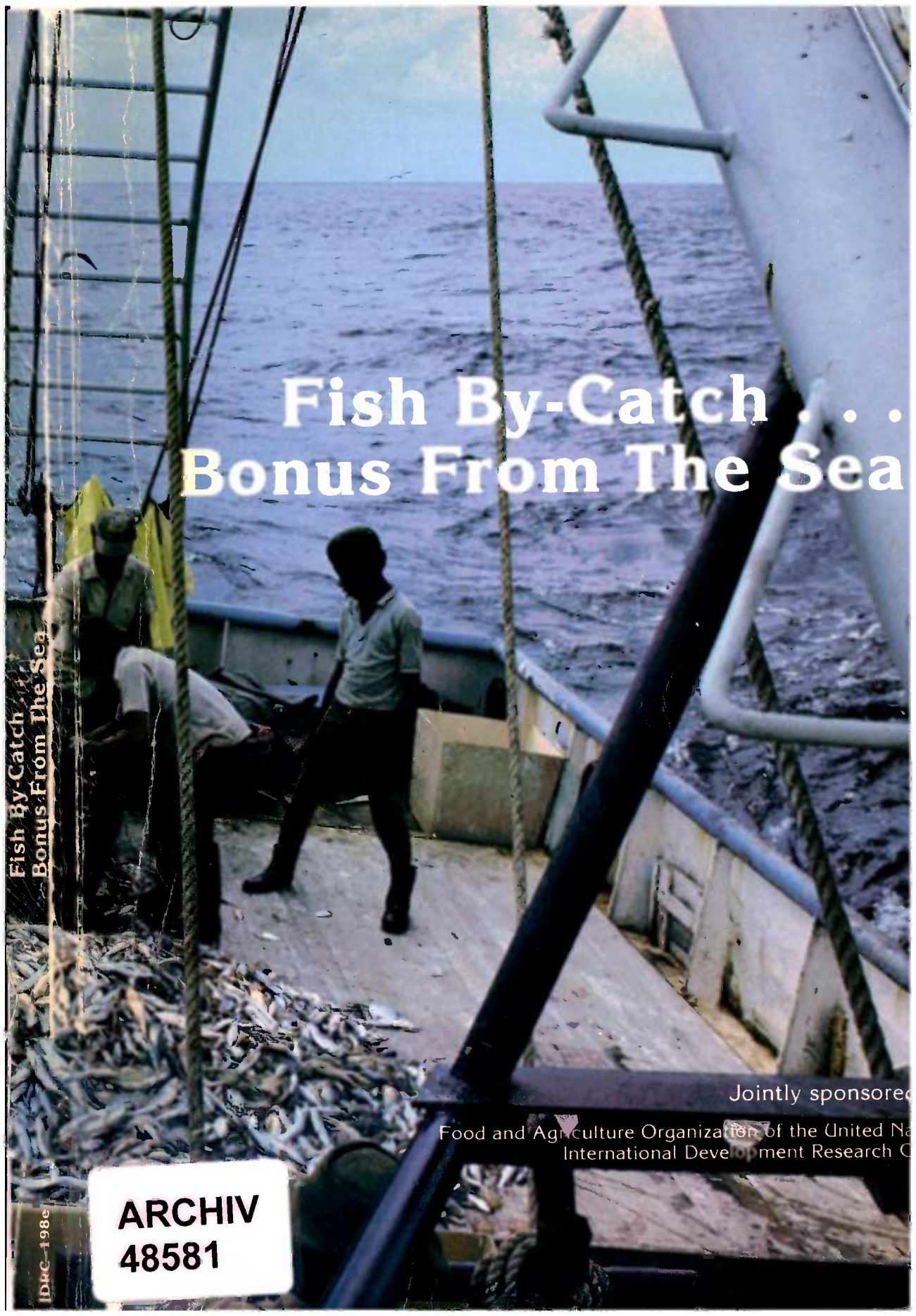

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Optimization of Processing of Three Underutilized Fish Species

