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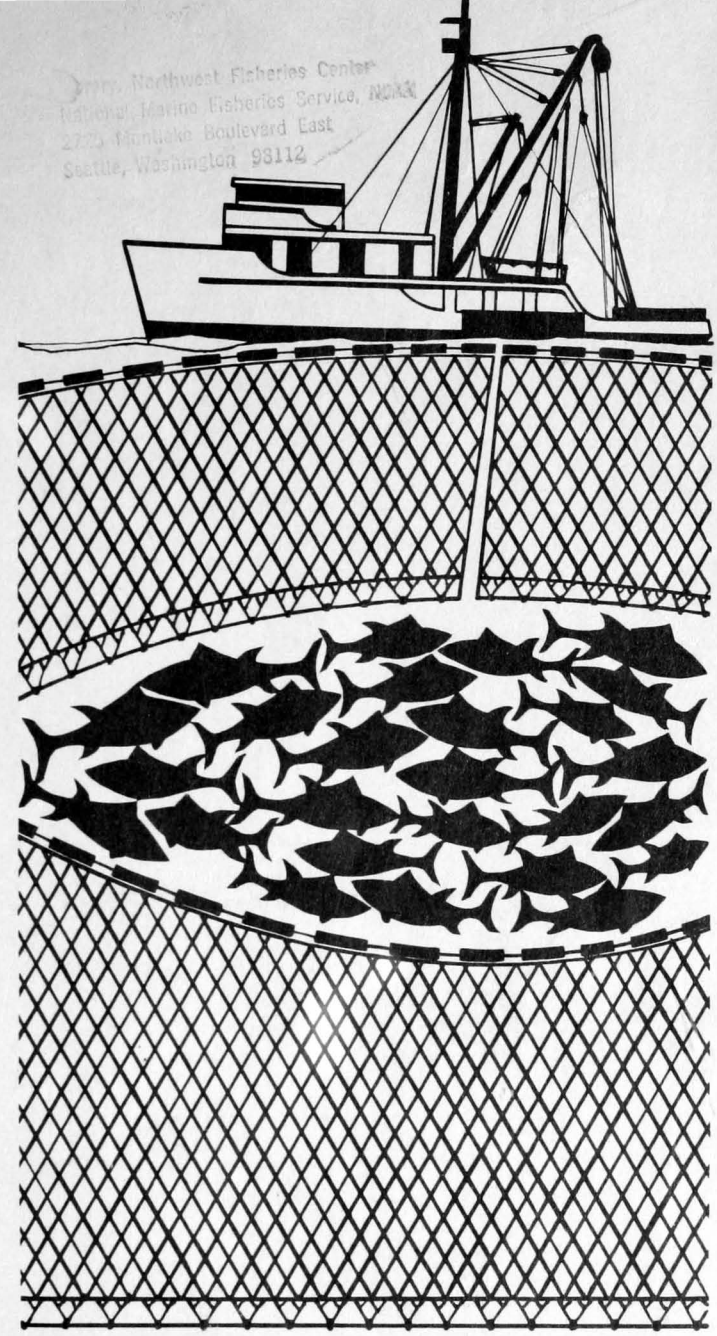

FISHERY INDUSTRIAL RESEARCH

VOLUME 6 NO. 4

United States Department of Commerce

National Oceanic and Atmospheric Administration

National Marine Fisheries Service

UNITED STATES DEPARTMENT OF COMMERCE

Maurice H. Stans, *Secretary*

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

Philip M. Roedel, *Director*

FISHERY INDUSTRIAL RESEARCH

Volume 6 -- Number 4

Washington, D. C.

NOVEMBER 1970

MACHINE SEPARATION OF EDIBLE FLESH FROM FISH

by

David Miyauchi and Maynard Steinberg

ABSTRACT

Meeting the expanding demand for fishery products will require us to utilize the undeveloped fisheries and the industrial fisheries as sources of food. This use, in turn, will require us to develop foods that are new and that are unique in appearance, palatability or nutritional qualities. One step we can take toward this goal is to recover a higher yield of edible flesh from fish economically. By use of a flesh-separating machine, such as the one reported upon here, we can significantly increase the yield of edible flesh.

CONTENTS

INTRODUCTION

In the United States, the utilization of fishery products has increased from about 6 billion pounds in 1948 to about 17 billion pounds in 1968. This trend of increasing utilization of fishery products is expected to continue, owing to the increase in population, even though the consumption of fishery products remains at about 10 to 11 pounds per capita. Most species of fish for which a strong demand exists—namely, halibut, salmon, tuna, crabs,

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Published August 1970.

lobsters, shrimp, and scallops—are fished extensively. In fact, many of these species are overfished. These commercially important species generally can be economically harvested and processed even though considerable waste occurs. Furthermore, most of them have good storage characteristics enabling them to be preserved until consumed as food.

In looking ahead to determine the resources available to meet the expanding demand for fishery products, we find that, in general, no reserve stocks of the species that are in high demand for human food exist in the fishing areas of the world. Instead, we see increasing emphasis being placed on resource management to ensure conservation of the resources for optimum production. Evidently, therefore, we must look toward those resources that have been underutilized for use as food because of a lack of consumer acceptability and must make more efficient use of the species of fish now being landed and in high demand.

The latent food resources may be divided into two groups: (1) the undeveloped fisheries such as those for hake, *Merluccius* sp.; walleye pollock, *Theragra chalcogrammus;* rockfish, *Sebastodes* sp.; flounder and sole, *Pleuronectidae* family; squid, *Loligo* sp.; and small crustaceans such as euphausiids and pelagic red crab, *Pleuroncodes planipes;* and (2) the industrial fisheries such as those for menhaden, *Brevoortia* sp., and northern anchovy, *Engraulis mordax,* in which the products — fish meal and oil, particularly the meal — are not used for human food. In the future, however, the greater value of fish as human food rather than as animal food will place menhaden and anchovies among the species that people eat.

The significant utilization of all these species as food or as food ingredients will require the development of products that have shed the identity of the species and that appeal to the consumer on the basis of their attributes alone. For the food scientist, this change means that a specific knowledge of the physical and chemical properties of the lipids and muscle proteins must be acquired. For the processor, wise use of these resources requires that he maximize his yield and minimize his cost of processing.

Recognizing these facts, we obtained for study, in the summer of 1968, a flesh-separator machine[1] developed by the Japanese and used by them in the manufacture of fish sausage and kamaboko (a fish cake common in Japan). Tests with the machine demonstrated that a high yield of edible flesh could be obtained from dressed fish of any of several species. In addition, the tests showed that this type of machine can be used to recover significant amounts of flesh from the fish frames produced in filleting, from the food-grade trimmings in the salmon-canning and tuna-canning industries, and even from the material ordinarily disposed of as waste in shrimp processing.

