

# Studies in **MARINE ECONOMICS**

## Relationship of Shrimp Body Width and Weight to Mechanical Sizing



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### INTRODUCTION

The relationship considered here of shrimp body width and weight has a direct bearing upon the development of more effective methods of processing the product of the expanding shrimp industry.

Landing of pink shrimp (*Pandalus jordani*) in Oregon has increased over a period of 10 years from nearly one million pounds per season to over 10 million pounds. Thus far the market for shrimp has expanded with the increased production. Oregon, as one of the Pacific coast states, has the capacity for further growth. Studies reported by the Bureau of Commercial Fisheries note that California, Oregon, and Washington have a potential annual output of 33.1 million pounds of shrimp within the limits of the Continental Shelf, compared to a present production of 18.5 million pounds.<sup>1</sup>

A system engineering study of processing fresh shrimp revealed that hand picking shrimp to remove the body meat from the head and shell diminishes in efficiency as shrimp size becomes smaller.<sup>2</sup> From motion picture film analysis it was determined that an average cycle time for picking a shrimp was 1.46 seconds. Hence, the labor costs

for picking shrimp would be high for small shrimp that yield little meat and more favorable for the higher yield of larger shrimp. Large, whole shrimp weighing 5.8 grams yielded body meat at a picking labor cost of 26¢ per pound. Corresponding labor costs of 1.7 gram shrimp are \$1.18 per pound and \$2.50 per pound for 0.8 gram shrimp. For small shrimp the picking cost alone exceeds the sale price of the product.

Ideally, shrimp too small for economic handling would be left in the ocean to grow larger. This would require selective harvesting equipment which is unavailable at this time. However, the idea of separation by net design is being developed by the Bureau of Commercial Fisheries to keep undesirable fish out of the shrimp catch.<sup>3</sup>

Pending development of escapement nets, effort could be directed to solving the technical problems related to placing sizing equipment on board the trawlers. Sizing on the vessel would permit more effective use of storage space on the occasional trips when capacity catches are available. Such a practice would not aid conservation through the release of small live shrimp, as in below-surface separation, since experience shows most of the shrimp are dead by the time the net is emptied. Many sizing units, each subject to limited use, would be required to equip the numerous trawlers that deliver to relatively few receiving plants. In contrast, sizing at the plants would require fewer, but higher-capacity, sizers that would be subject to more intensive use.

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<sup>1</sup> Donald P. Cleary, Demand and Price Structure for Shrimp, Working Paper No. 15, Bureau of Commercial Fisheries, Division of Economic Research, June 1969, page 11.

<sup>2</sup> William Engesser, Design of a Complete Shrimp System, Industrial Engineering, March 1970, Vol. 2, No. 3, page 24.

<sup>3</sup> High, William L., Ian E. Ellis, and Larry D. Lufz, A Progress Report on the Development of a Shrimp Trawl to Separate Shrimp from Fish and Bottom Dwelling Animals, Commercial Fisheries Review, March 1969, Vol. 31, No. 3.

Currently, separation by size and the attendant management options of product use appear most feasible at the processing plant. With the introduction of in-plant separation, larger shrimp could be isolated for hand picking and packing as a premium product when justified by a price advantage. Smaller sizes, costly to hand pick, could be diverted to mechanical picking. Still smaller sizes may be more effectively marketed as bait for sports fishermen, prepared as a by-product, or disposed of if no advantage is gained through added processing costs. Also, mechanical separation at the processing plant would aid in the elimination of damaged shrimp and trash smaller than the controlled dimension, thus reducing visual inspection and handling in subsequent operations.

Separation, in order to be effective, must be capable of recognizing shrimp by size individually and in quantity to match processing capacities of up to several thousand pounds of raw whole shrimp per hour. Weight, though an appropriate indication of size, would be difficult to determine mechanically for the volumes required. Likewise, length would be a difficult measure of size since the structure of a shrimp allows longitudinal flexibility and unless forcedly straightened out, its true length cannot be determined.

The width of a shrimp, if correlated with weight, would be a convenient dimension to govern separation since the widest part of the crustacean occurs between the side shields of the carapace. This exterior skeletal region covering the front part of the crustacean has firm dimensional stability at the point of measurement illustrated in Figure 1. The carapace width would govern which shrimp would pass through or be retained by an opening with parallel sides a given distance apart. At this part of the body there are no appendages to interfere with the dimension.

