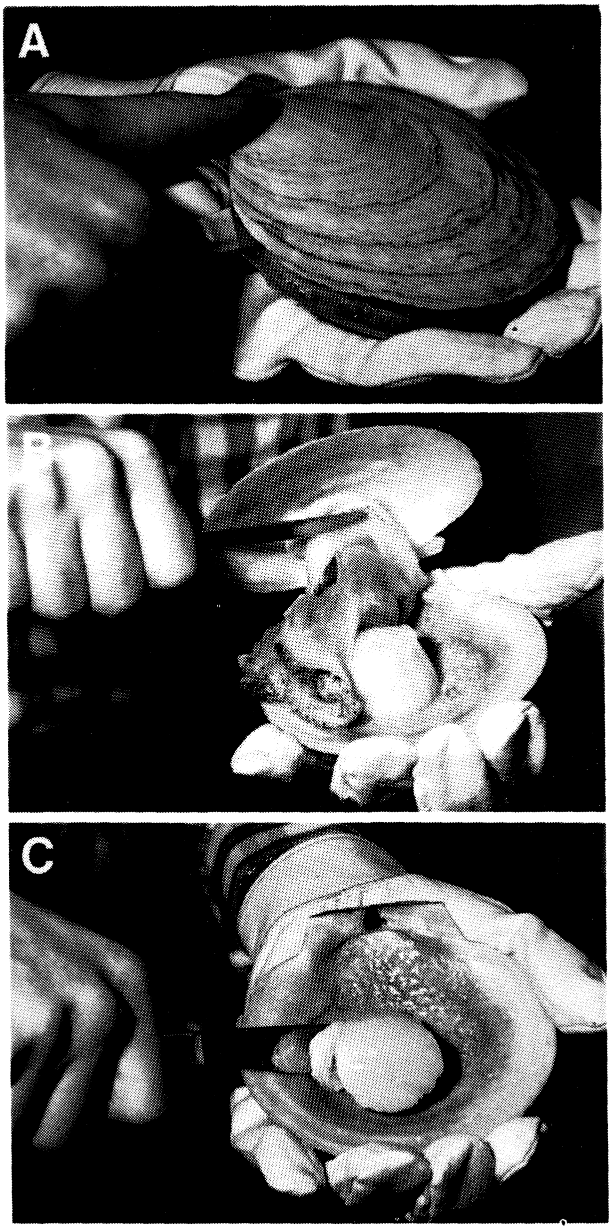

Fig. 3. Three phases of the procedure for shucking sea scallops (modified from MacPhail, 1954).

which may be attributable to such factors as experience and shucking habits. Rapid communal shucking, for example, frequently elicits a competitive response among participants, which tends to sacrifice the highest possible yield from individual scallops in favor of total volume of meats. Such differences are usually disordered in magnitude and difficult to estimate, but they were minimized in the present investigation because the commercial processing of scallops was carried out by one experienced shucker for each species. Systematic causes of variation, in terms of differences between potential and realized yields, are more readily determined. Because experienced shuckers were used in the present study, the estimates of loss in yield for each species are probably minimal. However, the between-species comparison of loss in yield must be considered tentative, because part of the difference may be attributable to differing experience and shucking habits of the two shuckers. Also, while both fishermen were about equally experienced in shucking the larger sea scallops, the one who shucked the Iceland scallops would have been less experienced with that species.

In terms of relative importance, the Iceland scallop had always been considered secondary to the sea scallop. Until recently, offshore stocks of the smaller Iceland scallop have been under-utilized (Naidu *et al.*, MS 1983; Naidu and Cahill, MS 1985), and one of the reasons for this was attitudinal. Not only is the Iceland scallop more difficult to shuck than the sea scallop but greater numbers must be caught and handled to produce a comparable mass (weight) of meat. In addition to the need for greater dexterity in handling Iceland scallops due to their smaller size, tight shell closure along the opposing margins of the valves renders entry of the knife blade relatively more difficult than in the sea scallop. This frequently results in severing the meat several millimeters from the base of the muscle. The greater shell curvature of both valves of the Iceland scallop (Fig. 4) coupled with furrows which run dorsoventrally make complete recovery of the adductor muscle relatively more difficult than in the sea scallop with its smooth inner shell surface. Sometimes the upper valve (relative to the shucker) is pried open before the knife blade has completely severed the muscle, and this results in some tearing of the meat. The same type of shucking knife is used for both species, but the shape of the blade which is customarily appropriate for shucking sea scallops does not fully accommodate shell morphology in the Iceland scallop, undoubtedly resulting in disproportionate loss in yield of meat from the latter. It is not uncommon to see several millimeters of muscle remnants still atttached to discarded Iceland scallop valves. In the sea scallop, efficient recovery of meat is facilitated by one of the valves being nearly flat and smooth.

Changes in shell curvature with size of scallops may affect efficiency of meat recovery in both species, but this aspect was not investigated. Neither was the relative propensity to tearing of the adductor muscle with size (age) of scallops. Such tearing was particularly evident in older scallops whose meats were grayish brown, flaccid and stringy in texture. These scallops are awkward to shuck because some or all of the adductor muscle becomes detached easily and is discarded with the mantle tissue. In any case, the conclusions from the present study would not be affected, because both components of the sample of each spe-

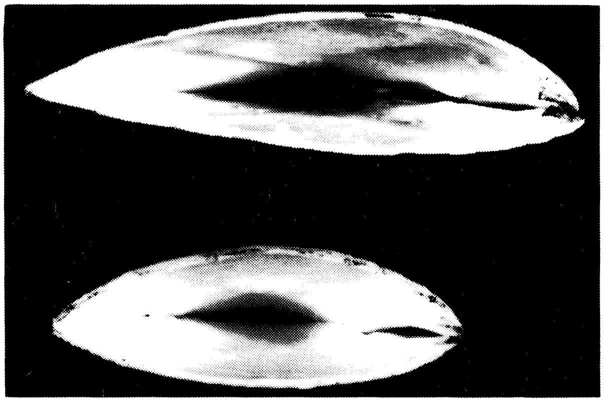

Fig. 4. Transverse sections (anterior-posterior axis) through the shell of a sea scallop (upper) and an Iceland scallop (lower) showing difference in shell curvature.

cies were drawn from the same population and their size distributions were essentially the same.

In view of the high unit value of scallop meats, it would seem worthwhile for the fishermen to shuck scallops slightly more slowly in order to recover more of the available muscle. Whether the increase in yield would be beneficial economically, when the additional cost of labor is considered, has not been determined. For the Iceland scallop, it may be worthwhile to examine other options, including mechanical shucking devices.

In addition to the loss in yield, there is the potential for considerable bias in estimating size (age) compositions from port sampling of landed meats, because the relationships between shell height and meat weight (e.g. Haynes, 1966) are invariably based on data from biological dissections with full recovery of the adductor muscle from all specimens. 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 of regulations, on the other hand, are based on the sampling of landed meats (i.e. the fishery is achieving better yield-per-recruit than landed-meat sampling would indicate).

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