The mechanical basis for this effective separation is simple, and it provides, in our judgment, the initial step needed by the U.S. industry to ensure total utilization of our fish and shellfish resources. The purpose of this paper is to report on our findings with the flesh separator. In the following main sections of the paper, we describe the flesh separator, report on the tests we made with it, and predict its impact on the U.S. fisheries.

I. DESCRIPTION OF FLESH SEPARATOR

The flesh separator works by squeezing the flesh from the skin and bones of fish and passing the flesh through the perforations on a stainless-steel plate or drum. The skin and bones do not pass through the perforations and are separated by the machine.

Our laboratory machine has: (1) a stainless-steel drum (about 8½ inches in length and 6½ inches in diameter) perforated with closely spaced holes ⅛-inch in diameter and (2) a continuous rubber belt (about 41 inches long and 8¼ inches wide), which runs over a series

[1] "Miny" Fish Separator of the Yanagiya Machine Works, 200 kilograms or 440 pounds per hour separating capacity; larger production-scale models are manufactured by several companies.
Note: The use of trade names is merely to facilitate descriptions of experimental procedures; no endorsement is implied.

of moving rollers. The position of the rollers is adjustable to regulate the pressure exerted against the drum by the rubber belt.

Here is how the machine works. Headed-and-gutted fish fed into the machine pass between the belt and the perforated drum (Figure 1). The pressure applied by the belt on the fish forces the fish flesh through the perforations of the drum while the skin and bones pass to the "waste" discharge chute. The operator can adjust the pressure exerted by the belt to remove most of the light meat during the first pass through the machine. If he wishes to remove the remaining light meat and the dark flesh under the skin, he can pass the "waste" through the machine again after the machine has been adjusted to increase the pressure exerted by the belt. As an alternative, he can adjust the pressure exerted by the belt to the maximum so that one pass removes all of the flesh — both dark and light.

II. TEST OF FLESH SEPARATOR

We tested the flesh separator both with fish and with small pink shrimp.

A. TESTS WITH FISH

In the tests with fish, we used both headed and gutted fish and filleting waste and trimmings.

1. Separating Flesh From Headed and Gutted Fish

a. Procedure.—We used several species of fish from the Pacific Ocean and the Gulf of Mexico. For each species, weighed batches of fish were headed and gutted by hand, washed, and reweighed to determine the weight of the head and viscera. The fish were passed through the machine with the tension of the belt adjusted to remove most of the light meat on the first pass. The separated minced flesh was weighed to obtain the yield. The waste from the first pass was then sent through the machine again, and the recovered flesh was weighed. The weight of the skin and bones was calculated by the difference in the weight of the fish passed into the machine and in the weight of the recovered flesh.

b. Results.—Table 1 gives the results with Pacific Ocean fish. The low yield of the first pass from some species does not indicate anything other than the yield obtainable at some arbitrary adjustment of the tension exerted by the belt. Higher or lower yields could be obtained by different adjustments of the tension. All yields are based on whole fish.

Table 2 presents data on Atlantic croaker, *Micropogon undulatus*, and porgy, *Calamus* sp., of small size from the Gulf of Mexico. The yield of minced flesh from the various species ranged from 37 to 60 percent. In comparison, the yield of flesh using conventional filleting

Table 1.—Yield of flesh and waste from some Pacific Ocean fish passed through a laboratory-model flesh separator

Species		Weight of fish used	Yield of flesh:			Yield of waste:		
Common name	Scientific name		1st pass	2d pass	Total	Head and viscera	Skin and bones	Total
		Kilograms	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Northern anchovy	*Engraulis mordax*	4.8	41.4	20.2	61.6	33.5	4.9	38.4
Spiny dogfish	*Squalus acanthias*	14.5	20.9	16.0	36.9	52.1	11.0	63.1
English sole	*Parophrys vetulus*	15.2	40.2	20.0	60.2	28.4	11.4	39.8
Pacific hake (Puget Sound)	*Merluccius productus*	17.7	33.0	16.0	49.0	44.6	6.4	51.0
Pacific herring	*Clupea harengus pallasi*	10.3	38.2	28.4	66.6	29.5	3.9	33.4
Lingcod	*Ophiodon elongatus*	266.2	26.2	20.8	47.0	39.0	14.0	53.0
Silvergray rockfish	*Sebastodes brevispinis*	19.8	35.8	10.7	46.5	42.3	11.2	53.5
Starry flounder	*Platichthys stellatus*	67.0	27.1	15.8	42.9	46.0	11.1	57.1
Pacific cod	*Gadus macrocephalus*	17.4	32.5	5.3	37.8	45.5	16.7	62.2

Note 1: Yield is affected largely by the anatomy of the species used; those species with relatively large heads and viscera masses give relatively low yields of flesh. All yields are based on whole fish.

Note 2: The data on waste skin and bones were obtained indirectly by calculation: weight of skin and bones = weight of fish used minus the sum of the weight of recovered flesh and weight of head and viscera.

