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Relationship Between The Weight of Processed and Completely Unprocessed Northern Shrimp (*Pandalus borealis*)

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Fisheries and Aquatic Sciences No. 2048

June 1995

RELATIONSHIP BETWEEN THE WEIGHT OF PROCESSED AND COMPLETELY UNPROCESSED NORTHERN SHRIMP (*Pandalus borealis*)

by

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TABLE OF CONTENTS

ABSTRACT/RÉSUMÉ iv

INTRODUCTION 1

PRODUCTS PRODUCED BY THE CANADIAN SHRIMP INDUSTRY 1

METHODS AND MATERIALS 2

Study Conducted by Inspection Branch 2
Cooked Shrimp for European Market 3
Raw Shrimp for European Market and for Industrial Market 3
Raw Shrimp for Japanese Market 4
Determination of Weight Loss Caused by Thawing 4

Study Conducted by Science Branch (Observer Program) 5

RESULTS 7

Study Conducted by Inspection Branch 7
Weight Change Caused by Processing 7
Weight Change Caused by Thawing 8

Study Conducted by Science Branch (Observer Program) 8

DISCUSSION 9

CONCLUSION 10

ACKNOWLEDGEMENTS 10

REFERENCES 11

FIGURES 12

TABLES 15

ABSTRACT

Botta, J.R. and D.W. Kulka. 1995. Relationship between the weight of processed and completely unprocessed northern shrimp (*Pandalus borealis*). Can. Tech. Rep. Fish. Aquat. Sci. No. 2048: iv + 31 p.

The Department of Fisheries and Oceans (DFO) Inspection Branch (Newfoundland Region) and the DFO Science Branch (Newfoundland Region) each recently independently conducted a study to determine the relationship between the weight of processed shrimp and the weight of completely unprocessed live shrimp. Each study investigated processed cooked and raw shrimp for the European market as well as processed raw shrimp for the industrial market and for the Japanese market. Both studies revealed that except for processed raw shrimp for the Japanese market, all shrimp products lost weight while being processed. This appeared to be solely related to differences in the actual processing procedures. In addition, the study conducted by the Inspection Branch revealed that weight loss caused by thawing was much greater than weight change caused by processing and the study conducted by the Science Branch revealed weight changes caused by processing were not affected by season during which the shrimp were caught.

RÉSUMÉ

Botta, J.R. and D.W. Kulka. 1995. Relationship between the weight of processed and completely unprocessed northern shrimp (*Pandalus borealis*). Can. Tech. Rep. Fish. Aquat. Sci. No. 2048: iv + 31 p.

La Direction des Services d'Inspection et la Direction des Sciences du Ministère des Pêches et des Océans (Région de Terra-Neuve) ont récemment conduit indépendamment ont étude pour déterminer la relation entre le poids des crevettes transformées et le poids des crevettes vivantes non transformées. Chacune des études concernait des crevettes transformées crues ou cuites destinées au marché européen ainsi que des crevettes transformées crues destinées au marché industriel et au marché japonais. Les deux études ont révélées qu'à l'exception des crevettes transformées crues destinées au marché japonais, tout les produits perdaient du poids lors de la transformation. Ceci apparaît comme étant du uniquement aux différences de processus. De plus, l'étude conduite par la Direction des Services d'Inspection montre qua le perte de poids lors de la décongélation était beaucoup plus importante que lors de la transformation et l'étude conduite par la Direction des Sciences à montré que les changements de poids lors de la transformation n'étaient pas reliés à la saison de pêche des crevettes.

INTRODUCTION

Two species of shrimp are fished commercially in Canadian waters, *Pandalus borealis* from management areas off Newfoundland, Labrador and in the Davis Strait and *P. montagui,* from Hudson Strait/Ungava Bay. These fisheries have existed since the mid 1970's (Anon., 1994) with landings reaching 28,000 t in 1989 and ranging from 22,000 to 29,000 t thereafter. For this valuable component of the Canadian fisheries, it is important that accurate records of both amount of product and of shrimp caught are kept both for stock management purposes and for market considerations. For the industry (market) requirements, catch and product weights are recorded in fishing and production logs by the vessel's crew. For stock management purposes, fishery observers deployed on the shrimp vessels estimate independent records of the catch effort and bycatch.

On commercial fishing vessels it is rarely practical to weigh what has been caught and thus indirect methods for estimating size of the catch must be employed (Kulka, 1985 and Kulka and Firth, 1987). In the case of the shrimp fishery, records of production provide the best opportunity for deriving amount of kept portions of the catch. Both the fishing company and the fishery observers use these production figures as part of the procedure for deriving live weight of the shrimp. This is accomplished by multiplying product weight in the hold by a product to live whole weight conversion factor to yield an estimate of the kept portion of the catch. Knowing how many units of each product type are in the hold, and the average weight per unit, the total unprocessed weight of shrimp that were processed can be calculated. Amount of discarded shrimp is then added to yield an estimate of total catch. Thus, reliability of catch figures derived from production depends on accuracy of three components; the product to live weight conversion factor used, the estimate of average weight of product units, and count of product units stored in the hold.

For market requirements, both boxed and bagged shrimp products contain more shrimp than the stamped weight (net weight recorded on the package), usually in the range of 3 to 30% depending on product.

Since these weight relationships are extremely important to DFO, both the Inspection Branch and the Science Branch have independently investigated this question. Both of these studies addressed the problem of accurately estimating the weight of completely unprocessed shrimp that are caught by commercial shrimp vessels. This was achieved by analyzing weight change due to processing during normal production at sea and during thawing (Inpection Study only) and by analyzing the factors that affect the reliable product to live weight conversion factors.

The results of these independent investigations are presented in this report.

PRODUCTS PRODUCED BY THE ATLANTIC CANADIAN SHRIMP INDUSTRY

Many types of shrimp products are produced at sea from the Labrador shelf and Davis

Strait fisheries. The following is a summary of the types of products observed. Prior to 1986, a portion of the catch was cooled and peeled before being frozen. Since that time all of the catch has been processed whole frozen, either cooked or raw. Any particular vessel only produces a subset of the products depending on production capability and market requirements. However, all vessels first size sort the shrimp before further processing into the categories shown in Table 1.

Once sorted by shakers (mechanical separators) into the various size classes, the shrimp are handled differently depending on whether they were to be cooked or left raw before packaging. Also, the processing methodologies vary somewhat among vessels.

