Fish By-Catch . . . Bonus From The Sea
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Fish By-Catch... Bonus from the Sea

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I intend to identify the major problems that, in my opinion, require solution and to focus on possible approaches to solving these problems, indicating solutions that have been successfully tested or that have been suggested for implementation. I will concentrate my remarks primarily upon suggestions that can be implemented on board the existing shrimping vessels. I believe the present problem — the waste in shrimp by-catch — far transcends in importance the needs of the shrimping industry. It needs a systems approach for its rational approach and resolution.

The urgency of the economic, energy, and food situation, worldwide, makes it imperative to devise means to reduce food loss and willful waste in both developing and fully industrialized countries. According to the U.S. Comptroller General, 20% of all the food grown in my country is lost. The reasons for waste are many, often firmly based upon long-standing systems of custom and belief, and it is usually easier to increase food production than to reduce waste.

Identification of Problems

The question is how to use, more efficiently and economically for human consumption, one of the by-products of the shrimp fishery, the by-catch, which constitutes a variable multiple in weight of the major harvest — the shrimp itself. If one is to consider the utilization of as great a proportion as possible of the by-catch for human food, it becomes necessary to look at the whole sequence of activities from harvest to consumer and address the problems that are being encountered at every step.

Solution of many of the problems is by no means important only today but will, in my view, become much more crucial in the future, when near-shore shrimp stocks will have dwindled, the shrimp will have moved farther away, and an even greater energy input will be required in harvest; energy prices are most likely to have become even more exorbitant, and the resource now called by-catch will have become the major — perhaps the sole — harvest required to feed hungry mouths everywhere. I predict, therefore, that the shrimp catch, a profitable luxury in industrialized countries today, will become scarcer — and perhaps generally unaffordable — and that the problem of efficiently utilizing the mixed-species by-catch will become the most important concern of fishing fleets here and elsewhere.

What, then, is the sequence of activities that we as experts in the field have to look at, the attending problems encountered at different stages, and the solutions or suggested strategies for developing appropriate answers to these problems?

It appears universally accepted that, because of the overall lifestyle of the shrimp, the method by which this resource is harvested today leads to the landing of hauls that consist of a large and variable composition of animal species within which shrimps represent only a relatively small, albeit most valuable, part. The shrimp, therefore, have to be separated from the rest of the catch by labour-intensive means on board, the by-catch — itself comprising many species — being tossed overboard.

The questions, here, are: Can shrimp and nonshrimp components be separated less expensively, more efficiently than is done now, and perhaps automatically, in the water or on board? Can separation be extended to the sorting of the fish species in the by-catch? The valuable shrimp catch is preserved (frozen or packed in ice) on board, and preservation would also be necessary for the nonshrimp component if it were to be used for human consumption.

The questions, here, are: What methods are available today that will, at the smallest expense, make it possible to preserve the by-catch for the longest possible time, either gutted or ungutted? What is known about the
storage conditions appropriate to preserve the
different by-catch species?

In processing of the by-catch, the questions
are: Whereas the frozen shrimp may be land-
ed heads-on or heads-off, what processing
steps for the by-catch can be performed
efficiently and economically on board the
shrimping vessel before the by-catch is fur-
ther preserved and landed? What methods are
available for processing the fish on land to
enhance the by-catch value significantly? In
particular, and most importantly, what are
the techniques that are available for process-
ing the usually large proportions of small
fish present in the by-catch?

The shrimp harvest commands a known
market price and represents almost hard cur-
rency by itself. Consisting of an unknown
mixture of species of various sizes, the by-
catch, in contrast, has an unknown market
value.

The question, here, is: What are the
economic considerations that must be taken
into account if the treatment of the by-catch is
to be economically attractive?

The acceptability of shrimp and the
marketing strategies for disposing of the
shrimp catch are about as unequivocal and
clearcut as those of any other single commodi-
ty — salmon, glycerol, petroleum, etc. — of
international trade. This, however, is by no
means the case for the by-catch, as a bag of
mixed species or as single species.

Question: What are the acceptability char-
acteristics of the by-catch components in
different countries, for different populations,
i.e., for different species of fish, differently
processed and presented to the consumer as
different end-products?

Possible Approaches to Answers

A few approaches have recently been sug-
gested as means to answer some of these ques-
tions and may have promise for easy and
sometimes inexpensive adaptation to local
conditions. To these, I wish to add my own
recommendations.

Harvest and sorting of catch

As pointed out by Sternin and Allsopp in
this volume, a number of selective fishing
methods and gears have been proposed and
developed; some have been tested with results
that promise to reduce significantly the pro-
portion of by-catch during the shrimping op-
eration. To their excellent discussion, I would
add the work done by Seidel and Watson
(1978) of the Southeast Fisheries Center in
Pascagoula, Mississippi, and published in
September 1978. They describe a selective
shrimp trawl that uses electricity to induce
the shrimp to jump through a large-meshed
bottom panel into the trawl and the fish to
move ahead of the electric field and avoid
capture. The underlying principle is that
shrimp and fish react differently to an electric
field. Although not widely accepted at present
by the fishing industry, the electric shrimp-
trawl system should, along with similar
developments, be pursued because it is an
effective harvesting device that promises to
increase shrimp production in day or night
operations. The main advantages of such a
harvesting strategy would be increased
harvest for the effort expended, greater profit,
and, therefore, the possibility of subsidized
harvesting and processing of the underutil-
ized food fish; these benefits would make food-
fish harvesting more attractive to the produc-
er. Although interesting experiments have
been conducted recently in Fiji (Brown and
King 1979) to harvest shrimp in deep-water
traps, the possibility of widespread introduc-
tion of this method seems too remote to war-
tant further discussion here.