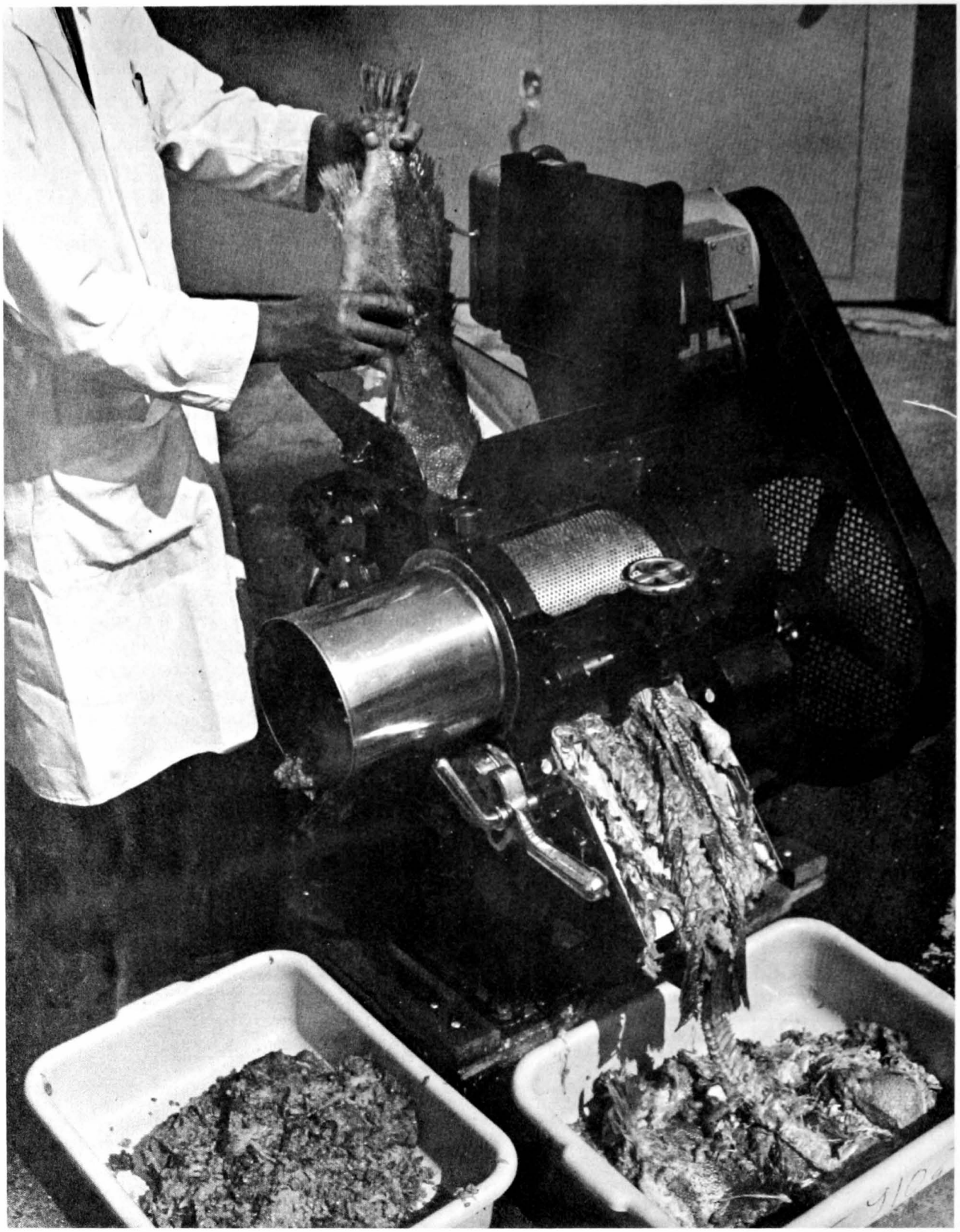

Figure 1.—Headed-and-gutted rockfish is fed into the laboratory-model, flesh-separator machine, which extrudes the flesh through perforations on the steel drum and passes the skin and bones to the "waste" discharge chute.

Table 2.—Recovery of flesh from Atlantic croaker, *Micropogon undulatus*, and porgy, *Calamus* sp., from the Gulf of Mexico using a laboratory-model flesh separator

Fish	Amount of fish used		Waste from heading and gutting	Yield after material passed through machine once	
	Weight	Average weight		Based on whole fish	Based on headed and gutted fish
	Kilograms	*Grams*	*Percent*	*Percent*	*Percent*
Croaker, whole	18.3	140	42	40	70
Croaker, headed and gutted	28.9	152	--	--	75
Porgy	26.2	51	38	41	62

Note: The "waste" from passing the porgy through the flesh separator yielded an additional 3-percent of flesh when it was passed through the flesh separator a second time.

techniques ranges from 25 to 30 percent. An estimate can be made of the relative costs of edible flesh obtained either as hand-cut fillets or as minced flesh from rockfish, which in 1969 was selling at an exvessel price of 6½ cents per pound. Using arbitrary, but reasonable, yield figures from rockfish of 30 percent for fillets and of 45 percent for machine-separated minced flesh and considering only the cost of the whole fish, we find that the increased yield of flesh alone lowers the cost per pound from 21.7 cents for fillets to 14.4 cents for the minced flesh.

2. Separating Flesh From Fillet Waste and Trimmings

a. Fillet waste.—Reported here are our findings with filleting waste from rockfish and from trout.

(1) Rockfish fillet waste.—To determine the amount of edible flesh that can be recovered from rockfish filleting waste, we cut away from the frames, the heads and viscera, which comprise 49 percent of the whole fish (Figure 2).