The shrimp to be cooked are usually transported via conveyor to a hopper where they were dumped in about 50 to 70 Kg. batches into a cooker containing sea water (salt added) for several minutes. The cooked shrimp are then dumped into cold water, moved to a conveyor then passed under a blower to remove excess water. En route to the freezer, the catch is spread out and small or damaged shrimp are removed and discarded. The conveyor moves the loose shrimp through a blast freezer tunnel. Once frozen, the shrimp are packaged into 0.2, 1, 4.5, 5, or 11 kg boxes, or 12 to 23 kg bags depending on size of the shrimp.

Shrimp that are to be frozen raw are usually held in water then conveyed to bathes containing antioxidant (fixing) and glazing agents. Small or damaged shrimp are removed prior to being placed into an antioxidant bath. After soaking, the shrimp are usually not passed under a blower, as is the case for cooked products. Rather, they are normally removed from the bath, wrapped and boxed immediately then placed on plate freezers for 1.5 to 3 hours. The raw products are packaged in 0.2, 0.4, 0.8, 1, 1.25, 4.5, 5, 11 or 12 kg boxes for larger Japanese and European products, or 12, 15, 16, 17, 18 19, 20 or 23 kg bags for smaller, industrial shrimp depending market destination.

METHODS AND MATERIALS

STUDY CONDUCTED BY INSPECTION BRANCH

A study to determine the extent of weight changes between live, unprocessed shrimp and frozen processed shrimp was carried out onboard the fishing vessel "Ocean Prawns", during April/May, 1993. The weight relationship between the unprocessed and processed shrimp was determined for each of the seven different shrimp products. In order to ensure realistic values, the experimental samples were processed in a manner almost identical to that used when the products were commercially produced onboard the Ocean Prawns.

All exceptions to the Ocean Prawns' production procedure were made to ensure accuracy of the observed weight changes. All initial weights and final weights were determined using DFO digital balances, which were used soley for this study and were calibrated prior to the start of each experimental "run". All samples were drained for 5 to 10 minutes, prior to the determination of each initial weight in order to ensure that all excess water was removed,

thereby preventing abnormally high weight changes. During the production of raw processed shrimp for the industrial market, the entire bycatch was removed, in order to ensure that the exact weight changes of the shrimp themselves were measured. Except for these three exceptions, each of the seven different products were produced in a manner identical to that used when the products were commercially produced onboard the Ocean Prawns.

The initial processing was the same for all products produced. The shrimp was received from the holding tank and most of the by-catch was manually removed, prior to the shrimp being automatically sorted by size. Once sorted according to size, the shrimp went to the various processes. Shrimp of 70/90 count and 90/105 count were utilized soley for processed raw shrimp (packed in 1 Kg boxes) for the Japanese market; shrimp of 90/120 count and 120/150 count were utilized for either processed cooked shrimp (packed in 5 Kg boxes) for the European market or processed raw shrimp (packed in 5 Kg boxes) for the European market; and shrimp of greater than 150 count were utilized soley for processed raw shrimp (packed in 17 Kg capacity bags) for the industrial market.

Cooked shrimp for European Market

A detailed outline of the processing of this product is shown in Figure 1 and outlined below. The initial sample of shrimp was removed from the processing line, immediately after the shrimp was sorted according to size. The weight of each sample varied from 10 to 50 kg, with 75% of the samples weighing between 20 and 25 kg. Once collected, each initial sample was allowed to drain for 5 to 10 minutes, prior to being weighed. Immediately after being cooked, the shrimp were dumped into a cooling tank, removed from the cooling tank by conveyor and transported to the continous blast freezer. Any damaged shrimp plus the non-shrimp species were removed before the sample entered the blast freezer. All shrimp discards that had been removed were weighed and subtracted from the initial sample weight. Since cooking of ten separate samples had previously been observed to decrease the weight of the discards by 1.8%, the weight of the discards were increased by 1.8% prior to subtraction from the initial sample weight. Once frozen, the sample was packed in 5.0 Kg boxes using the Ocean Prawns packing scales and the sample immediately reweighed using a DFO balance. The weight of all packaging material was subtracted from the final product weight. During processing, greatest efforts were made to ensure integrity of the sample. The conversion factor (initial weight/final weight) necessary to convert the weight of cooked shrimp for the European market to the weight of completely unprocessed shrimp was calculated for each sample.

Raw Shrimp for European Market and for Industrial Market

The raw shrimp utilized for either the European market or the industrial market were processed in a similar manner. An outline of the processing of these products is shown in Figure 2. Normally the only differences between these two different products was: the size of the shrimp utilized; the percentage of by-catch and broken shrimp packed; and the package size. Generally, all damaged shrimp and the entire by-catch were removed from the European product, prior to its being frozen, whereas with the industrial shrimp no damaged shrimp was usually removed and the removal of the by-catch was less thorough, which resulted in small percentage of by-catch being packed with the industrial shrimp. However in order to determine

the exact weight changes caused by processing all by-catch had to be removed from the samples of industrial shrimp (>150 count) utilized during the study. In addition, while the study was being conducted, processed raw shrimp for the European market was not being commercially produced onboard the Ocean Prawns. Thus in order to determine weight relationships for this product, 90/120 count shrimp and 120/150 count shrimp were each separately processed using the prodution line used for industrial shrimp. These products were then packed in 5 kg capacity boxes.

An initial sample of approximately 17 kg was removed from the processing line immediately after the shrimp were sorted according to size. Once collected, each sample was allowed to drained for 5 to 10 minutes, prior to being weighed. When the shrimp reached the sorting table, all discards were removed from the sample, weighed and this weight was subtracted from the initial sample weight. The blast frozen 90/120 count and 120/150 count shrimp were packed in 5 Kg capacity boxes whereas the >150 count shrimp were packed in 17 Kg capacity sacks. Once closed or sewn, each container was weighed using a DFO balance. The weight of all the packing material was subtracted from the weight of each final product. The conversion factor (initial weight/final weight) necessary to convert the weight of processed raw shrimp to the weight of completely unprocessed shrimp was calculated for each sample.

Raw Shrimp for Japanese Market

The manner by which these products were produced is described in Figure 3 and is outlined below. The initial sample of shrimp was taken from the production line immediately after manual sorting of damaged shrimp and removal of the remaining by-catch was completed. The weight of each initial sample varied from 8 to 17 Kg with 86% of the samples weighing between 11 and 16 Kg. Each initial sample was allowed to drain for 5 to 10 minutes, prior to being weighed. The sample was then placed in a hopper which dumped the sample into the antioxidant dip. After 30 secs in this solution the shrimp were automatically dumped into a glazing solution. From this tank, the shrimp were conveyed underneath a drying fan prior to being conveyed to the Ocean Prawns' packing scales and automatically packed into one Kg boxes. The shrimp were then frozen in plate freezers for approximately 2.5 hours. Once frozen each sample was immediately reweighed, using a DFO balance. The conversion factor (initial weight/final weight) necessary to convert the weight of processed (frozen) raw shrimp for the Japanese market to the weight of completely unprocessed shrimp, was calculated for each sample.

