What We Know About Shrimp Size and the Tortugas Fishery[1]

MILTON J. LINDNER
U.S. Bureau of Commercial Fisheries
Galveston, Texas

SEVERAL MONTHS AGO I was asked if I would give a paper today entitled "It pays (or it does not pay) to catch small shrimp in the Tortugas shrimp fishery." But what do you do when you are on the horns of a dilemma? At the time, I was on those horns, so after thinking a bit I replied that I'd give a paper on "What we know about shrimp size and the Tortugas fishery." I thought this subject was innocent enough because we had a mark-recapture experiment going which I was sure would provide answers. I didn't know it was going to take so long to get the answers, though.

Before tackling the yield curves the computer coughed up, I think we should have an understanding of how Tortugas pink shrimp grow in relation to time.

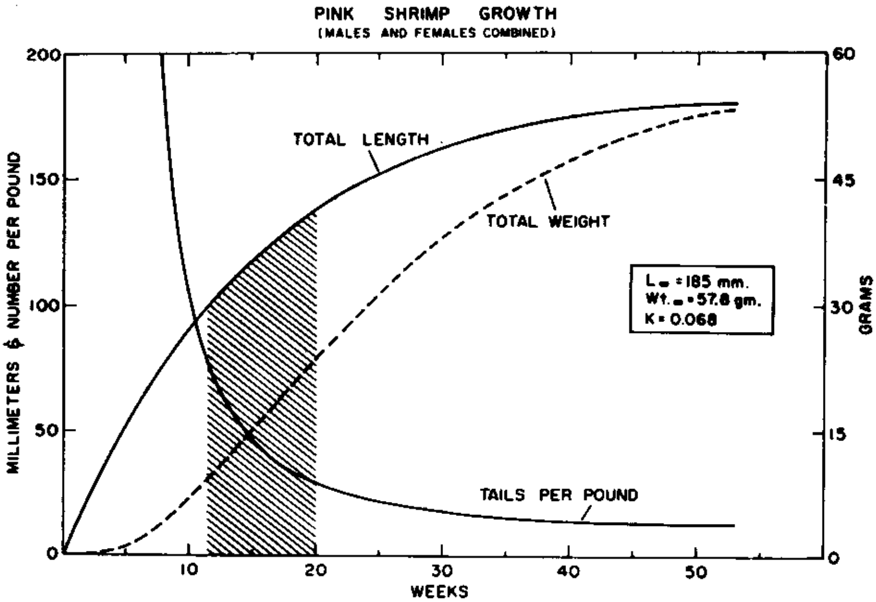

FIG. 1. Growth of Tortugas pink shrimp determined from mark-recapture experiments.

Fig. 1 shows the growth of pink shrimp on the Tortugas shrimping grounds. Like much of the data I shall present, this graph is based on mark-recapture experiments and represents our latest approximation. We have combined males and females and have used the Von Bertalanffy growth equation since it seems to fit our data well.

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Time, in weeks, is given along the horizontal axis. As we proceed from left to right, the first ascending curve shows increase in length with time and the next ascending curve, increase in weight with time. The descending curve shows the count of shrimp in tails-per-pound with time. The figures in the box on the right—185 mm, 57.8 grams, and 0.068—represent the constants used in calculating the total length and total weight curves. The shaded area covers the portion under discussion today.

I think this illustration is most revealing in that it demonstrates the rapidity with which action takes place in the growth of pink shrimp and the short period of time and slight increment in length with which we are dealing.

If we consider 100 mm (4 inches) total length or 80 count tails as the size at which the shrimp are fully subject to fishing, we find that within about 9 weeks they have increased about 1½ inches in length and their weight has increased to where they are about 30 count. With these facts in mind, I think we can better understand that which follows.

Using these growth curves, Dick Berry of our staff has made an analysis of the size composition of the commercial landings from the Tortugas grounds from 1956 through 1964. This analysis reveals that a total instantaneous mortality of about 0.25 per week best describes the size distributions of the landings. On a percentage basis, about 22% of the shrimp are removed from the population each week by a combination of fishing and natural deaths.

Carefully designed and controlled mark-recapture experiments by staff members, Costello and Allen, and Berry and Knight, suggest that the instantaneous natural-mortality rate on the Tortugas grounds probably lies between 0.075 and 0.125 weekly. In other words, the natural mortality rate is between about 7 and 12% a week.