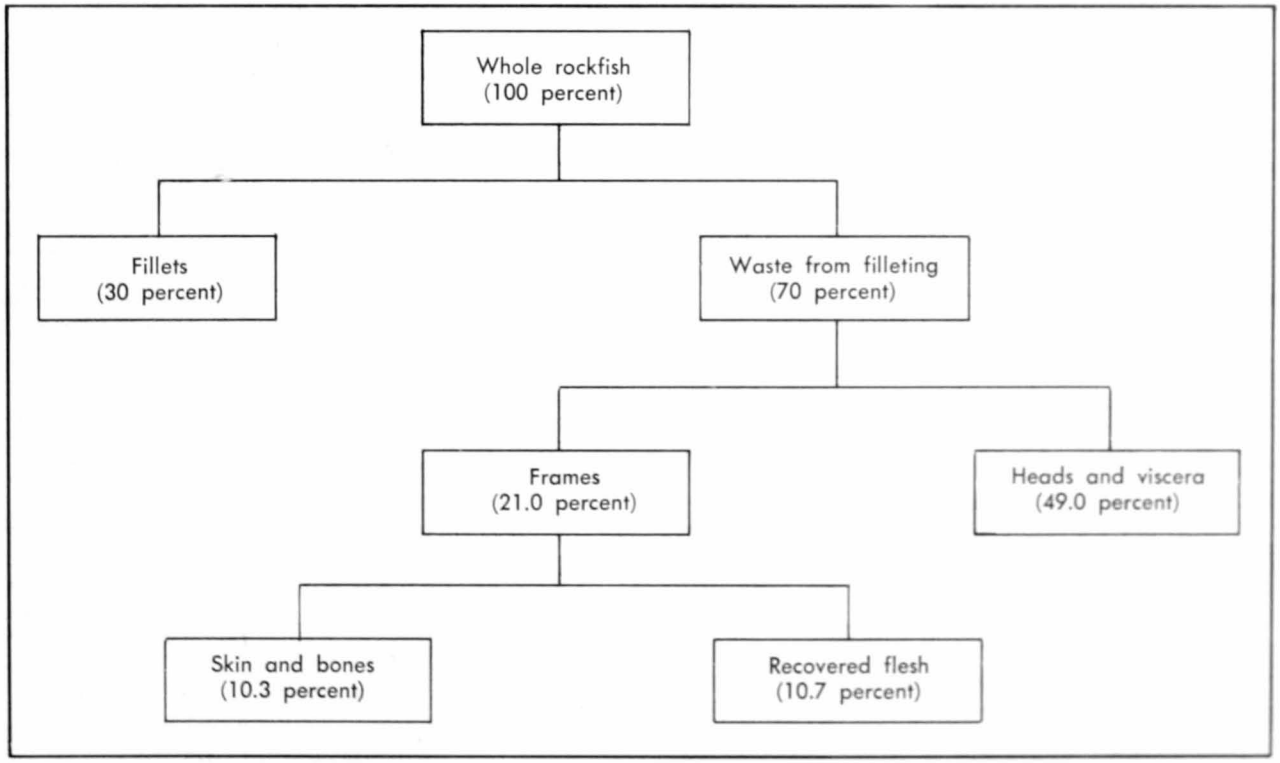

Figure 2.—Yield of various components of edible flesh and waste from rockfish, *Sebastodes* sp., including the edible flesh recovered from the frames by means of the flesh-separator machine.

The frames were then fed into the flesh separator. The flesh removed by the machine was 10.7 percent of the weight of the whole fish; the skin and bones were 10.3 percent.

Preliminary data on rockfish landings in Washington and Oregon in 1968, the latest year for which published data are available, were about 26 million pounds. On the basis of our findings, we estimate that 10 percent of the landed weight, or 2.6 million pounds, was edible flesh left on the frames, which was disposed of in forms less valuable than human food. The recovery of this edible flesh through the use of the separator thus would make this material available for incorporation into a human food, which would have a higher value.

(2) Trout fillet waste.—The findings with rockfish hold true for other species. For example, headless and eviscerated hand-filleted frames of rainbow trout, *Salmo gairdneri*, yielded 68 percent of their weight as edible flesh.

b. Salmon trimmings. — When frozen dressed salmon are cut into steaks, the trimmings from the steaking operation include the collar and tail sections. Similar sections are available from salmon canneries. Trimmings from both pink salmon, *Oncorhynchus gorbuscha*, and sockeye salmon, *O. nerka*, were passed through the flesh separator. Table 3 shows the results. From the pink salmon trimmings, about 78 percent of the collar section and tail section was recovered as edible flesh. From the sockeye trimmings, 67 percent of the collar section was recovered as edible flesh, and 24.5 percent of the tail section was recovered. The recovered flesh could be used in products such as salmon spreads.

B. TESTS WITH SMALL PINK SHRIMP

The results of the few tests we made with whole pink shrimp, *Pandalus* sp., indicate that the flesh-separator machine could be used to remove the soft proteinaceous parts from the shells of these crustacea and of similar ones. Whole shrimp ranging in weight from 1.5 to 8 grams (average weight 3 grams) were run through the machine to separate the soft parts from the shell. The yields were 90 percent from raw shrimp and 85 percent from cooked shrimp.

The soft parts or proteinaceous material were extracted with isopropyl alcohol to produce a protein concentrate (81 percent protein), which was white in color and faintly shrimplike in odor. Thus, the flesh separator permits the production of a shell-free protein concentrate from shrimp too small in size to be processed economically into food by other methods. This finding doubtlessly will hold true for other crustacea.

The shrimp waste from processing plants consists primarily of the cephalothorax with bits of adhering meat. Because of the high content of shell, this shrimp waste makes a relatively low-grade meal for use in poultry feed. Separation of the shell from the proteinaceous parts would increase the nutritive value of the meal and could change the economics of marketing shrimp meal. In areas where the local demand for shrimp meal is low and the costs of labor and transportation are high, this separation of the proteinaceous material may aid in simplifying the problem of plant-waste disposal.

Table 3.—The recovery of edible flesh from the collar and tail sections (trimmings) of pink salmon and sockeye salmon

Source of material	Materials studied	Weight	Flesh yield
		Pounds	*Percent*
Trimmings from steaking frozen pink salmon	Collar section	21.1	---
	Flesh recovered	16.6	78.7
	Tail section	12.2	---
	Flesh recovered	9.5	77.9
Sockeye salmon cannery trimmings from the "Iron Chink"	Collar section	21.5	---
	Flesh recovered	14.5	67.4
	Tail section	25.7	---
	Flesh recovered	6.3	24.5

III. POTENTIAL IMPACT OF FLESH SEPARATOR ON U.S. FISHERIES

The potential of the flesh-separating machine for (1) increasing yield and lowering costs and (2) mechanizing the whole process of flesh separation and recovery is high. This development can lead us into new concepts of research on the total utilization of our fishery resources. The research is proceeding currently in two major areas to ensure broad application of this new technology. Underway are studies:

1. On the chemistry of wet-fish proteins and on the effects of physical processes and chemical additives relative to food applications.
2. On the development of various high-protein processed foods from minced fish flesh and on techniques for modification of flavor, texture, and keeping quality as determined by acceptability tests.

The use of this new technology could lead to the expansion of the U.S. fisheries into the production of the fast-growing processed, high-protein snack-type and convenience foods utilizing long-neglected species as a source of protein. Successful introduction of fish protein into only one or two of these high-volume food products could create a new demand that can be met only by tapping our underutilized fishery resources. U.S. fishermen, processors, and consumers could all benefit.

SUMMARY

In the flesh-separator machine described here, the pressure applied by a belt forces the flesh of fish through perforations in a drum while the skin and bones pass to a discharge chute. The total yield of minced flesh from the various species of fish passed through the machine ranges from 37 to 60 percent, whereas the yield of flesh using conventional filleting techniques ranges from 25 to 30 percent. By means of the flesh-separating machine, significant quantities of edible flesh can be recovered from filleting waste and fish trimmings and from small crustacea. The potential of the flesh-separating machine for increasing yield and lowering costs and for mechanizing the whole process of flesh separation and recovery represents a long step toward our goal of totally utilizing our fishery resources.

MS. #2055

BLUEING OF PROCESSED CRAB MEAT
1. A STUDY OF PROCESSING PROCEDURES THAT MAY CAUSE A BLUE DISCOLORATION IN PASTEURIZED CRAB MEAT

by

Melvin E. Waters

ABSTRACT

Although the yearly economic loss due to the sporadic blueing of canned pasteurized crab meat usually is small, processors understandably are anxious to avoid this problem.

To study the causes of blue discoloration, I varied the commercial methods.