John W. Brown and Melvin E. Waters *U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Center, Charleston Laboratory, Charleston, South Carolina, USA*

*Spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogon undulatus*), and weakfish (*Cynoscion regalis*) are commonly found in the by-catch of shrimp operations in the waters off the coast of the southeastern United States. The economics of preparing these three species whole, deboned (minced), and filleted (both with and without the skin) are evaluated. The product yield for each stage of the process and the mechanical difficulties encountered are included. Results are expressed in diagrammatic form so that the product that maximizes profit for a given set of input–output prices is indicated.*

During the past few years, the Charleston Laboratory of the Southeast Fisheries Center has been investigating the mechanical processing of spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogon undulatus*), and weakfish, also known as gray seatrout (*Cynoscion regalis*). In the United States, these species are considered to be underutilized, although each is sought as part of a directed effort. For instance, croaker are caught as part of the mixed-species groundfish fishery for petfood in the Gulf of Mexico.

These three species are also an important part of the shrimp by-catch. Together, they compose more than 50% of the by-catch by weight in the Carolinas and Georgia. Spot accounts for roughly 39% of the by-catch in North Carolina, 40.2% in South Carolina, and 28.0% in Georgia. Croaker accounts for 24% by weight of the North Carolina by-catch, 9% of South Carolina's, and 21% of Georgia's. Weakfish accounts for 4%, 3%, and 7% of the by-catch, for North Carolina, South Carolina, and Georgia, respectively. The utilization of spot and croaker between 1973 and 1975 was less than 1% by weight of the by-catch in South Carolina and Georgia (Keiser 1977b).

When landed, these fish normally move through the marketing channels whole, and, only when they reach the retail market, are they headed and gutted or filleted. Exactly why this method of marketing has evolved is uncertain, but two reasons can be suggested. First, the low value and small size of the fish make hand processing uneconomic except for the retailer who can charge for the entire round weight of the fish and sometimes extra for processing. Second, purchasing whole fish is preferred by the customers so they can better judge the quality of the product (Pariser and Hammerle 1966).

We believe the economic feasibility of introducing mechanization into the processing of the three species deserves to be explored. Thus, we applied linear programing to laboratory data on yields from mechanical processing. The focus of the mathematical models was limited to fish preparation.

Experimental Procedures

Fresh fish packed in ice were obtained during 1979–81 from a commercial seafood dealer in North Carolina. For each of three sampling periods, about 68 kg of each species were obtained on the dock, iced, and transported to the Charleston Laboratory for processing. The fish had been harvested off the coast near Morehead City, North Carolina, 36–48 hours earlier. They were selected at random and represented the total catch.

The fish were graded by weight into various categories as a means to maximize efficiency in mechanical processing. Croaker were sized as small (<0.23 kg), medium (0.23–0.45 kg), and large (>0.45 kg); weakfish were sized as small (<0.34 kg) and medium (0.34–0.68 kg). Spot were not sized, as they averaged about 0.15 kg. The size ranges of the fish used in this work are not truly representative of the size

ranges of these species as they are found in the South Carolina shrimp by-catch, where the average weight of the three species is: croaker 0.02 kg, spot 0.04 kg, and weakfish 0.02 kg (Keiser 1976). The differences in size occurred because the fish were purchased through commercial market channels. The analysis presented in this paper focuses on the fish that are larger than standard by-catch species and yet too small to merit a premium price in the market.

The yields were calculated as a percentage of the weight of the whole fish. The spot skinless fillets were skinned and filleted by hand, whereas we used mechanical equipment for all other processing (Fig. 1 and 2). The equipment comprised a Simard[1] scaler, Lapine machines for heading, gutting, and filleting, a Bibun flesh-and-bone separator, and an Arenco fillet skinner. The yields were determined by the weight of fish before and after each step (Table 1). Other equipment on the market may be more effective and can process larger fish than that used in this work.