Determination of weight loss caused by thawing

Samples of both processed cooked shrimp for the European market and processed raw shrimp for the Japanese market were evaluated to determine the amount of weight loss caused by thawing. The samples used for this study were randomly selected from the Ocean Prawns' regular production, appropriately labelled and weighed at sea using a DFO balance. Once the Ocean Prawns' returned to port, the samples were transferred to the Northwest Atlantic Fisheries Centre and stored at - 30°C for 40 days. A 1 Kg subsample from each 5 Kg package of processed cooked shrimp for the European market and the entire contents of each 1 Kg package of processed raw shrimp for the Japanese market was subjected to thawing. Each 1 kg

subsample and each 1 Kg sample was weighed, placed in 4 litres of 8°C water until completely thawed (approximately one hour), immediately placed on absorbant paper, allowed to drain for 10 minutes and reweighed.

STUDY CONDUCTED BY SCIENCE BRANCH (OBSERVER PROGRAM)

Four hundred and ninety-five experiments were conducted on board 15 shrimp trawlers between 1988 to 1991 (Table 2) to determine the effect of shrimp size and season on weight loss or gain resulting from conversion to final product, for both cooked and raw products. Fishery observers weighed batches of live shrimp then allowed these samples to pass through normal production after which they were re-weighed. Ships' scales were used to weigh both unprocessed shrimp and the final product. The observers also collected information on factors that might affect change in weight of live shrimp during conversion into the final product.

Many product types were produced; combinations of cooked or raw, shrimp size categories (refer to Table 1) and packaged into boxes or bags in a variety of sizes. For the purpose of the conversion factor experiments, the many product varieties were grouped into 12 categories according to whether they were cooked or raw, whether shrimp count was 150+ (Industrial), 90-150 (European) or 50-90 (Japanese), and when they were produced during the year, either during January to April or May to December. For the experiments conducted, how the product was frozen was particular to product type (plate frozen for 50-90 raw and blast frozen for the rest) and was therefore not included in the categorization of the products.

The experiments were conducted by extracting approximately 50 kg batches of shrimp depending on factory conditions. This sample size was chosen to correspond with batch size for the cooker and thus varied by batch size. Refer to Table 11 for average sample weights by product category. Prior to extraction of the samples, shrimp were first size sorted by the crew: 50-90 shrimp per kg. (samples included either 50-70 or 70-90 count products), 90-150 per kg. (included either 90-105, 90-120 or 120-150 count products), and more than 150 per kg. The batches of sorted live shrimp were allowed to sit for 5 minutes to allow excess water to drain away. According to target product type, the samples were then passed by the crew through normal production.

Each stage of production was monitored for any factors or processes that might result in weight gain or loss such as discarded or lost shrimp, water baths, blowers, or misting. For both cooked and raw products, there were a number of situations identified where shrimp could be lost or are removed as they passed through production. Conveyor belts from the shakers carrying small shrimp could be reversed or redirected, allowing the shrimp to be dumped to the floor or to a discard chute. Some shrimp, particularly broken, blackhead, and soft shrimp were discarded incidentally, along with bycatch species from the sorting belt. As well, spillage occurred at several sites along the processing line, at the machines and from the conveyor belts. After being sorted by the shakers, small shrimp were usually collected in a water-filled holding tank before processing. When left unattended, these holding bins were observed to overflow on occasion or the conveyor belt feeding it became blocked, resulting in lost shrimp. Also when the tank was drained, shrimp were sometimes lost. There are also a number of factors which

could add weight to the shrimp product. Water could be added from the chemical bath particularly where there was improper drainage after passing through the holding tank. All of these factors were accounted for and weight of discards and lost shrimp were added to the product weight.

Once processed, the experimental batch of shrimp was re-weighed. Wherever possible, the weighing was done before the shrimp were packaged. If this was not possible, the product was weighed in the package and the package weight was subtracted. These procedures were done for each product category in such a manner to reflect as much as possible the normal production sequence. Data accompanying each experiment included weight of shrimp before and after processing, how it was processed, raw or cooked, shrimp count per kg., freezing method (plate or blast) and date. It was assumed that size of the product unit or packaging did not affect weight change of the shrimp since package materials were not included in the product weight. Any information on other factors that might affect weight of the product were noted. Departure from normal production procedures that could affect weight change were also noted and atypically processed samples were removed from the database.

The sample results were divided according to product form, shrimp count and season to determine if there was any differences in magnitude of weight loss or gain caused by these three factors. The conversion factor of product to live weight was estimated as the slope in the regression of product to unprocessed weight using the REG procedure in SAS (SAS Institute Inc). Initially, a separate line was fitted for each product form (cooked or raw), shrimp count (150+, 90-150 or 50-90) and season (Jan-Apr. or May-Dec.) combining for a total of 12 regressions with live weight as the dependant variable and product as the independant variable. An examination of scatter plots for each of the 12 combinations indicated a tight linear fit and lack of patterns in the residuals confirmed the appropriateness of a linear model. It is expected that as live weight of the shrimp approaches zero so does product weight since for each experiment, the same shrimp were found in both the live and product component. This hypothesis was examined by testing for intercept significantly different from zero for each of the twelve regressions.

The effects of shrimp size categories, and season on slope, in this case the conversion factor for live to product weight, were examined using analysis of covariance with a full model to test for equality of slopes using the GLM procedure in SAS (SAS Institute Inc):

$$Y_{ijk} = \mu + A_i + B_j + AB_{ij} + X_{ijk} + AX + BX + ABX + \varepsilon_{ijk}$$

where Y (live weight) is the response variable and X (product) is the continuous covariate, A and B are the discrete or class variables (shrimp count and season) and AB is the optional interaction term. A separate analysis was done for the raw and cooked products. The analysis tested for the most appropriate model ie., common slope (conversion factor) or multiple slopes for shrimp count and season combinations. Interaction affects were assessed by examining two way and three way interactions in the model. A hierarchal approach to subset selection (Hendrix

et al. 1982) was used.

RESULTS

STUDY CONDUCTED BY INSPECTION BRANCH

Weight change caused by processing

Almost all (95%) of the processed cooked shrimp for the European market lost weight during processing (Table 3). The observed conversion factor for cooked shrimp ranged from 0.995 to 1.079 with 75% of the 120/150 count shrimp and 89% of 90/120 count shrimp having a conversion factor $\geq$1.01 but < 1.07, respectively (Table 3). The mean conversion factor for 120/150 count cooked shrimp was 1.040, whereas the conversion factor for 90/120 count cooked shrimp was 1.036 (Table 3). Thus shrimp size did not appear to substantially affect the magnitude of the conversion factor for processed cooked shrimp.