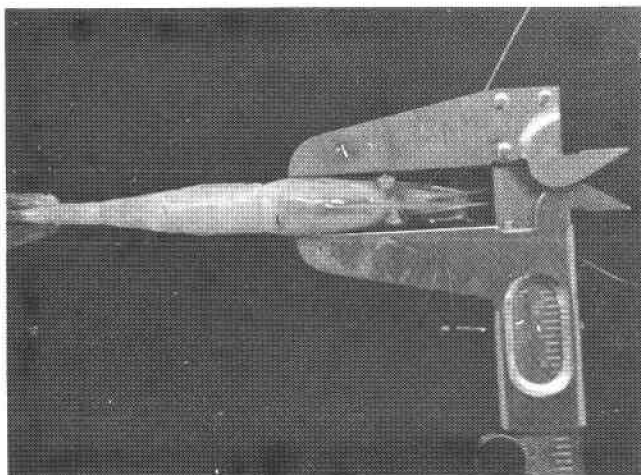


Figure 1. For the test correlating weight and width the shrimp were measured, as shown, with a vernier caliper at the widest point.

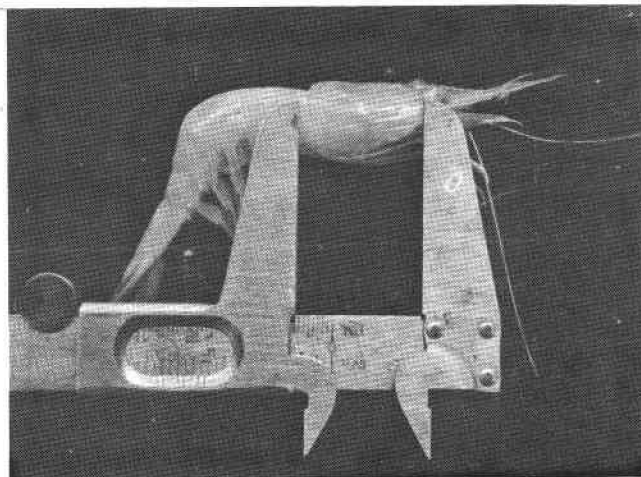


Figure 2. Earlier tests of shrimp characteristics measured carapace length from the base of the eye stock to the dorsal posterior part as illustrated.

Research has been reported in which carapace lengths, as shown in Figure 2, were measured from the indentation on the carapace at the base of the eye stock to the dorsal posterior part of the carapace.<sup>4,5</sup> These studies provide positive graphic demonstration that carapace length is related directly to the age, sex, mean total length, and total weight of shrimp, including the Oregon pink shrimp (*Pandalus Jordani*). From the results it may be concluded that carapace length could be used to distinguish shrimp size in terms of weight. Carapace length, however, is a measure that cannot be readily sensed by mechanical means for use in commercial processing.

For the benefit of shrimp processing system designers, plant managers, and equipment builders, a brief study was designed to determine the nature of the relationship between width and weight of shrimp.

## PROCEDURE

On three occasions during the summer of 1969, samples of pink shrimp were obtained at the receiving station of a seafood processing plant. A sample of shrimp was drawn from among several of the wood boxes in which the iced shrimp arrived. A tied plastic bag containing the sample was iced and immediately brought to Oregon State University where a sub-sample was randomly drawn and measurements were made for each

<sup>4</sup> Ronholt, L. L. and A. R. Magill, Biological Observations and Results of the 1960 John N. Cobb Exploratory Shrimp Cruise Off the Central Oregon Coast, Fish Commission, Oregon Research Briefs, 1961, 8(1:31-46).

<sup>5</sup> Butler, T. H., Growth, Reproduction, and Distribution of Pandalid Shrimps in British Columbia, Journal of the Fisheries Research Board of Canada, Vol. 21, No. 6, November 1964.

shrimp within that sample. Width and weight measurements were made respectively in centimeters and grams. In both cases measurements were recorded to the hundredth decimal place.

Upon completion of each sample's measurement, a linear regression analysis was performed using the stepwise regression program available at the Oregon State University computer center.

After completing regression analyses for each of the three samples of shrimp, it was statistically determined that no significant difference existed between either the means of weight or the means of width for each respective sample. Justified by close agreement of the characteristics of the samples, an overall regression equation was calculated by combining all three samples into one sample of 517 observations.