We have used these figures to construct some yield curves. Fig. 2 demonstrates the relative yield in weight that could be expected from a brood of shrimp that entered the fishery at 80 count tails-per-pound. In these two curves, which represent what we now think are the extremes, we have used the growth rate I just mentioned and a total instantaneous mortality of 0.25. The lower curve was developed by taking fishing and natural mortality each at 0.125 and the upper curve with a natural of 0.075, and a fishing of 0.175. For those of you who are interested, we did not use the Beverton and Holt (1957) formula but that of Thompson and Bell (1934) with a time interval of 1 day. The formulas are essentially the same, but the integrated formula of Beverton and Holt does not offer a ready means for the addition of price, which we needed. To put it simply, what we have done is to tie together growth, natural mortality, and fishing mortality to come up with some curves that show the tail count shrimp should reach before fishing begins in order to get the greatest poundage out of a brood.

In Fig. 2, the horizontal axis is in units of headless shrimp per pound and the vertical axis is in relative yield.

The lower curve tells us that if the rates used were the true rates, we would catch as many pounds of shrimp if we started fishing them when they were first fully recruited at 80 count to the pound, as we would if we waited until they grew to 60 count size.

The upper curve tells us that if the rates used were the true ones, we would catch the most pounds of shrimp if we did not start fishing until they reached 60 count, and we would still catch about the same number of pounds if we waited until they grew to 40 count. This is now what we believe to be our ballpark. The bounds lie somewhere between 80 and 40 tail count for maximum weight.

Note how the curves are broad-topped, rise slowly to a maximum, and decline rather abruptly thereafter. They indicate that though maximum weight may be obtained by starting to fish between 80 and 40 count, the safest size for maximum weight is about 60 count.

Now let's take a look at what happens when we add price as another factor. Fig. 3 shows the same two curves with price added. We now are considering growth, natural mortality, fishing mortality, and price paid the fishermen. The prices we used for these curves ranged from 21.5 cents a pound for 70 and over count to 86 cents a pound for under 15 count. A break in price was made for each 5-count change in size. For example, 21-25 count shrimp were valued at 76 cents a pound, 26-30 count at 71 cents, and 31-35 count at 65 cents.