As long as selective fishing methods are not
widely adopted, one can assume that con-
siderable by-catch will be produced and will
have to be handled by the crew of the
shrimping vessel. Equipment to sort the catch
automatically into shrimp and large,
medium, and small fish by pattern recogni-
tion can, of course, be assembled but would be
very costly in vessel space as well as dollars. I
feel, therefore, that, for the time being at
least, one has to deal with the question of
whether the mixed by-catch, from which the
shrimp have been removed manually, should
be preserved immediately or presorted on
board and then stored. I do not believe that a
single approach can be generally applied be-
cause the decision will largely depend upon
local conditions: on-board storage capacity,
availability of suitable shore facilities to pro-
cess small species, marketing conditions, lo-
cal regulations concerning permission to pro-
cess mixed species, etc.

Preservation

Especially in view of the decline of the
shrimp catch per unit effort in the Gulf of Mexico (Seidel and Watson 1978) and elsewhere but also in view of increasing costs of fuel, dramatically increasing food needs worldwide, etc., the problems in preserving and utilizing the less-valued food fish such as spot, sand seatrout, black sea bass, juvenile croaker, Gulf menhaden, silver hake, blue whiting, etc. transcend in importance the question of what to do with the conventional shrimp by-catch; what is now referred to as by-catch may very well become the major food fishery of tomorrow, and one must learn how to deal with it.

Recent publications indicate that preservation of single or mixed species of fish in mechanically refrigerated and circulated seawater (RSW), RSW with spray, or chilled seawater (CSW) — a slushy mixture of ice and seawater — is more desirable than preservation of fish in ice. Baker and Hulme (1977) found that fish held in CSW are more readily unloaded by pumps than by the traditional basket method and can be separated more economically on shore than at sea. Sea trials resulted in superior-quality fish, the only questionable disadvantage being the scaling that occurred in rough weather. Although the studies were conducted with the lean fish in the by-catch, fatty fish, also, can be much better and longer preserved in CSW than in ice. The system, tried in Morocco with sardines and reported this year in Boston, is easy and quick, the low temperature of the slush helping to maintain good texture of the fish and the water acting as a buffer to prevent bruising. There is indication that CSW provides protection against rancidity.

Although the technology for RSW and CSW has been used for preserving industrial fish for at least 10 years, application to the food-fish industry has lagged. The National Marine Fisheries Service (NMFS) laboratory in Charleston, South Carolina, has therefore undertaken shipboard tests to compare the economic and qualitative effectiveness of RSW and CSW systems when applied to representative underutilized species from the U.S. southeast, especially croaker (Micropogon undulatus) and black sea bass (Centropristis striata). Not surprisingly, the results are encouraging.

Another method, worthy of mention because it allows easy and inexpensive application anywhere, concerns the methods that Icelandic fishing personnel, especially shrimpers, use to transport fish for human consumption. In Iceland, the 70–80-L plastic box has completely taken over the deep-sea trawler fleet and the smaller inshore boats. The latter land their catch ungutted and need, therefore, a method for quick and thorough chilling of their haul. Icelandic fishing personnel use the boxes for CSW preservation and have found that the hours of labour needed on board and on land with this method are half those needed for icing of the fish.

Húsavík, in northern Iceland, is one of the fishing villages where most fish are landed by small inshore boats and are ungutted. Mostly, the boats land their catch in the evening — a fact that produces labour problems. Thus a cold-water tank system was purchased from the firm Kvaerner Kule A/S with a capacity of 40 m$^3$ or 22–25 t of fish. It has a unit for refrigeration and circulation of fresh or salt water and can use ice for cooling, too. The system can lower the temperature of the tank's contents from about 10°C to 0°C in 4 hours. In Húsavík, fresh water is used for the system, kept at 0°C throughout the keeping period.

Removal of fish from such tanks has been a major problem. For the tank at Húsavík, a compressed air system was developed. Thus, the fish are lifted to the surface by air bubbles. A conveyor then takes the fish to the processing line. Emptying the tank (25 t) only takes 30 minutes.

In the course of a workshop, in January 1981 in Sumatra, examining fish handling to reduce postharvest losses, the use of fish-storage boxes was demonstrated by the ASEAN Food Handling Bureau in Kuala Lumpur, Malaysia. The results obtained in several countries using the containers included improved quality of fish and better revenues for the fishing personnel.