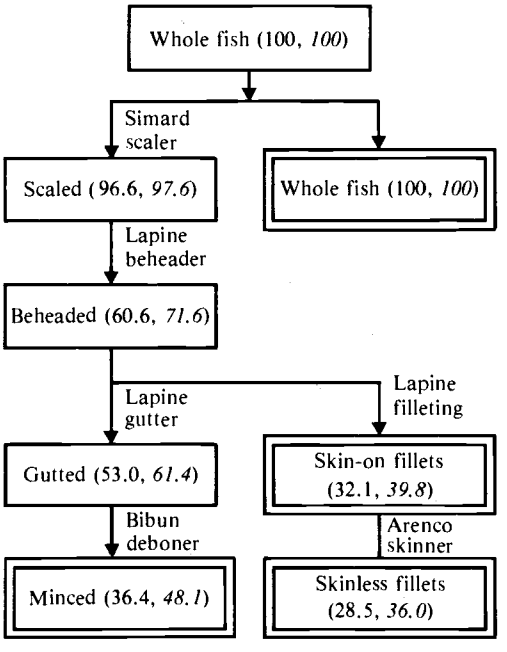

Fig. 1. *Processing of weakfish and croaker; yields appear in parentheses (those for weakfish are italicized). End-products are double boxed.*

[1]Use of trade names or products does not imply endorsement by the U.S. Department of Commerce.

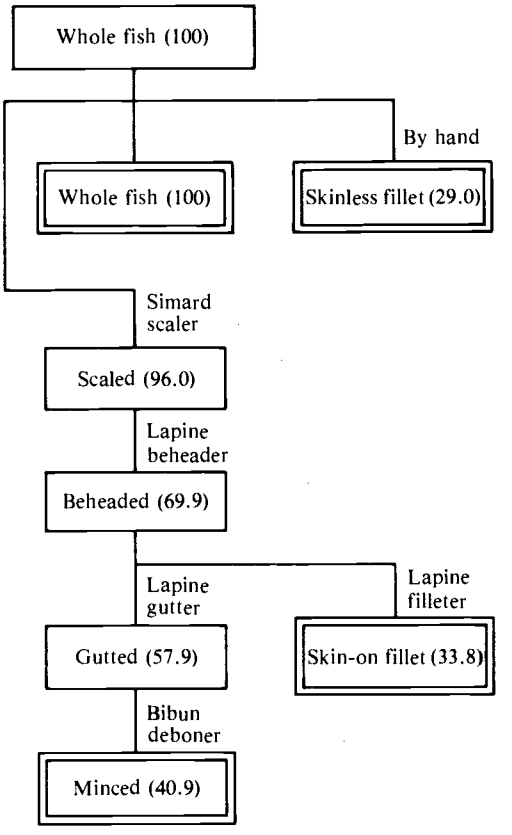

Fig. 2. *Processing of spot; yields appear in parentheses. End-products are double boxed.*

The equipment had been designed to process underutilized species indigenous to the southeastern United States. The scaler was designed to process fish weighing between 0.1 kg and about 1.4 kg and required only minimal adjustments to accommodate various-sized fish.

The beheader required only minor adjustments once it was set for a particular species, although configuration of the fish dictated positioning of the cutting blade to prevent excessive removal of flesh with the head. Variations in size of the fish seemed to make little difference in the beheader's performance. The maximum-sized fish it could handle was about a 1-kg croaker and a 1.4-kg weakfish.

The gutter was designed for fish from about 0.1 kg up to 1.4 kg. Some postprocess cleaning of the fish was required for removal of small amounts of viscera, kidney, and blood near the backbone.

Table 1. Processing yields (%) by species and size.