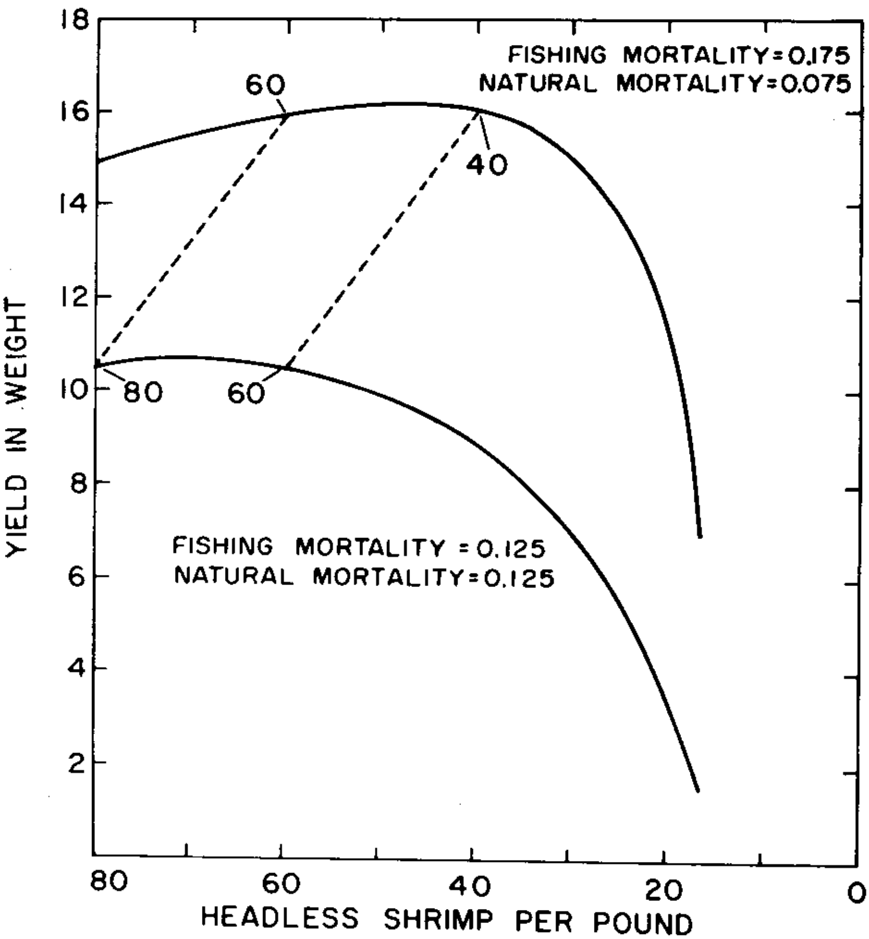

FIG. 2. Yield in weight curves for Tortugas pink shrimp.

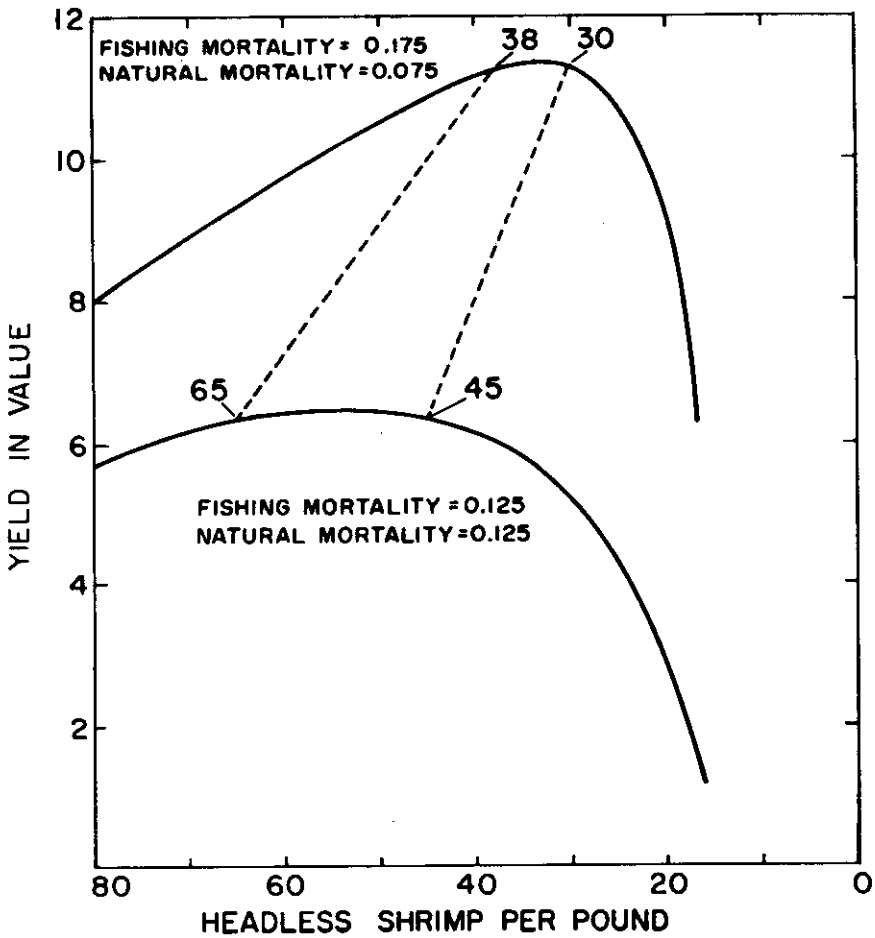

FIG. 3. Yield in value curves for Tortugas pink shrimp.

You will notice that when we take price into account, the curves shift to the right or toward a larger size shrimp for maximum value against a smaller size for maximum weight. The same growth, fishing, and natural mortality rates that gave a maximum weight of between 80 and 60 count give a maximum value between 65 and 45 count. At the other extreme, the maximum changes from between 60 and 40 count for weight to between 38 and 30 count for value.

This information looks good. We have now considered growth, natural mortality, fishing mortality, and price. It isn't complete, however. We lack something. We lack fishing cost. We haven't entered fishing cost into our curves because, as yet, we have no good measure of it. For lack of a better term, I shall use "maximum profit" to indicate the situation when growth, natural mortality, fishing mortality, price paid the fishermen, and fishing cost are all taken into consideration.