Pasteurizing at temperatures above 170° F. (regardless of processing time) caused some blueing of the meat. Aging the meat before pasteurizing it shortened its shelf life but did not cause blueing. Exposing the meat to the metal of cans as well as to bits of solder placed in the meat also did not cause blueing. Heating the meat at 170° F. for 5 minutes was adequate to pasteurize meat containing 49 x 10^4 microorganisms per gram and resulted in a product free from blueing during a shelf life of more than 12 months.

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Published September 1970.

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INTRODUCTION

The problem of the blue discoloration, or blueing, that is sometimes encountered in canned and pasteurized meat of the blue crab, *Callinectes sapidus*, is one of long standing. Although this phenomenon is not well understood, several explanations have been offered, and several remedial treatments have been tried. Blueing, however, still occurs sporadically. Attempts to correlate the discoloration with such factors as the season of the year, geographical location, sex of the crabs, processing technique used, and quality of the water inhabited by the crabs have proved fruitless.

Blueing of crab meat is described as discoloration that ranges from a blue-grey to a light blue. This discoloration, depending on severity, may partially or entirely cover a fiber and may or may not affect each fiber in the can. The discoloration is not confined to any particular location in the can.

The yearly economic loss to the industry is usually small. Nevertheless the processor cherishes the confidence placed in his product by the consumer and, as a consequence, desires a method of processing that will ensure that his product will not become discolored blue.

The literature points to a number of causes of the blueing in canned crab meat. Oshima (1932) suggested the following four possible substances as being the causes: (1) iron sulfide, (2) copper sulfite, (3) melanin (dark brown or black pigments of animal origin), and (4) the biuret complexes. Later, Fellers and Harris (1940) suggested that the blueing in heat-processed blue crab meat was due mainly to copper-ammonia complexes and, to some extent, to sulfides. Elliott and Harvey (1951) studied the bleeding of Dungeness crabs and found that the discoloration is definitely correlated with the blood content. Organoleptic observations revealed that bleeding the crabs before processing them improved the canned product by reducing the blue-grey discoloration. Groninger and Dassow (1964) found that king crab, *Paralithodes camtschatica*, meat was discolored blue had similar properties to those of copper proteins and biuret complexes.

Japanese workers have reported that, during cooking, volatile sulfur compounds are formed in Kamchatka crabs. Because the female crab contains more sulfur, its flesh is considered to be inferior for canning.

Dassow (1963) stated that the blueing in canned blue crab meat is due to the interaction of the copper pigment (hemocyanin) in crab blood with the ammonia and sulfur compounds formed from the breakdown of the proteins during heat processing. The oxidation of these compounds results in the characteristic blue color in the meat.

The blueing of crab meat is apparently associated with heat processing. In the pasteurization process, the method of heat processing varies widely from one processing plant to another. The temperature used ranges from 170° to 190° F., and the time of heating used ranges up to 30 minutes.

Other factors in processing, however, may also be of importance, such as, for example, the time that elapses between the time that the crab meat is picked and the time that it is pasteurized. Another factor of possible importance is the contact of the canned crab meat with the metal of the can.

The purpose of this paper therefore is to report on a study to determine the relation, if any, between the blueing of pasteurized crab meat and (I) the processing temperature and time, (II) the freshness of the crab meat prior to its being pasteurized, and (III) the exposure of the crab meat to metal.

I. RELATION OF BLUEING TO TEMPERATURE AND TIME OF PASTEURIZATION

In this first experiment, the crab meat was observed (A) visually for the development of blue discoloration, if any, in relation to the temperature and time of processing and (B) bacteriologically. The bacteriological analyses were made to give insight into the spoilage and public-health aspects of the temperature-time variations in the processing method.

A. VISUAL ANALYSES FOR BLUEING

1. Procedure

The procedure involved: (a) pasteurizing cans of crab meat, (b) measuring the internal temperature during pasteurization, and (c) making the visual analyses for color.

a. Pasteurizing the crab meat in cans.—Freshly picked crab meat was obtained from a local processor (live crabs were taken from the open waters of the Mississippi Sound in June) and was mixed to provide a homogenous sample. The picked crab meat was preprocessed at the plant as outlined by Ulmer (1964). Four point five ounces of the crab meat was packed in 307 x 113 C-enamel cans and sealed at atmospheric temperature and pressure. Two hundred and ninety cans were prepared in this manner and were divided into three lots. The differences in processing the cans in each lot were as follows: Lot 1 was heated to an internal temperature of 170° F.; Lot 2, to an internal temperature of 180° F.; and Lot 3, to an internal temperature of 190° F. Each lot was heated in boiling water until the internal temperature approached the desired temperature. The heat was then reduced to allow the cans of crab meat to remain at that temperature for the desired length of time. (The crab meat reached 170° in about 20 minutes, 180° in about 25 minutes, and 190° in about 30 minutes.) When the cans reached the desired internal temperature, a portion of each lot was removed after 5, 10, 20, and 30 minutes, and the cans were immediately cooled in running tap water. The samples obtained from all treatments were stored at 38° F. Samples from each treatment were analyzed in triplicate after 0, 1, 3, 6, 9, and 12 months of storage.

b. Measuring the internal temperature of the cans.—Before the pasteurization process began, thermocouples (copper-constantan) were placed in the geometric center of six cans of crab meat, and a seventh thermocouple was placed in the heated water to monitor its temperature. The thermocouples were connected through a junction box to a Leeds and Northrup[1] potentiometer calibrated to read temperature directly in degrees Fahrenheit. The cans of crab meat containing the thermocouples were positioned in the following manner: one was placed at the north side and one was placed at the south side of the bottom layer, two others were placed in the same positions in the top layer, and two others were placed at the east and west sides of the center of the pack. After the cans reached the desired temperature, the temperature was read and recorded at 1-minute intervals throughout the rest of the processing.

c. Making the visual analyses for color.—The degree of blueing was judged visually, as indicated in Table 1.

2. Results

Table 1 reports the visual ratings.

[1] Trade names are used merely to simplify descriptions; no endorsement is implied.

Table 1.—Results of visual and bacterial analyses of canned crab meat pasteurized at 170°, 180°, and 190° F. for varying lengths of time and stored at 38° F.