All of the processed raw shrimp for the European market lost weight during processing (Table 4). The mean conversion factor for 120/150 count shrimp and 90/120 count shrimp was 1.048 and 1.046, respectively (Table 4). In addition the range of the conversion factors, within each of the two different counts of shrimp, was quite similar (Table 4). Consequently the observed results indicated that shrimp size did not affect the magnitude of the factor necessary to convert the weight of processed raw shrimp for the European market to the weight of completely unprocessed shrimp.

The mean conversion factor for industrial shrimp was 1.052, with every sample losing weight during processing (Table 5). The observed conversion factor for industrial shrimp ranged from 1.032 to 1.083 with 89.5% of of the samples having a conversion factor > 1.03 but < 1.07 (Table 5).

Almost all (94%) of the samples of processed raw shrimp for the Japanese market were observed to gain weight during processing (Table 6). Although the range of the observed conversion factors was slightly larger for the 90/105 count samples, the mean conversion factor for each of the two different sizes of shrimp was almost identical (0.971 versus 0.970) (Table 6). This close similarity suggested that the size of shrimp processed did not affect the magnitude of the conversion factor appropriate for processed raw shrimp for the Japanese market.

Since the size of shrimp processed did not appear to affect the magnitude of the conversion factor appropriate for product type, a single conversion factor for each of the three types of products has been calculated (Table 7).

All of the samples of processed cooked shrimp, processed raw shrimp for the European market and processed raw shrimp for the industrial market were blast frozen (Fig. 1 and 2). Almost all (97.4%) of these blast frozen samples were observed to lose weight during processing (Tables 3 to 5). Since the shrimp were blast frozen prior to being packaged, it is suspected that

this blast freezing caused some desiccation of the product (Fennema, 1975), at least partially explaining this observed loss of weight.

All of the samples of processed raw shrimp for the Japanese market were plate frozen (after being packaged) while being processed (Fig. 3) and 94% of these samples were observed to gain weight during processing (Table 6). However unlike all other types of samples (processed cooked shrimp, processed raw shrimp for the European market and processed raw shrimp for the industrial market), each sample of processed raw shrimp for the Japanese market was subjected to a controlled stay in a preserving liquid (Fig. 3). Therefore it is suspected that the actual observed weight gain was due to a combination of these two factors.

Weight change caused by thawing

Thawing of processed cooked shrimp for the European market and processed raw shrimp for the Japanese market was observed to cause 7.37% and 6.15% weight loss, respectively (Table 9). This weight loss is noticeably greater than any weight gain that was observed to occur during the processing of either of these two different products (Tables 3 and 6). Thus using only weight loss caused by thawing (to determine the weight of the completely unprocessed shrimp) could easily yield erronous values. For example if the present mean thawing weight changes (rather than the weight changes caused by processing itself) were utilized, the quantity of shrimp required to produce the final product would be underestimated by 117 Kg (256 lb) for each metric ton of processed cooked shrimp and by 46 Kg (102 lb) for each metric ton of processed raw shrimp for the Japanese market (Table 9).

STUDY CONDUCTED BY SCIENCE BRANCH (OBSERVER PROGRAM)

Initially, a separate line was fitted for each shrimp count/season combination where the dependant variable was live weight of the shrimp and the independant variable the resulting product weight. Five of the twelve intercepts for the live to final product weight regressions were negative values and all were close to zero. A t-test for each model indicated that for 11 of the 12 product/season regressions the intercept was not significantly different from zero at the 0.01 level (8 of 12 not significant at the 0.05 level). Forcing the intercept through zero resulted in little change in the magnitude of the slope. Thus slope from a linear model with zero intercept was chosen to estimate the conversion factors.

Table 10 shows the linear relationships of product to unprocessed live weights for each of the 12 categories plus the values for grouped relationships. The results indicate a highly significant relationship for all product categories where r^2 was never less than 0.9982 and coefficient of variation did not exceed 4.26. Product to unprocessed live weight conversion factors and yield for selected shrimp products are summarized in Table 11. The estimates of conversion factor (slopes) for the three size selected raw products were similar, regardless of season and were very close to 1, suggesting no weight loss or gain due to processing for raw products. The experiments for raw industrial product yielded conversion factors of 1.017 during Jan. to Apr. and 1.011 during May to December, 1.013 for Jan. to Apr. and 0.999 during May to Dec for European product, and 1.0 for Jan. to Apr. and also May to Dec for Industrial product. Average conversion factor for all raw products tested was 1.006 (yield of 99.3%). In

contrast, the experiments for cooked products suggested that weight loss occurred for all shrimp sizes and during both seasons. Industrial product yielded conversion factors of 1.059 Jan. to Apr. and 1.067 during May to December, 1.041 for Jan. to Apr. and 1.053 during May to Dec for European product, and 1.069 for Jan. to Apr. and 1.031 May to Dec for Industrial product. Average conversion factor for all cooked products tested was 1.048 (yield of 95.4%). indicating that there was weight loss when converting live shrimp to cooked products.

Table 12 summarizes the results of the analysis of covariance which was used to compare slope (conversion factors) by product and season. A hierarchal approach to subset selection resulted in the final reduced model:

$$Y_{ijk} = \mu + A + X_{ijk}$$

ie., there was no interaction with the main effects nor heterogeneity terms with the covariate. However, for the main effects for both cooked and raw products, there was a marginal difference detected for shrimp size category, but no seasonal differences. Thus, magnitude of the conversion factor did not vary significantly throughout the year, but it did vary marginally according to shrimp size category comprising the product. However, in practical terms, the observed difference between the lowest (Japanese) and highest (industrial) raw product values was very small, only a 1.5%. Similarly for cooked products, the observed difference between the lowest (Japanese) and highest (industrial) raw product was only a 1.4%. A considerably greater difference, 4% was observed between cooked and raw products. Although the results presented in this paper pertained to the species *P. borealis*, a limited number experiments on *P. montagui* suggested that the conversion factors would be valid for both species.

DISCUSSION

The specific value of the conversion factors determined by the independently conducted study by the Inspection Branch (Table 7) was supported by the specific values of the conversion factors (of similar products) determined by the independently conducted study by the Science Branch (Tables 7 and 11). For example, if one metric ton (2,200 lb) of each of: processed cooked shrimp for the European market; processed raw shrimp for the European market; processed raw shrimp for the Industrial market and processed raw shrimp for the Japanese market were produced the results of the Inspection Branch study would indicate that a total of 4,108 Kg (9,037 lb) of ucompletely unprocessed shrimp had been utilized (Table 8) whereas the the results of the Science Branch study would indicate that a total of 4,070 Kg (8, 954 lb) of completely unprocessed shrimp had been utiliized (Table 8). That there was a very small difference of only 38 Kg (83 lb) out of 4,000 Kg (8,800 lb) collaborates the independant studies.