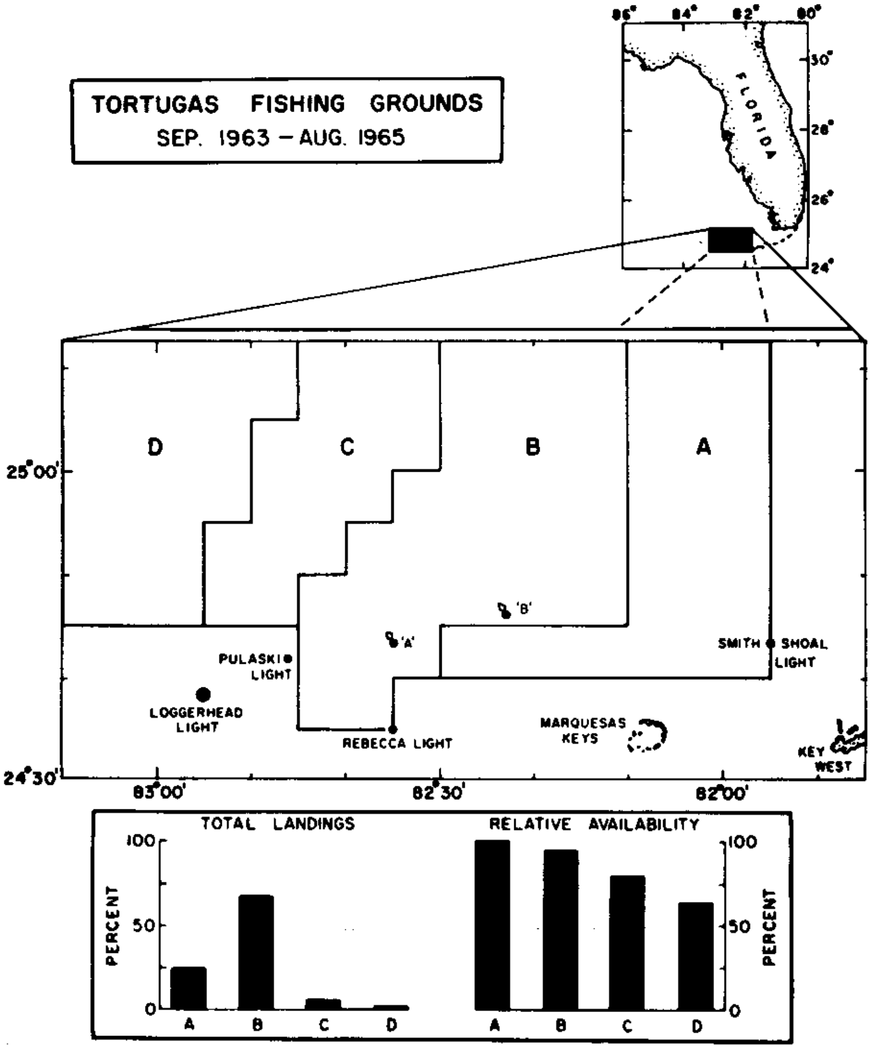

FIG. 4. Total landings and relative availability of pink shrimp from four fishing zones on the Tortugas fishing grounds. Zone depths in fathoms are: A, 9-12; B, 13-18; C, 19-23; and D, 24-30.

When fishing cost is added, we think we know the direction the curves will shift, but we don't know the extent of the shift. We believe for the Tortugas fishery that when fishing cost is added to the value curves, maximum profit will lie to the left of maximum value. This shift means that the size at which fishing should begin to obtain maximum profit from a brood of shrimp will be less (a larger count size) than the size that will give maximum value. For example, let's say to get maximum value, fishing should be delayed until shrimp reach 40 count; then, to get maximum profit, fishing should not be delayed so long. For maximum profit, perhaps fishing should start at 50 or 60 count. We suspect when it is developed, that the count size for maximum profit will lie somewhere between the sizes for maximum value and maximum weight. Why do we suspect this? I think Fig. 4 will explain this.

Before discussing this figure, I want to make a flat statement to which I think most will agree. Fishing cost, or the cost of catching a pound of shrimp, is bound to be closely associated with the pounds of shrimp caught per hour of fishing and with the distance one has to travel from port to the fishing grounds. Fishing cost, then, must be closely associated with shrimp availability and with travel time.