## RESULTS

From the observations and regression analysis, the following predictive equation was derived so that width was dependent upon variation in weight, that is  $\text{width} = f(\text{weight})$ .

Width in centimeters =  $0.6310 + 0.0818$

(Weight in grams)

This approach, rather than the reverse condition of  $\text{weight} = f(\text{width})$ , was selected because a mechanical separator would be capable of distinguishing only width. Its adjustment, therefore,

would be dependent upon a selection of weight governed by market or processing circumstances. From a known weight it is then possible, through use of the regression equation or its representative graph, to determine the width that would make the desired division of product by weight.

Table 1. Regression analysis summary for the relationship of shrimp body width to weight for the combination of three samples of shrimp with a resulting sample size of  $n = 517$ . Weight limits were from a minimum of 1.18 grams to a maximum of 9.85 grams for whole shrimp.

Weight=G	Mean G	Std. Error	$R^2$	F-Level
Width=C	Mean C	Std. Error		
G in gm.	5.55	1.72	0.7660	1685.93
C in cm.	1.09	0.16		

As shown further in Table 1, the above equation explains 76.60% of the variation of width when regressed on weight and is highly significant at the F-level shown. For purposes of practical application, the equation may be used with 99% confidence in a predictive capacity within the limits of the measurements from which the equation was derived. A graphic expression of the equation is shown in Figure 3. From the graph it may be seen that shrimp below 4.00 grams in weight would fall