Species, size	Weight (kg)	Scaled	Headed	Gutted	Skin-on	Skinless	Minced
Weakfish							
Small	0.25	98.0	71.5	61.7	37.0	33.0	49.0
Medium	0.46	97.3	71.7	61.1	42.6	38.9	47.2
Average	0.35	97.6	71.6	61.4	39.8	36.0	48.1
Croaker							
Small	0.16	96.9	60.7	52.4	30.2	25.9	35.3
Medium	0.31	96.7	61.3	53.2	33.9	30.7	37.1
Large	0.61	96.1	59.1	53.2	32.2	29.0	36.9
Average	0.36	96.6	60.6	53.0	32.1	28.5	36.4
Spot	0.15	96.0	69.9	57.9	33.8	29.0[a]	39.2

[a]Cut by hand.

The filleter handled croaker up to about 0.45 kg and weakfish up to about 2 kg. Sizing of the fish within fairly narrow limits was necessary with the filleter because of its two vertical rotating blades that are adjusted to the width of the backbone. Even with readjustments for various-sized fish, the filleter did an incomplete job of removing the rib bones, and some hand trimming was necessary.

The fillet skinner did a poor job on soft-textured fillets but, when the fillets were chilled, complete removal of the skin without mutilation of the flesh was obtained.

The flesh-and-bone separator was not limited by the size of the fish and performed well. It was easy to clean and sanitize. Maintenance and breakdown were minimal under our light schedule of use.

Linear Programing Models

The three linear programing models developed for our analysis were based on the processing activities and do not include steps before processing (such as unloading the fishing vessels and sorting the fish) or after (such as packing and icing or freezing the product for shipment), even though these steps mean additional costs for the processor. Thus, the output prices used in the model represent a partial cost for the processor. Working backward from the wholesale price for the final market form, one would have to subtract these additional costs to determine the partial costs used in the models.

The linear programs chose the most profitable alternative, taking into consideration the product's yield, input requirements, and input and output prices. The programs do this by maximizing a linear equation for profit. Profit is a function of the level (amount) of a series of activities, such as selling mince or buying processing equipment time. The level of an activity multiplied by its unit revenue (or cost) determines its contribution to profit (Hillier and Lieberman 1974).

We assumed production costs to be $4.50/hour for machine-operator labour and $3.60/hour for hand labour. Trout is purchased for $0.99/kg exvessel, spot for $0.55/kg, and croaker for $0.88/kg. The machinery costs were calculated on a bond-financing basis at a 15% interest rate for 7 years. The yearly payment was divided by the number of days of operation — assumed to be 200. On the basis of these assumptions, the model determined the number of hours of daily use for each machine; the hourly costs were then determined and inserted into the model for the final estimation of costs.

The material-balance coefficients were experimentally determined; they indicated the weight of an intermediate product that would be used by a processing step to make 1 kg of its product. As an example, it takes 1.035 kg of whole croaker to make 1 kg of scaled rounds. We calculated this figure by taking the ratio of the percentage yield of the previous stage to that of the current stage (i.e., 100%/96.6% = 1.035). These coefficients were also multiplicative among the steps of a process. For example, it takes 1.886 kg of whole croaker to produce 1 kg of gutted rounds (i.e., 1.035 × 1.594 × 1.142 = 1.886, or 100%/53%).

The coefficients for machine and labour use were calculated from the manufacturers' specifications; they indicated the hours of machine or labour time necessary to produce 1 kg of product. The restrictions forced the amount of input purchased equal to the

amount used. In scaling croaker, for example, the scaler was rated at 2400 fish/hour, so that in 1 hour 788 kg of scaled rounds could be produced (2400 fish × 0.34 kg/fish × 0.996 kg of scaled rounds per kg of whole fish). This would be 0.00127 hour/kg of product. The final restriction in the models limited the amount of whole fish purchased to 4545 kg/day.