Now let's look at Fig. 4. Here we have divided the Tortugas fishing grounds into four zones. Zone A covers depths between about 9 and 12 fathoms; B, between 13 and 18 fathoms; C, between 19 and 23 fathoms; and D, between 24 and 30 fathoms. The data cover 2 years from September 1963 through August 1965.

The bar diagram at the lower left shows the average percentage landings from these zones. During these 2 years, about 25% of the landings originated in Zone A, about 68% in Zone B; 6% in Zone C, and 1% in Zone D.

The bar diagram at the lower right represents the relative availability of shrimp in these zones as judged by the total landings from each zone divided by the total hours fished in each zone. The height of the bars shows the comparative availability of shrimp in each zone. With Zone A equated to 100%, the relative availability in Zone B is 95%; in Zone C, 70%, and in Zone D, 64%. Thus, if 1 hour of fishing in Zone A would produce 100 pounds of shrimp, the same hour of fishing in Zone D would produce only 64 pounds.

We must remember though that these figures are based on landings and not catch. On the basis of catch, there would be an even greater disparity between Zones A and D because of culling. A greater proportion of small shrimp are caught in Zone A than in Zone D. As a consequence, a greater proportion of the catch in Zone A is discarded, thereby lowering the landings from this Zone to a greater degree than those from Zone D.

It seems evident from these data, that the grounds nearest the port of Key West produce more pounds of shrimp for each hour of fishing than do the most distant grounds. We also know that Zones A and B produce smaller shrimp than Zones C and D. Since availability and distance favor the areas where smaller shrimp occur, it is apparent that the element of cost also favors the area of smaller shrimp.

It is dangerous to attempt to predict what the outcome of a research problem may be before the research is done, but from a superficial examination it looks as though the slope of the cost line favoring small shrimp will be less than that of the price line favoring large shrimp. This difference would place the size at which to start fishing to get maximum profit somewhere between the sizes for maximum weight and maximum value.

Just for argument's sake and so that I can have something further to talk about, let's hypothesize that we eventually come up with information that tells us we should not start fishing until shrimp reach 60 count.

Our goal now becomes, no shrimp caught until they reach 60 tails to the pound. Shrimp of this size are about 110 mm or about 4½ inches in total length.

The problem now is: how can we best attain this goal?

Right at the start, we know from the studies of Ingle, Eldred, Jones, and Hutton (1959), those of Iversen, Jones, and Idyll (1960), and ours that, owing to the ranges in shrimp size distributions and availability on the fishing grounds, either we are going to have to compromise on this size or else we have to have a gear that will not catch shrimp smaller than about 4½ inches long. So let's examine the possibility of gear modification in order to reach our goal.

At least for once, I anticipated a problem before it arose, and a couple of years ago I put Dick Berry to work on mesh-selectivity studies. His results are not greatly different from some unpublished preliminary conclusions Bill Anderson and I reached about 30 years ago nor do they differ much from those of Regan, Idyll, and Iversen (1957). All show that some slight benefit might be gained by using a larger mesh in the trawls. But, when the mesh size is increased sufficiently to get a significant increase in size of shrimp that escape, too many large shrimp also escape. So fishing becomes a nonpaying proposition. Furthermore, for proper escapement, the chafing gear would have to be removed.

With some fishes, mesh selectivity seems to be the answer for controlling the size at which harvest should begin. In fish, however, I think you will find that the animal dealt with is considerably larger than our shrimp, and that there are several inches in the animal's length and girth with which to deal. In shrimp, where only about 1½ inches in total length means the difference between 80 and 30 tail count, it is understandable why the control of mesh size is not adequate for our purposes.

It doesn't appear as though we have an easy way out, such as that provided by selective gear. Nor does it appear that we will be able to attain a sharp cut-off point at 60 count or any other count that eventually may be decided upon. The habits of the shrimp and their size distribution on the fishing grounds preclude any sharp cut-off point. We will always catch some small pink shrimp. All we can hope for is to arrive at some compromise that will give us the most profitable approach toward approximating our goal—particularly because we have no evidence that present fishing practices are depleting the shrimp stocks. What we are after is to conduct our fishing in such a fashion that we are getting maximum profit.