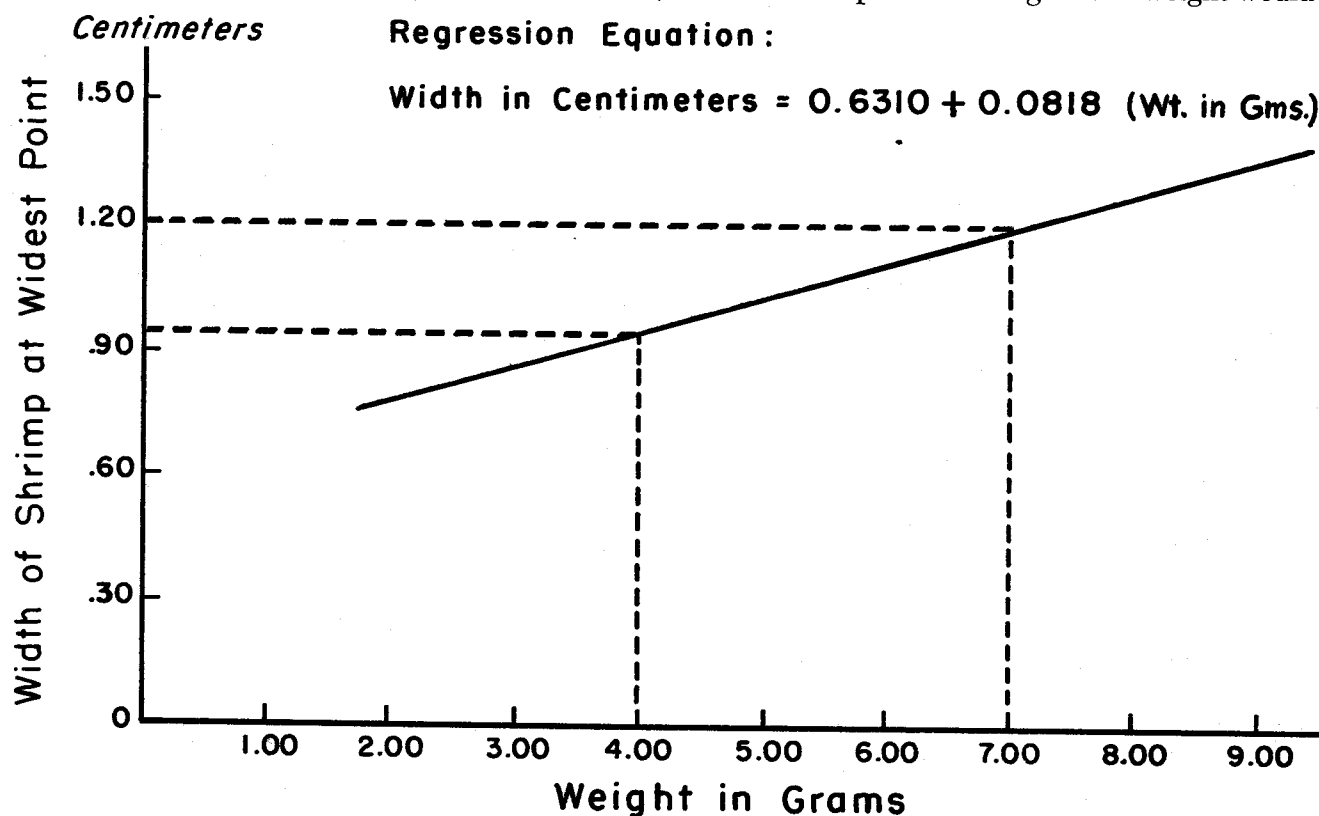


Figure 3. Relationship of shrimp width at widest point in centimeters to weight in grams. The regression equation results from pooling data from three samples with 517 total observations.

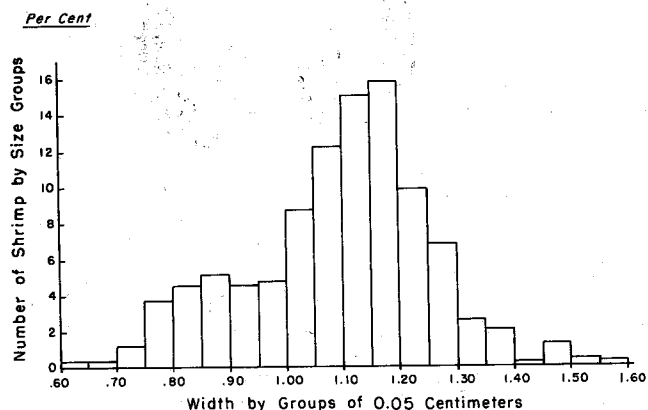


Figure 4. This histogram shows the percent of shrimp in the sample that are present in increment of 0.05 centimeters of increasing width.

through a gap that is 0.96 centimeters in width, thus separating them from shrimp that are wider and in turn heavier.

The percent occurrence of shrimp for each increasing increment of .05 centimeters in width has been plotted to construct a series of bars on a chart shown in Figure 4. A near normal distribution is revealed by the resulting histogram. The chart for this sample reveals very few shrimp of width below 0.70 centimeters or above 1.50 centimeters. The greatest number of shrimp, almost 16%, are in the size group from 1.15 centimeters to 1.20 centimeters wide.

A more convenient expression of the data for use by equipment designers and processing plant operators is developed in Figure 5 to show the total percent of shrimp included up to a selected width. For this test data it can be illustrated with the aid of the graph that the elimination of shrimp below 1.00 centimeters in width would include 25% of the product.

Percent of shrimp related to weight also can be determined. For example, if an order requires

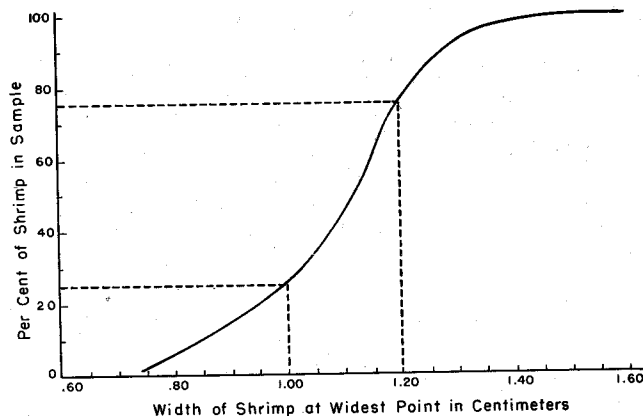


Figure 5. For the sample available this curve shows the quantity of shrimp that are included below a given width.

whole shrimp with a minimum weight of 7.0 grams, these shrimp, as revealed in Figure 3, would have to be at least 1.20 centimeters in width based on the sample analyzed in this study. Referring back to Figure 5, shrimp up to 1.20 centimeters in width involves 76% of the product, so the remaining 24% would qualify for the order of 7-gram minimum weight shrimp.

## SUMMARY

Statistical analysis of physical measurements of shrimp has shown that a predictable relationship, which can be applied with confidence, exists between the width and weight of shrimp. Such knowledge can be of practical use in the design of mechanical handling and processing equipment, particularly that which can separate shrimp by weight employing the correlated width. For management, this ability increases the opportunities for processing system improvement and extends, through sizing the possible development of products more adaptable to the market.