Processing time	Storage time	Visual rating for meat pasteurized at:			Bacterial-analysis data					
					Total plate count for meat pasteurized at:			Coliform MPN's for meat pasteurized at:		
		170° F.	180° F.	190° F.	170° F.	180° F.	190° F.	170° F.	180° F.	190° F.
Minutes	*Months*	[1]	[1]	[1]	*No./g.*	*No./g.*	*No./g.*	*No./100 g.*	*No./100 g.*	*No./100 g.*
0	0	0	+	+++	490,000	490,000	490,000	21,000	21,000	21,000
5		0	+	+++	<300	300	<300	<300	<300	<300
10		0	+	+++	<300	<300	<300	<300	<300	<300
20		0	+	+++	<300	<300	<300	<300	<300	<300
30		0	+	+++	<300	<300	<300	<300	<300	<300
5	1	0	+	+++	<300	--	<300	<300	<300	0
10		0	+	+++	<300	<300	<300	<300	<300	0
20		0	+	+++	<300	300	<300	<300	<300	0
30		0	+	+++	<300	300	<300	<300	<300	0
5	3	0	+	+++	500	500	<300	0	0	0
10		0	+	+++	<300	<300	<300	0	0	0
20		0	++	+++	<300	<300	<300	0	0	0
30		0	++	+++	<300	<300	<300	0	0	0
5	6	0	+	+++	<300	--	<300	--	0	0
10		0	+	+++	<300	--	<300	--	0	0
20		0	+	+++	<300	--	<300	--	0	0
30		0	++	+++	<300	--	<300	--	0	0
5	9	0	+	+++	<300	<300	<300	0	0	0
10		0	+	+++	<300	<300	<300	0	0	0
20		0	++	+++	<300	<300	<300	0	0	0
30		0	+	+++	<300	<300	<300	0	0	0
5	12	0	++	+++	<300	<300	<300	0	0	0
10		0	++	+++	<300	<300	<300	0	0	0
20		0	++	+++	<300	<300	<300	0	0	0
30		0	++	+++	<300	<300	<300	0	0	0

[1] 0 = no blueing.
\+ = very slight blueing.
++ = slight blueing.
+++ = moderate blueing.

Note: MPN means most probable number.

Pasteurization at 170° F. did not cause any immediate blueing with any of the processing times, and blueing did not appear during the 12-month period of storage. When the cans were opened, their contents had all the characteristics of freshly picked crab meat. Anzulovic and Reedy (1946) reported that pasteurizing meat of the blue crab at 170° F. (internal temperature) for 1 to 2 minutes did not produce blueing.

Pasteurizing at 180° F. caused a very slight (+) blueing to a light (++) blueing. At this temperature, some correlation existed between the blueing and (1) the increase in time of processing and (2) the length of time the cans were held in storage. Increased blueing appeared at the beginning of the 3-month examination and increased significantly at the 12-month examination.

Pasteurizing at 190° F. caused considerable blueing regardless of the length of time of processing. The intensity of blueing did not change during storage.

Table 1 thus shows a direct relation between the temperature of pasteurization of the crab meat and the intensity of blueing. The table also shows some indication that length of storage may contribute to this discoloration. Prolonged heating (5 to 30 minutes) at any of the processing temperatures did not intensify the blueing except in the lot processed at 180° F. The effect of the length of processing time at 180° F. on the blueing appeared during the storage period.

B. BACTERIAL ANALYSES

1. Procedure

Bacterial analyses consisted of TPC (total plate count) and coliform MPN (most probable number) determinations made according to standard bacteriological methods (incubation at 35° C.)

2. Results

Table 1 reports the data. The packed and unprocessed crab meat had an initial (0-month storage) total plate count of 49 x 10^4 per gram. When the cans were held at an internal temperature of 170° to 190° F. for 5 to 30 minutes, the bacterial count remained almost nil throughout storage. These cans, however, may not have contained any bacteria capable of growing and reproducing at 95° F. (35° C.). Byrd's patent (1951) calls for heat processing to an internal temperature of 171° to 210° F. for pasteurized crab meat. Table 1 shows that heat processing to 170° F. for 5 minutes is sufficient to destroy the bacteria, yet we observed that the meat retained its "freshlike" appearance. Littleford (1957) also recommended that pasteurization be carried out at 170° F. for 1 to 2 minutes and pointed out that prolonged exposure might infringe on the Byrd patent.

CAUTION: Although, in our study, processing at 170° F. for 5 minutes was sufficient to destroy 49 x 10^4 microorganisms per gram in the unprocessed product, if the preprocessing count had been substantially above 49 x 10^4 per gram, processing at 170° F. for 5 minutes might not have been adequate. Any processor who anticipates using this recommendation should first conduct a total-plate-count survey of his raw product over a period of time to establish the total-plate-count tendencies of the product and then should be guided according to his findings.

Recently, the possibility of botulism poisoning from pasteurized crab meat has been of serious concern, particularly when the meat is heat processed at 170° F. and then held under refrigeration. To date, no illness or fatality has been attributed to botulism poisoning from pasteurized crab meat, although this is not to say that it could not occur.

Commercially, pasteurized crab meat is generally held at about 40° F. for up to a year. Schmidt, Lechowich, and Folinazzo (1961) reported that mildly heat-shocked spores of four strains of Type E *Clostridium botulinum* produced toxin within 31 to 45 days when the culture was held at 38° F. The inoculum contained about 4 to 12 million spores per tube. Gross contamination of this order is not likely to be encountered, however, in the pasteurized crab meat industry. On the other hand, the question as to the maximum level of botulinum

spores necessary to cause the formation of toxin during the normal period (up to 1 year) of commercial storage under the normal temperature (40° F.) of storage is yet to be answered.

Conclusion from the Study of Temperature and Time

Pasteurizing meat of the blue crab at 170° F. (internal temperature) for 1 minute did not produce blueing yet was sufficient to maintain good quality for 12 months when the meat was stored at 38° F. Pasteurization at 180° F. for 1 minute induced a slight amount of blueing, which increased further after 3 months of storage. Considerable blueing was observed in the lot pasteurized at 190° F. The blue discoloration was evenly dispersed through the meat. All processing temperatures were sufficient to destroy 49 x 10^4 microorganisms per gram of the unprocessed crab meat.

II. RELATION OF BLUEING TO AGE OF CRAB MEAT BEFORE PASTEURIZATION

Before debacked and washed crabs are pasteurized, they sometimes are held in a cooler for 2 to 3 days during the weekend or when some malfunction in processing occurs. Crab meat that has been prepared as "fresh iced crab meat" but has failed to move into the market place may also be pasteurized after being held for some time. This second phase of the study was designed to determine if holding crab meat for varying lengths of time before it is pasteurized has an adverse effect upon the color of the product.