Basically, fishing should be conducted in such a manner that the fishermen get the greatest dollar return from the stocks of shrimp for the least cost of fishing, while at the same time the total catch should be as near to the maximum weight as possible. This problem, by its very nature, probably requires a compromise position though it may not prove to be so. When all the facts are in, we may wind up concluding that maximum weight is about the same as maximum profit.

Now that I've got that off my chest, let's proceed to look at control by size limit. You now have in Florida a size limit set at 70 count tails-per-pound with a 5% permissibility for shrimp smaller than 70 count.

Let me ask you shrimp people a few questions.

Don't answer them! Just think about them!

1. Where can you fish shrimp and not catch more than 5% over 70 count?
2. How do your catches in these places compare with your catches in areas where you get more than 5% over 70 count?
3. Is a caught shrimp a dead shrimp?
4. Does the law create wasteful practices?

5. Is this law truly enforceable?

6. Is it accomplishing what you wanted it to accomplish?

After you think about these questions a while, I believe you will agree with me that you already know the answers, or at least enough of them to arrive at the conclusion that an out-and-out size limit does not meet your needs. Furthermore, since it forces the fishermen to cull their catches, it is causing a waste that should not be.

A size limit in itself reminds me of the fellow with an ingrown toenail who, instead of trying to heal it, cut his toe off. Here is a real all-or-nothing solution. Very few problems with a biological foundation can be solved by the all-or-nothing process. To get the most out of nature, one must compromise with her. Also, to obtain the cooperation of the fisherman, and no regulation will work successfully without his cooperation, the fisherman must be convinced that the regulation is for his benefit.

Let's now look at a closed-season approach to the problem. If there were a particular time of the year when undersized shrimp were extremely abundant on the fishing grounds and large shrimp were not abundant, it might prove profitable to establish a closed season during that time. Unfortunately, from about September to May, when undersized shrimp are most abundant, the fishing grounds are most productive of large shrimp. It is only between about June and August, when shrimp are scarce and little fishing occurs, that undersized shrimp are not present in abundance on the grounds.

If you will recall Fig. 1, that of growth and time, I think you will understand why this situation exists.

So, the idea of a closed season goes down the drain.

Up till now, it seems I've been telling you what you should not do. I suspect, if I continue in this vein, one of you, at any moment, will pop up and ask, "Well, Lindner, what should we do?"

Now that I've been asked the question, here goes! I have three recommendations:

1. Repeal your size-limit law. It is not accomplishing what you want, nor will such a law, in Florida or anywhere else in our shrimp fisheries, accomplish what is wanted. The size distributions of our shrimp on the fishing grounds are such that size limits cause more waste than benefit.

2. You are really not hurting very much, though you may think you are, so sit tight until something better comes along. There are times when doing nothing is better than doing the wrong thing. At the moment, I think you are better off doing nothing. By nothing I mean nothing more than repealing the size-limit law.

3. Explore in detail the shrimp size-depth-availability relations that exist on the Tortugas grounds to see if closed areas are advisable.

My first and second recommendations speak for themselves. The third probably should be expanded a bit. You undoubtedly have gathered from what I have already said that I think our problem now is one of determining maximum profit. I believe we already know broadly the requirements for maximum weight and maximum value, but for maximum profit, we have one specifically unanswered question.

This question is: is there an area, or are there areas, where we should not fish in order to get maximum profit?

Fishing for maximum profit, of course, carries with it the connotation of no culling of the catch. All shrimp caught should be brought in and sold.

This question, I believe, can be answered by carrying out my third recommendation.

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The Use of Liquid Nitrogen in the Shrimp Industry

DWIGHT C. BROWN
Applied Research and Development
Air Products and Chemicals, Inc.
Allentown, Pa.

Abstract

The manufacture and properties of liquid and gaseous nitrogen are briefly described. The present and future uses of liquid nitrogen (LIN) for freezing and glazing peeled and deveined (P&D) individually quick frozen (IQF) shrimp are described for complete freezing and crust freezing. The advantages of liquid nitrogen freezing over conventional blast room or blast tunnel freezing are discussed. Also discussed is the application of liquid nitrogen to catch preservation at incipient freezing to extend fishing and running times with attendant improved quality of green headless shrimp. A possible application of liquid nitrogen is discussed in which the gas is generated at the fishing grounds by large ship-board generators for use in freezing. Other attendant uses for nitrogen are treated such