In addition, as part of their catch estimation procedure, fishery observers weighed units (bags and boxes of processed shrimp) then subtracted the weight of packaging to determine the difference between stamped weight of the product (what is written on the product container) and the actual weight in the container. Actual weight was generally observed to be between 3 and

30% above stamped weight, usually in the 5 to 20% range. This difference is referred to as "overpack" and is a market requirement. Representatives of the Canadian Atlantic Shrimp Industry have suggested a portion of the difference between stamped and actual product weight is not due to excess shrimp but rather to water that has been added to the product. However if the overpack is actually the result of added shrimp weight and stamped weight is used to estimate product weight in the hold (ie number of product units multiplied by stamped weight) then kept weight of shrimp would be underestimated by the amount of overpack.

CONCLUSIONS

The Department of Fisheries and Oceans (DFO) recently conducted two independent studies designed to accurately determine the relationship between the weight of processed shrimp and the weight of completely unprocessed live shrimp.

Both studies clearly revealed that except for processed raw shrimp for the Japanese market, all shrimp products were observed to lose weight (usually between 1 and 6%) while being processed.

The study conducted by the Inspection Branch revealed that processing of raw shrimp for the Japanese market caused a weight gain of approximately 3% whereas the study conducted by the Science Branch revealed that processing of raw shrimp for the Japanese market did not cause either a weight gain or a weight loss.

The study conducted by the Science Branch clearly indicated that season of catching (not investigated by the Inspection Branch) did not affect the magnitude of weight loss or gain resulting from the conversion of live shrimp to final product.

The study conducted by the Inspection Branch revealed that using weight loss caused by thawing (not investigated by the Science Branch) to convert weight of final product to weight of unprocessed shrimp yielded erroneous values.

The current DFO policy for estimating shrimp catch weight is that a product to live weight conversion factor of 1.0 be used, suggesting no weight gain or weight lose occurs during the commercial processing of shrimp. However, depending on the mix of shrimp products being produced, both independent studies suggest that commponents of the current shrimp catch is being underestimated by up to 6%.

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Figure 1. Flow diagram indicating the manner by which cooked shrimp, packed in 5 Kg boxes, was produced.

Receipt from shrimp holding tank.
Manual sorting of by-catch.

Automatic grading by size.

Initial weight was determined at this stage

Automatic cooking in sea water,
salt added.

Cooling in water tank with feeding
conveyor to sorting table.
Drying fan on feeding conveyor.

Manual sorting of broken, damaged
and undersized shrimp.

Manual sorting of remaining by-catch.

Weight of discards was determined at this stage

Single freezing on conveyor belt, inside
continuous blast feezers.

Dry buffer tank with feeding conveyor
to electronic scales.

Empty boxes made by automatic box erector

Shrimp placed into paper boxes by use of
electronic scales, automatic stopping of
feeding conveyor when box is at pre-set weight.

Box hoods manually erected by operator

Hood is put on box. Box automatically
marked with content and date of production.

Final weight was determined at this stage.

Each box automatically sealed by hot
shrink plastic.

Storage on pallets. Pallets wrapped
with plastic when filled up.
Pallets moved into elevator by cranes.

Figure 2. Flow diagram indicating the manner by which raw shrimp, packed in 5 Kg boxes, for the European market and raw shrimp, packed in 17 Kg cacity bags, for the inusdtial market were produced.

Receipt from shrimp holding tank.
Manual sorting of by-catch.

Automatic grading by size.

Initial weight was determined at this stage

Storage in water filled tank with
feeding conveyor to sorting table.
Drying fan on feeding conveyor.

Manual sorting of broken, damaged and
undersized shrimp (only shrimp packed in 5 Kg
boxes). Complete manual sorting of remaining
by-catch from shrimp to be packed in 5 Kg boxes.
Incomplete manual sorting of remaining by-catch
from shrimp to be packed in 17 Kg bags.

Weight of discards was determined at this stage

Single freezing on conveyor belt,
inside continuous blast freezers.

Dry buffer tank with feeding conveyor
to electronic scales.

Empty boxes made by automatic box erector

Shrimp automatically placed into 5 Kg capacity
paper boxes by use of electronic scales to control
pre-set weight or manually placed into 17 Kg capacity
knitted plastic bags, until bags were full.

Box hoods manually erected by operator.

Hood put on box. Box automatically marked with
content and date of production. Bags closed by
hand operated sewing machine.

Final weight was determined at this stage

Each box automatically sealed by hot shrink
plastic. Each bag stamped with production date.

Individual bags and boxes on pallets moved to elevator.

Figure 3. Flow diagram indicating the manner by which raw shrimp, packed in 1 Kg boxes, for the Japanese market were produced.

Receipt from shrimp holding tank.
Manual sorting of by-catch.

Automatic grading by size.

Manual sorting of broken, damaged
and undersized shrimp.

Manual sorting of remaining by-catch.

Initial weight was determined at this stage.

Automatic controlled stay in preserving
liquid, required by and delivered by customer.

Stored in water filled buffer tank with
feeding conveyor belt to scales.
Drying fan on feeding conveyor.

Empty boxes made by automatic box erector

Shrimp placed into paper boxes by use of
electronic scales, automatic stopping of
feeding conveyor when box is at pre-set weight.

Transported by conveyor to horizontal plate
freezers. Packs are stored in trays during
freezing to correct core temperature. Boxes
taken out of plate freezer when frozen.

Final weight wes determined at this stage.

Each box automatically sealed by hot shrink
plastic. Boxes put into 12 Kg master boxes.

Master carton marked with content, size, date
of production and sealed by tape.

Master boxes stored on pallets. Pallets, wrapped
with plastic when filled up. Pallets moved into
elevator by crane.

Table 1. Size, Count and Market Destination for the *Pandalus borealis* products

Size	Count [1]	Market Destination	Packaging
Small	150+	Industrial	12 - 23 kg bags
Medium	120-150	European	5-12 kg. boxes
Medium	90-120	European	5-12 kg. boxes
Med/Large	90-105	Japanese	5 kg. boxes
Large	70-90	Japanese	0.2 - 1 kg. boxes
Extra Large	50-70	Japanese	0.2 - 1 kg. boxes

[1] Count refers to average number of shrimp per kilogram.