Results

The results (Fig. 3) showed the range of output prices for which producing each of the products (whole fish, mince, and fillets) would maximize profits. They indicated that a profit can be made from producing a minced product or fillet but that more profit can be made from selling the fish whole when there is a market for that product form. For example, when whole weakfish can be sold for \$1.76/kg, the minced product must be sold for better than \$3.71/kg, or the skinless fillets must be sold for better than \$4.99/kg, to increase profits by producing these items.

However, the whole-fish selling price is relevant for the calculations of opportunity cost for the minced or filleted forms only as long as one can actually sell all of the available fish whole at this price. Because the opportunity cost represents the difference between using an input in the most profitable way and using it another way, it is equal to zero when there is a surplus of fish or when the fish are too small for the market. The relevant costs are then only the actual purchase price of the fish and the machinery and labour costs.

The cost of cutting the fish into fillets was calculated from the models, and the amount was shown to decrease markedly as the numbers of fish, processed per day, increased (Fig. 4). The reason is that machinery and cleanup-time costs are spread over the larger quantities of fish. The minimum level of daily output required to bring the cutting costs below

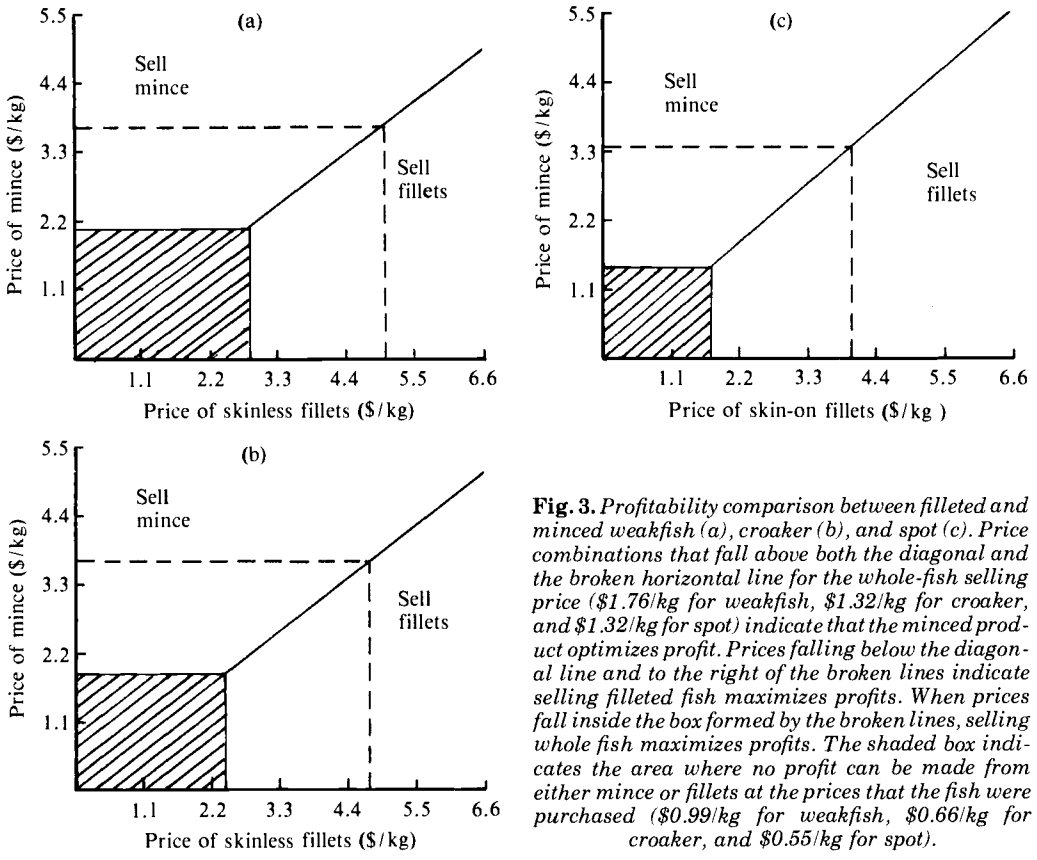

Fig. 3. *Profitability comparison between filleted and minced weakfish (a), croaker (b), and spot (c). Price combinations that fall above both the diagonal and the broken horizontal line for the whole-fish selling price (\$1.76/kg for weakfish, \$1.32/kg for croaker, and \$1.32/kg for spot) indicate that the minced product optimizes profit. Prices falling below the diagonal line and to the right of the broken lines indicate selling filleted fish maximizes profits. When prices fall inside the box formed by the broken lines, selling whole fish maximizes profits. The shaded box indicates the area where no profit can be made from either mince or fillets at the prices that the fish were purchased (\$0.99/kg for weakfish, \$0.66/kg for croaker, and \$0.55/kg for spot).*

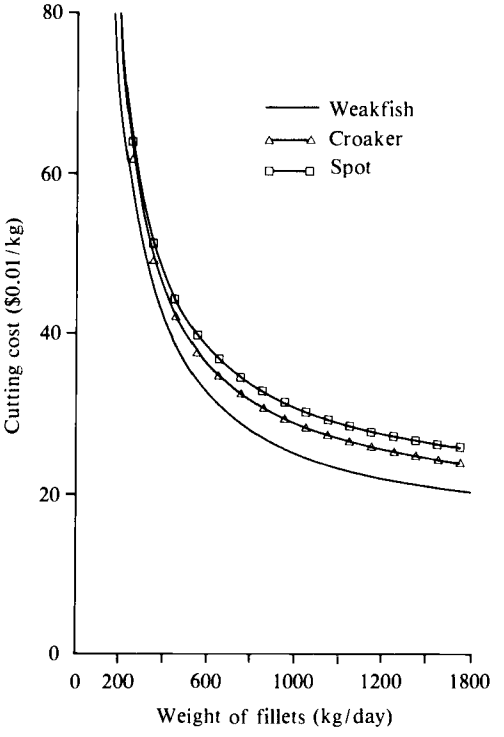

Fig. 4. *Cutting cost for weakfish and croaker skinless fillets and for spot skin-on fillets.*