The study was divided into two parts. Part A was concerned with the aged crab meat before pasteurization; Part B, with the aged crab meat after pasteurization and during storage.

A. AGED CRAB MEAT BEFORE PASTEURIZATION

1. Procedure

Described here are the methods that were used to age the crab meat and then to analyze it.

a. Aging of the crab meat. — Freshly picked crab meat was obtained as in the previous experiment, thoroughly mixed, placed in 307 x 113 C-enamel cans, and divided into five lots. Lot 1 was analyzed immediately; Lot 2 was held 1 day at 38° F. before being analyzed; Lot 3 was held 3 days; Lot 4, 6 days; and Lot 5, 10 days.

b. Analyses. — The crab meat was analyzed organoleptically (visually), chemically, and bacteriologically. The meat was examined visually for blueing in the same way as in the previous experiment. The chemical analyses were for pH and for total volatile nitrogen determined by the Conway method as outlined by Farber and Ferro (1956). The bacteriological analyses were for total plate counts only, using nutrient agar incubated at 95° F. (35° C.) for 48 hours.

2. Results

Visual analyses (Table 2) revealed no blueing of the crab meat during the 10-day period of aging at 38° F.

As the unpasteurized crab meat aged, the pH increased only slightly up through the 6th day. The pH then increased markedly, indicating that the crab meat was beginning to spoil.

Table 2.—Analytical data on freshly picked crab meat aged up to 10 days by storage at 38° F.

Length of time unpasteurized crab meat was stored at 38° F.	Visual rating	pH	Total volatile nitrogen	Total plate count
Days	[1]		*Mg. N/100 g.*	*No./g.*
0	0	7.94	20.79	$3x10^4$
1	0	7.89	33.07	$5x10^4$
3	0	7.95	18.48	$7x10^4$
6	0	7.96	25.22	$136x10^4$
10	0	8.29	174.16	$4{,}200x10^4$

[1] 0 = no blueing.
+ = very slight blueing.
++ = slight blueing.
+++ = moderate blueing.

The total volatile nitrogen correlated well with pH in that when the pH increased markedly, the total volatile nitrogen also did, further indicating that the quality was decreasing.

The total plate count increased as the storage time increased, also correlating with the chemical analyses. Although the total plate count reached 136 x 10^4 on the 6th day of aging, spoilage odors were not noticeable until the 10th day.

B. AGED CRAB MEAT AFTER PASTEURIZATION AND DURING STORAGE

1. Procedure

After Lots 1 through 5 had been stored at 38° F. for 0, 1, 3, 6, and 10 days, respectively, as was described earlier, they were pasteurized commercially (that is, at 185° F. for 1 minute). Each of the five lots was divided into five sublots. Sublot 1 was analyzed immediately. Sublot 2 was analyzed after storage for 1 month at 38° F.; Sublot 3, after storage for 3 months; Sublot 4, after storage for 6 months; and Sublot 5, after storage for 12 months.

The method of analyses were the same as those used earlier.

2. Results

Table 3 reports the analyses of the aged crab meat that was pasteurized and then stored at 38° F.

Pasteurization did not affect the color. Except for the crab meat aged 10 days for which the pH increased markedly, the pH remained relatively unchanged.

In many of the samples, the total plate count was less than 300 microorganisms per gram.

Table 3.—Analytical data on pasteurized crab meat that was aged 0 to 10 days at 38° F. before being pasteurized commercially and then stored at 38° F. for 0 to 12 months

Time in storage		Visual rating	pH	Total volatile nitrogen	Total plate count
Unpasteurized crab meat	Pasteurized crab meat				
Days	*Months*	[1]		*Mg. N/100 g.*	*No./g.*
0	0	0	7.87	21.6	<300
1	0	0	7.87	22.2	1,400
3	0	0	7.91	26.6	<300
6	0	0	8.96	27.2	<300
10	0	0	8.58	170.8	<300
0	1	0	7.71	21.2	$2x10^4$
1	1	0	7.18	28.0	$3x10^4$
3	1	0	6.94	60.5	$>300x10^4$
6	1	0	8.10	27.1	$<3,000x10^4$
10	1	+	8.59	182.6	$<300,000x10^4$
0	3	0	7.68	19.4	$2x10^4$
1	3	0	7.90	27.3	$0.4x10^4$
3	3	+	6.95	104.6	$100x10^4$
6	3	+	7.95	20.3	$700x10^4$
10	3	+++	[2]	[2]	[2]
0	6	0	7.94	43.0	$50x10^4$
1	6	+	7.90	22.0	$300x10^4$
3	6	++	6.61	56.8	$200x10^4$
6	6	+++	7.70	26.6	$5,000x10^4$
10	6	--	[2]	[2]	[2]
0	12	0	8.29	21.9	$73x10^4$
1	12	0	7.85	25.1	$960x10^4$
3	12	+	7.37	110.2	$1,210x10^4$
6	12	+	8.34	41.2	$8,300x10^4$
10	12	+++	[2]	[2]	[2]

[1] 0 = no blueing.
+ = very slight blueing.
++ = slight blueing.
+++ = moderate blueing.
[2] Spoiled beyond experimentation.

Although the crab meat pasteurized immediately after being picked decreased slightly in pH (Table 3), it then increased continuously in pH for 3 months through 12 months of storage. The aged crab meat generally followed the same pattern except for the lot aged 6 days before being pasteurized. Samples decreased in pH during the first period of storage and then increased toward the end of storage at 12 months. (The pH of some iced seafoods at first increases with storage time and decreases when they become spoiled.)

The concentration of total volatile nitrogen in the stored crab meat changed somewhat erratically but usually increased when the pH increased. The total volatile nitrogen, however, did not correlate well with the bacterial count. The Conway method of determining total volatile nitrogen is not accurate enough even for this type of study because of the small amount of sample used — a fault of the method.

The total plate count of all samples increased during storage. The sample that was aged 10 days increased in total plate count so rapidly that the sample was completely spoiled after 1 month of storage and had to be discarded. Samples aged for 3 and 6 days prior to being pasteurized were spoiled when examined at the end of 6 months of storage. Nevertheless, the analyses were completed throughout the 12-month period. The crab meat that was aged only 1 day had a slightly putrid odor after 12 months of storage.

Conclusion from the Study of Pasteurization Aged Crab Meat

Results of this experiment is evidence enough that processors must not hold refrigerated unpicked crabs or picked crab meat more than 2 or 3 days before pasteurization. There is a direct relationship between the aged crab meat and its pasteurized counterpart — the longer the aging before pasteurization, the shorter the shelf life. Crab meat used in this experiment did not turn blue when processed at 185° F. This result is contrary to that reported in the previous experiment. Consequently, I believe that other factors, coupled with overheating of the meat, caused the blueing.