Table 2. Vessels where conversion factor experiments were performed by fishery observers and general product types produced by these vessels.

Vessel	Years	Product		Freezer
Ango	1989	Cooked/Raw		
Arctic Viking	1988, 1989	Cooked	Various, incl European	Blast
	1990	Raw	Japanese	Plate
		Raw	Industrial	Plate
Aqviq	1989	Cooked	Various	
Cape Adair	1990	Cooked	Various	Blast
		Raw	Japanese	Plate
		Raw	Industrial	Blast
Faroe Prawns	1988, 1989	Cooked	Various	Blast
		Raw	Japanese	Plate
		Raw	Industrial	Blast
Helen Basse	1988	Raw		Blast/Plate
Hogifossor	1991	Cooked	Various	Blast
		Raw	Japanese	Plate
		Raw	Industrial	Blast
Hvilvtenni	1988, 1989	Cooked	Various	Blast
	1990	Raw	Japanese	Plate
		Raw	Industrial	Blast
Labrador Trader	1989, 1990	Cooked	Various	Blast
		Raw	Japanese	Plate
		Raw	Industrial	Blast
Nfld Lynx	1989, 1990	Cooked	Various	Blast
	1991	Raw	Japanese	Plate
		Raw	Industrial	Blast
Nfld Otter	1990	Cooked	Various	Blast
		Raw	Japanese	Plate
		Raw	Industrial	Blast
Norbubvin	1988, 1989	Cooked/	Various	Plate
	1990	Raw		
North. Kingfisher	1988	Cooked	Various	Blast
		Raw	Japanese, Industrial	Plate
Ocean Prawns	1988, 1989	Cooked	Various	Blast
	1990	Raw	Japanese	Plate
		Raw	Industrial	Blast
Thortrawl	1988, 1989	Cooked	Various	Blast
	1990	Raw	Japanese	Plate
		Raw	Industrial	Blast

Table 3. Relationship between the weight of live unprocessed shrimp and weight of processed cooked shrimp, packed in 5 Kg boxes, for the European market.

Sample number	Count per Kg	Initial wt minus wt of discards	Final wt minus wt of package	Conversion factor
1	120/150	21.080	20.534	1.027
2	120/150	41.707	41.484	1.005
3	120/150	23.428	22.812	1.027
4	120/150	22.614	22.502	1.005
5	120/150	21.099	20.668	1.021
6	120/150	21.729	20.136	1.079
7	120/150	24.173	23.064	1.048
8	120/150	46.679	43.854	1.064
9	120/150	46.611	44.294	1.052
10	120/150	24.557	23.054	1.065
11	120/150	16.102	15.338	1.050
12	120/150	24.524	23.456	1.046
13	120/150	22.835	21.684	1.053
14	120/150	20.536	20.590	0.997
15	120/150	20.525	19.732	1.040
16	120/150	21.409	20.034	1.069
17	120/150	21.229	19.820	1.071
18	120/150	21.381	20.740	1.031
19	120/150	9.775	9.670	1.011
20	120/150	21.713	20.775	1.045
MEAN				1.040
STANDARD DEVIATION				±0.024
21	90/120	20.836	20.215	1.031
22	90/120	22.167	22.142	1.001
23	90/120	22.658	21.364	1.066
24	90/120	25.794	25.936	0.995
25	90/120	49.139	46.588	1.055
26	90/120	24.021	22.842	1.052
27	90/120	20.042	19.842	1.010
28	90/120	24.790	23.967	1.034
29	90/120	40.824	39.122	1.044
30	90/120	50.196	48.510	1.035
31	90/120	48.808	47.524	1.027
32	90/120	44.270	42.276	1.047
33	90/120	45.236	43.578	1.038
34	90/120	25.260	24.120	1.047
35	90/120	22.310	21.518	1.037
36	90/120	14.136	13.702	1.032
37	90/120	21.509	20.546	1.047
38	90/120	22.000	20.838	1.056
MEAN				1.036
STANDARD DEVIATION				±0.018

Table 4. Relationship between the weight of live unprocessed shrimp and weight of processed raw shrimp, packed in 5 Kg boxes, for the European market.

Sample number	Count per Kg	Initial wt minus wt of discards	Final wt minus wt of package	Conversion factor
39	120/150	18.510	17.650	1.049
40	120/150	17.882	16.612	1.076
41	120/150	17.804	17.008	1.047
42	120/150	17.954	16.822	1.067
43	120/150	17.517	16.922	1.035
44	120/150	17.161	16.102	1.066
45	120/150	17.200	16.660	1.032
46	120/150	17.500	17.020	1.028
47	120/150	17.380	16.488	1.054
48	120/150	17.730	17.354	1.022
MEAN				1.048
STANDARD DEVIATION				±0.018
49	90/120	18.212	17.386	1.047
50	90/120	17.483	16.824	1.039
51	90/120	17.153	16.140	1.063
52	90/120	17.392	16.544	1.051
53	90/120	17.208	16.518	1.042
54	90/120	17.802	17.122	1.040
55	90/120	17.773	17.094	1.040
56	90/120	17.609	17.100	1.030
57	90/120	17.705	16.898	1.048
58	90/120	17.431	16.506	1.056
MEAN				1.046
STANDARD DEVIATION				±0.010

Table 5. Relationship between the weight of live unprocessed shrimp and the weight of processed cooked industrial shrimp, packed in 17 Kg capacity bags.

Sample number	Count per Kg	Initial wt minus wt of discards	Final wt minus wt of package	Conversion factor
59	>150	16.975	15.990	1.062
60	>150	17.380	16.785	1.035
61	>150	18.005	17.130	1.051
62	>150	18.530	17.500	1.059
63	>150	18.050	17.385	1.038
64	>150	18.541	17.472	1.061
65	>150	18.030	17.318	1.041
66	>150	17.813	16.794	1.061
67	>150	17.499	16.160	1.083
68	>150	17.968	17.120	1.050
69	>150	17.759	16.546	1.073
70	>150	17.620	16.862	1.045
71	>150	17.690	16.696	1.060
72	>150	18.550	17.396	1.066
73	>150	17.610	16.892	1.043
74	>150	17.720	16.900	1.049
75	>150	17.930	17.250	1.039
76	>150	17.722	17.040	1.040
77	>150	17.765	17.206	1.032
MEAN				1.052
STANDARD DEVIATION				±0.014

Table 6. Relationship between the weight of live unprocessed shrimp and weight of processed raw shrimp, packed in 1 Kg boxes, for the Japanese market.