that of a hand-cutting operation, can be determined from the results. For example, if hand cutting weakfish currently costs $0.30/kg, then at least 1000 kg/day of fillets would have to be produced to justify mechanization. The assumptions underlying the cutting-cost calculations were that machinery cleanup would take 8 person-hours/day; that 8 people would be working the processing line; and that labour costs would be $4.50/hour. Other assumptions were that equipment costs and the number of days of use would be the same as for calculations of process superiority. This approach assumed that the yields would be the same for both hand and machine filleting.

Two facts that have not been embraced by our models are that solid waste produced by mechanical processing of the fish is substantially larger than that incurred when fish are sold whole and that, in the filleting of fish, one has another attractive option — mechanically deboning the frames.

Discussion

We have shown that the mechanization of either filleting or mincing fish will be profitable if several conditions are met. First, there has to be a surplus of raw material, either because of overabundance or because the fish are too small for the whole-fish market. For the shrimp by-catch, this would normally be those fish larger than the minimum required by the machinery and smaller than the minimum for the market. The shrimper must also be able and willing to sort, hold, and land fish of this size. Second, there has to be a market for the product. Someone has to be willing to purchase a minced product or very small fillets made from one of these three species. To date, market acceptance has not been demonstrated for the products from these species. Third, the catch mix must be such that reasonably long production runs can be made without readjustment of the machinery. Fourth, these conditions must exist for a sufficient number of days of the year so that the capital costs of the machinery can be reasonably amortized.

We have not tried to define exact parameters for the above conditions, because they will vary greatly with locale. But we have chosen to outline them so that they can be examined when an investment decision is being considered. The technique of linear programing has been shown to be useful, when combined with experimental processing data, in the determination of the factors necessary to initiate a successfully mechanized facility for processing the shrimp by-catch.