Preserving fish in containers with CSW is also of considerable interest in Denmark where layering techniques were developed to accommodate slow filling of containers with intermittent arrivals of fish. In a paper given recently on this subject by Poul Hansen of the Danish Ministry of Fisheries, results showed that the bacterial counts are always lower in CSW-stored fish than in fish in melting ice. The difference is most pronounced when the chilled seawater is not aerated, in which case ultimate spoilage of the fish is caused by anaerobic organisms. The slush seems to pro-
tect against fat oxidation and rancidity in fatty fish better than does the melting ice. However, the use of containers for RSW and CSW preservation depends heavily for its success upon the existence of a reasonable infrastructure to provide transportation, loading, unloading, and other facilities at sea and on shore.

**Processing**

A vast array of products, processes, and equipment has been developed during the last 10–20 years for underutilized species of edible fish. A good account of some of the most important of these products and processes is available from the Inter-American Development Bank (IDB 1980).

One of the important points not sufficiently discussed in the IDB document is the problems of dealing with very small fish that, often, constitute almost half the weight of the by-catch. Apart from the manufacture of fish meal for human consumption from such fish, undertaken in Norway in sanitary equipment and under carefully controlled conditions, no process or machine is available or even on the drawing boards capable of heading, tailing, gutting, and cleaning small fish (12 cm) on board a fishing vessel. If, in the future, small fish are to be fully utilized as human food—not as raw material for fish meal for animal feed—serious consideration must be given to the question of how to process this type of fish. Processing would probably have to be done on land because the machines that will be used will be sensitive, operate at high speeds, require special maintenance provisions, etc. The technology for this kind of operation certainly exists but is, so far, still much too expensive for installation on board a fishing vessel. A reasonably successful prototype of such a machine for land-based operations was recently built and tested in Gloucester, Massachusetts, by the NMFS, processing small fish (3600 fish/hour or a fish/second). The price tag for this machine was about U.S. $40 000, but the machine needs much improvement, especially in its capacity to handle a range of fish sizes (Mendelsohn and Callan 1980).

**Economic considerations**

If one assumed, for the sake of my argument, that all the questions concerning harvesting techniques, sorting, preservation, processing, end-product acceptability, marketing, and distribution of the by-catch were solved, what would be the major economic considerations? They are more complex and thornier, by far, than are the purely technical problems.

The first and overriding consideration is the magnitude and nature of the incentive that the shrimper or shrimp-fleet owner needs to be persuaded to reequip a vessel, retrain crew, and make a concerted effort to preserve part of the by-catch. For, as long as shrimp remains the major crop and commands a much higher price than the by-catch species, persuading this individual will be very difficult. Persuasion will, of course, become easier as the abundance of shrimp dwindles and the by-catch becomes more desirable and, thus, more valuable. Initially, subsidizing by-catch recovery and processing may be necessary to introduce the idea to the fishing industry and demonstrate at least its technical feasibility.

There are, however, other avenues that can be pursued to make the economic picture more attractive. For instance, in view of the spiraling fuel costs, my colleagues and I at Massachusetts Institute of Technology (MIT) are working on methods to provide fishing boats with sail assistance to save fossil fuel. Of course, wind power will not always be sufficient to drag the trawls, and different boat structures will require different riggings, but appropriate sails could get the fishing boat to and from the fishing grounds. We expect this fact will represent a very substantial saving over time. Sail-assist technology is advantageous because financial gain is immediately apparent and can be used as a basis for convincing vessel owners.

Another attractive avenue capable of saving money is the use of engine waste and exhaust heat, either for drying fish on board or for the production of ice or other forms of refrigeration. As simple and effective means of preservation are core considerations for any successful by-catch utilization scheme, any process to make refrigeration a less capital-intensive undertaking is important.

**Market considerations**

I will not spend time on market considerations, but I should emphasize that market conditions are, by definition, highly locale-specific, depending upon national and regional legislation, regulation, cultural preferences, food customs, per-person income, social structure, nature of the available resources,
etc. Does the food and drug administration in a particular country permit the use of mixed fish species in food products to be sold on the free market? What is the composition, textural characteristics of the fish species most prominently present in the usual shore by-catch? Does the public, by and large, accept as food products those in which the identity of the raw material has been lost? In other words, must fish be used \textit{qua} fish and not as a food ingredient? These, and many other, questions need knowledgeable and precise answers before strategies in by-catch use are developed and implemented. Questions such as those about price, profit, acceptability, etc. have direct bearing upon all the problems and decisions down the line — indeed to the very shape of the vessel hull.

\textbf{Conclusions}

The proper use of the by-catch for human consumption is an urgent and important problem that must be addressed more vigorously and cooperatively than it has been hitherto; it is a problem that can be solved with the available technologies in a way that makes solutions acceptable and profitable to different local circumstances, wherever the problem arises. It is important to address the problem not only for its own immediate sake but also because local experience and knowledge are needed in the handling of mixed catches of groundfish in preparation for the day when shrimp is overfished, fuel overpriced, and other food dangerously depleted, a day when the by-catch will become a major food harvest.

The whole issue is a typical interdisciplinary complex of interrelated problems requiring the input of experts from many areas of research and development. A systems approach is needed, and we at MIT and, I am sure, many others are ready to assist.