Sample number	Count per Kg	Initial wt minus wt of discards	Final wt minus wt of package	Conversion factor
78	90/105	14.650	15.275	0.959
79	90/105	11.865	12.685	0.935
80	90/105	11.685	12.295	0.950
81	90/105	12.810	12.802	1.001
82	90/105	13.505	13.428	1.006
83	90/105	12.470	12.724	0.980
84	90/105	14.035	14.664	0.957
85	90/105	13.375	14.030	0.953
86	90/105	11.960	12.720	0.940
87	90/105	12.685	13.002	0.976
88	90/105	13.106	13.566	0.966
89	90/105	13.440	13.782	0.975
90	90/105	13.125	13.472	0.974
91	90/105	15.990	16.586	0.964
92	90/105	15.780	16.266	0.970
93	90/105	17.300	17.690	0.978
94	90/105	14.260	14.502	0.983
95	90/105	12.120	12.454	0.973
96	90/105	12.340	12.472	0.989
97	90/105	12.300	12.432	0.989
MEAN				0.971
STANDARD DEVIATION				±0.018
98	70/90	13.300	13.818	0.963
99	70/90	11.685	12.204	0.957
100	70/90	10.440	10.870	0.960
101	70/90	12.510	13.080	0.956
102	70/90	12.485	13.036	0.958
103	70/90	10.995	11.368	0.967
104	70/90	12.895	13.386	0.963
105	70/90	14.580	15.112	0.965
106	70/90	15.920	16.258	0.979
107	70/90	15.090	15.508	0.973
108	70/90	17.480	17.686	0.988
109	70/90	12.635	12.702	0.995
110	70/90	15.550	15.678	0.992
111	70/90	7.785	8.124	0.958
112	70/90	12.695	13.048	0.973
MEAN				0.970
STANDARD DEVIATION				±0.013

Table 7. Factor necessary to convert the weight of specific processed shrimp products to the weight of completely unprocessed live shrimp immediately prior to being processed.

Product Evaluated	**Study by Inspection Branch**		**Study by Science Branch**	
	n	Conversion Factor	n	Conversion Factor
Processed cooked shrimp for the European market	38	1.038	217	1.048
Processed raw shrimp for the European market	20	1.047	81	1.006
Processed raw shrimp for the industrial market	19	1.052	35	1.016
Processed raw shrimp for the Japanese market	35	0.971	111	1.000

Table 8. Weight of live completely unprocessed shrimp necessary to produce one metric ton of each of the four different types of processed shrimp, investigated during the study by the Inspection Branch.

One Metric ton (2,200 lb) of processed (frozen) Northern Shrimp	**Weight of completely unprocessed shrimp if determined using**	
	Inspection Branch Conversion Factor	Science Branch Conversion Factor
Processed cooked shrimp for European market	1,038 Kg (2,284 lb)	1,048 Kg (2,306 lb)
Processed raw shrimp for European market	1,047 Kg (2,303 lb)	1,006 Kg (2,213 lb)
Processed raw shrimp for industrial market	1,052 Kg (2,314 lb)	1,016 Kg (2,235 lb)
Processed raw shrimp for Japanese market	971 Kg (2,136 lb)	1,000 Kg (2,200 lb)
Total processed product, 4,000 Kg (8,800 lb)	4,108 Kg (9,037 lb)	4,070 Kg (8,954 lb)

Table 9. Relationship between weight of processed shrimp and weight of completely thawed shrimp.

	Processed cooked shrimp for European market	**Processed raw shrimp for Japanese market**
Mean weight change caused by thawing	7.37%	6.15%
Complete range of observed weight change	4.67% - 10.07%	2.20% - 13.08%
Range observed with 85% of the samples	5.55% - 8.62%	2.50% - 9.65%
Weight of completely unprocessed product, if thawing loss was used to convert one metric ton (2200 lb) of processed product	926 Kg (2,038 lb)	939 Kg (2,065 lb)
Weight of completely unprocessed product, if average of Inspection Branch and Science Branch conversion factors (Table 7) was used to convert one metric ton (2200 lb) of processed product	1,043 Kg (2,294 lb)	985 Kg (2,167 lb)

Table 10 - Regression Statistics for Shrimp Product to Unprocessed Weight. Intercept = 0.

1a) Product - Raw **Count = 150+** **Season = Jan. - Apr.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	103,729.54	103,729.54	16,656.94	0.0001
Error	24	149.46	6.23		
Total	25	103,879.0			
	r^2= 0.9986	slope= 1.017	cv= 4.201		

1b) Product - Raw **Count = 150+** **Season = May - Dec.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	29,837.73	29,837.73	42,848.25	0.0001
Error	9	6.27	0.97		
Total	10	29,944.0			
	r^2= 0.9998	slope= 1.011	cv= 1.636		

2a) Product - Raw **Count = 90-150** **Season = Jan. - Apr.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	116,759.36	116,759.36	29,906.91	0.0001
Error	35	136.64	3.90		
Total	36	116,896.0			
	r^2= 0.9988	slope= 1.013	cv= 3.951		

2b) Product - Raw **Count = 90-150** **Season = May - Dec.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	98,689.67	98,689.67	29,898.40	0.0001
Error	41	135.33	3.30		
Total	42	98,825.0			
	r^2= 0.9986	slope= 0.999	cv= 3.968		

3a) Product - Raw **Count = 50-90** **Season = Jan. - Apr.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	125,101.03	125,101.03	78,864.02	0.0001
Error	46	72.97	1.59		
Total	47	125,174.0			
	r^2= 0.9994	slope= 1.0	cv= 2.659		

3b) Product - Raw **Count = 50-90** **Season = May - Dec.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	95,918.12	95,918.12	58,370.35	0.0001
Error	62	101.88	1.64		
Total	63	96,020.0			
	r^2= 0.9989	slope= 1.0	cv= 3.678		

4a) Product - Cooked **Count = 150+** **Season = Jan. - Apr.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	29,329.92	29,329.92	6,229.27	0.0001
Error	10	47.08	4.71		
Total	11	29,377.0			
	r^2=0.9984	slope= 1.059	cv= 4.255		

4b) Product - Cooked **Count = 150+** **Season = Jan. - Apr.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	22,9889.67	22,9889.67	12,620.01	0.0001
Error	9	16.32	1.81		
Total	10	22,906.0			
	r^2=0.9993	slope= 1.067	cv= 2.928		

5a) Product - Cooked **Count = 90-150** **Season = Jan. - Apr.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	506,538.68	506,538.68	100,300.29	0.0001
Error	86	434.32	5.05		
Total	87	506,973.0			
	r^2=0.9991	slope= 1.041	cv= 3.331		

5b) Product - Cooked **Count = 90-150** **Season = May - Dec.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	419,508.12	419,508.12	96,312.91	0.0001
Error	129	561.88	4.36		
Total	130	420,070.0			
	r^2=0.9987	slope= 1.053	cv= 4.025		

6a) Product - Cooked **Count = 50-90** **Season = Jan. - Apr.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	26,896.35	26,896.35	7,638.64	0.0001
Error	7	24.65	3.52		
Total	8	26921.0			
	r^2=0.9991	slope= 1.069	cv= 3.583		

6b) Product - Cooked **Count = 50-90** **Season = May - Dec.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	54,330.41	54,330.41	23,973.56	0.0001
Error	21	47.59	2.27		
Total	22	54,378.0			
	r^2=0.9991	slope= 1.031	cv= 3.136		

7) Product - Raw **Count = 150+** **Season = All Months.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	52,218.88	52,218.88	16,290.14	0.0001
Error	20	64.11	3.21		
Total	21	52,283.0			
	r^2=0.9988	slope= 1.063	cv= 3.683		

8) Product - Raw **Count = 90-150** **Season = All Months.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	926,014.77	926,014.77	194,527.71	0.0001
Error	216	1,028.23	4.76		
Total	217	927,043.0			
	r^2=0.9989	slope= 1.046	cv= 3.755		

9) Product - Raw **Count = 50-90** **Season = All Months.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	81,203.49	81,203.49	24,656.15	0.0001
Error	29	95.51	3.29		
Total	30	81,299.0			
	r^2=0.9988	slope= 1.043	cv= 3.691		

10) Product - Cooked **Count = 150+** **Season = All Months.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	133,566.50	133,566.50	29,017.73	0.0001
Error	34	156.50	4.60		
Total	35	133,723.0			
	r^2=0.9988	slope= 1.016	cv= 3.764		

11) Product - Cooked **Count = 90-150** **Season = All Months.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	215,436.07	215,436.07	58,219.64	0.0001
Error	77	284.93	3.70		
Total	78	215,721.0			
	r^2=0.9987	slope= 1.006	cv= 4.030		

12) Product - Cooked **Count = 50-90** **Season = All Months.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	221.019.13	221,019.13	137,764.02	0.001
Error	109	174.87	1.60		
Total	110	221,194.0			
	r^2=0.9992	slope= 1.0	cv= 3.151		

13) Product - Cooked **Count = Mixed** **Season = All Months.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	40,098.58	40,098.58	14,624.66	0.0001
Error	10	27.42	2.74		
Total	11	40,126.0			
	r^2=0.9993	slope= 1.063	cv= 2.891		

14) Product - Raw **Count = All** **Season = All Months.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	578,480.45	578,480.45	204,739.71	0.0001
Error	226	638.55	2.83		
Total	227	579,119.0			
	r^2=0.9989	slope= 1.006	cv= 3.698		

15) Product - Cooked **Count = All** **Season = All Months.**

Source of Variation	DF	Sum of Squares	Mean Square	F Value	P-Value
Model	1	1,099,499.54	1,099,499.54	244,242.93	0.0001
Error	278	1251.46	4.50		
Total	279	1,100,751.0			
	r^2=0.9989	slope= 1.048	cv= 3.762		

Table 11 - Product to Whole Weight Conversion Factors for Selected Shrimp Products as Determined by Experiments from Sea Production. Experiments were performed by fishery observers. All Products are Frozen.

Product Form	Shrimp[1] Count	Market Description	Freezing Process	Season	Conversion Factor	Percent Yield	Number of Experiments	Average[2] Sample Size
Raw	150+	Industrial	Either	Jan-Apr	1.017	98.3	25	59
		Industrial	Either	May-Dec	1.011	97.9	10	54
				All Months	1.016	98.2	35	56
Raw	90-150	European	Blast	Jan-Apr	1.013	98.7	36	50
		European	Blast	May-Dec	0.999	100.1	45	48
				All Months	1.006	99.4	81	49
Raw	50-90	Japanese	Plate	Jan-Apr	1.000	100.0	47	47
		Japanese	Plate	May-Dec	1.000	100.0	64	36
				All Months	1.000	100.0	111	42
Raw		**All**	**All**	**All Months**	**1.006**	**99.3**	**227**	**49**
Cooked	150+	Industrial	Blast	Jan-Apr	1.059	94.4	11	51
		Industrial	Blast	May-Dec	1.067	93.7	10	46
				All Months	1.063	94.1	21	49
Cooked	90-150	European	Blast	Jan-Apr	1.041	96.1	130	52
		European	Blast	May-Dec	1.053	95.0	87	68
				All Months	1.046	95.6	218	60
Cooked	50-90	Japanese	Blast	Jan-Apr	1.069	93.5	8	52
		Japanese	Blast	May-Dec	1.031	97.0	22	47
				All Months	1.043	96.4	30	50
Cooked	Mixed	Mixed	Blast	Jan-Apr	1.063	94.1	10	56
Cooked	**All**	**All**	**Blast**	**All Months**	**1.048**	**95.4**	**268**	**53**

[1] Shrimp count is expressed in number of shrimp per kilogram. Counts may represent more than one product.
[2] Sample size is expressed in kg.

Table 12 - Analysis of covariance showing the main effects, Shrimp size category and season for cooked and raw products separately. Interaction terms were not significant.

Product = **Raw Frozen**, r^2=0.995671

Source	DF	Type I SS	F value	PR > F	DF	Type III SS	F Value	PR > F
Product Weight	1	572765.47	50127.79	0.0	1	93767.68	8206.39	0.0
Size Category	3	135.02	3.94	0.0092	2	78.03	3.41	0.0347
Season	1	43.45	3.80	0.0525	1	43.45	3.80	0.0525

Product = **Raw Frozen**, r^2=0.995671

Source	DF	Type I SS	F value	PR > F	DF	Type III SS	F Value	PR > F
Product Weight	1	572765.47	49494.13	0.0	1	97582.64	8432.37	0.0
Size Category	3	135.02	3.89	0.0098	2	135.02	3.89	0.01

Product = **Cooked**, r^2=0.997754

Source	DF	Type I SS	F value	PR > F	DF	Type III SS	F Value	PR > F
Product Weight	1	1061308.89	99999.99	0.0	1	190891.34	21007.57	0.0
Size Category	3	260.22	9.55	0.0001	2	75.62	4.16	0.0166
Season	1	0.05	0.01	0.9403	1	0.05	0.01	0.9403

Product = **Cooked**, r^2=0.997754

Source	DF	Type I SS	F value	PR > F	DF	Type III SS	F Value	PR > F
Product Weight	1	1061308.89	99999.99	0.0	1	202452.77	22364.14	0.0
Size Category	3	260.22	9.58	0.0001	2	260.22	9.58	0.0001