III. RELATION OF BLUEING TO EXPOSURE OF CRAB MEAT TO METALS

Iron sulfide discoloration of canned shrimp (due to the contact of the metal of the can with the shrimp) is sometimes observed, especially when the pH of the raw material is high. The discoloration is black or grey-black and is different from that sometimes encountered in pasteurized crab meat. The experiment reported here was to determine whether or not exposure of pasteurized crab meat to the metal of the cans or to solder, which is used in the manufacture of the cans, could cause blueing in the meat.

A. EXPOSURE OF PASTEURIZED CRAB MEAT TO METAL OF CANS

1. Procedure

About fifty 307 x 113 C-enamel cans were scratched (that is, the enamel was removed from several places on the inside of the cans and lids). The cans were then packed with freshly picked crab meat as in the two previous experiments and were processed under commercial conditions. Immediately after the cans were processed, six of them were examined for evidence of blueing. The remaining cans were stored at 38° F. and were examined at intervals of 1, 3, 6, 9, and 12 months.

2. Results

The cans of crab meat stored through 3 months showed no evidence of discoloration. At 6 months, light-brown rust spots appeared, however, where the crab meat was in contact with the side seam of the cans. The rust appeared only in small areas in the seams. The brown discoloration of the meat and the rusting of the side seams increased in intensity as the storage time increased beyond 6 months. The crab meat did not become discolored where the enamel had been scratched. The color of the meat during the entire storage period did

not change other than for the brown, rusty color. The scratched areas on the cans had turned dark, however, after 9 months of storage, indicating that the can had been detinned at the scratches.

Semling (1965) compared the pasteurization of crab meat in plastic "cans" with that of crab meat in conventional tin cans. He found that, after storage for 4 months, the crab meat along the side seams in the tin cans tended to be greyish and that the meat had a slight metallic taste. The crab meat in the plastic cans remained unchanged.

B. EXPOSURE OF PASTEURIZED CRAB MEAT TO CAN SOLDER

1. Procedure

Twenty-five cans of crab meat were pasteurized, stored, and examined as in the immediately previous experiment except that instead of the cans being scratched before the crab meat was pasteurized, small bits of solder were placed throughout the meat.

2. Results

The crab meat in contact with the solder showed no discoloration, and the color of the meat in the can did not change during the entire period of storage except where the meat was in contact with the side seam. Here the meat turned brown, as in the previous experiment.

Conclusion from the Study of Exposure to Metals

Exposure of pasteurized crab meat to the metal of the can or to solder used in the manufacture of the can does not result in blueing. The meat in contact with the side seam, however, may be discolored a rusty brown.

SUMMARY AND CONCLUSION

This study investigated three variables that might possibly be related to the blueing in blue crabs — namely, temperature and time during pasteurization, age of crab meat before pasteurization, and exposure of the crab meat to metals.

Temperature and Time

Freshly picked crab meat in C-enamel cans was pasteurized at 170°, 180°, and 190° F. for varying lengths of time, and the lots were stored for 12 months at 38° F. Pasteurizing the meat at 170° F. for periods up to 30 minutes did not cause the meat to develop any discoloration throughout the period of storage. Pasteurizing the meat at 180° F., however, caused some blueing, the intensity of which increased only slightly as the time of processing increased. The 3-month examination indicated that the blueing increased slightly during storage. Heat pasteurization at 190° F. caused considerable blueing, the intensity of which did not increase with length of processing time or of storage time.

Thus, under the conditions of this experiment, the crab meat could be pasteurized at 170° F., using processing times of up to 30 minutes, without the crab meat becoming blue. The length of time for processing would depend on the initial bacterial count of the raw material. The temperature at which the crab meat is pasteurized influences the blueing more than does the length of time that the meat is pasteurized or is held in storage after being pasteurized.

The blueing that accompanies the overheating of the crab meat is blue-grey and is evenly dispersed through the meat. It does not appear to be the same as that occasionally described in the literature as a true-blue discoloration. This difference in color may account for the differences between the causes and available remedies reported in this study and those reported in the literature.

Age of Crab Meat

The crab meat aged in a cooler for varying lengths of time before being pasteurized did

not change in color during storage, and the color did not change when the meat was pasteurized nor when it was subsequently stored at 38° F. Factors other than, or coupled with, heat is offered as an explanation of why the crab meat did not change in color when heated to 185° F. (commercial pasteurization). The shelf life of the pasteurized product is inversely related to the age of the fresh crab meat — that is, the longer the fresh meat is aged, the shorter is the shelf life of the pasteurized product. Debacked crabs or picked crab meat should not be held more than 3 days before being pasteurized.

Exposure of Crab Meat to Metals

When crab meat was pasteurized in C-enamel cans in which the enamel was purposely scratched, the meat became discolored only where it was in contact with the side seams of the can. This discoloration was brown, however, and was not typical of the blue color sometimes found in pasteurized crab meat. Another experiment also showed that solder is not the cause of blueing in pasteurized crab meat. Exposure of the crab meat during pasteurization and subsequent storage to the metal of the can or to the solder used in manufacturing the can apparently is not the cause of blueing in pasteurized crab meat.

General

Although blueing was associated primarily with overheating of the product, other factors (that is, the presence of Cu and Fe ions, tannic acid, and molting stage of the crab) doubtlessly require study before the blueing problem that the industry occasionally experiences can be elucidated completely.

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THE OCEAN QUAHOG, *Arctica islandica*, RESOURCE OF THE NORTHWESTERN ATLANTIC

by

Phillip S. Parker and Ernest D. McRae, Jr.

ABSTRACT

The ocean quahog is a species of marine clam. Some of the anatomical differences between it and the hard clam, *Mercenaria mercenaria*, are discussed. The range and population density of the ocean quahog in Continental Shelf areas off the Atlantic seaboard vary considerably with changes in water depths and bottom sediments.

Much of the basic information for this article was gathered during the survey of the surf clam, *Spisula solidissima*, by the Bureau of Commercial Fisheries. The gear, method used, procedure, and results of the survey pertinent to ocean quahogs are presented.

The ocean quahog resource is generally unused. It is waiting for anyone willing to reap the harvest.

CONTENTS

INTRODUCTION

The ocean quahog (Figure 1) is the only known living species of the family Arctididae (Abbott, 1954). This species is included in the large group of bivalves that make up about one-fourth of the known species of marine mollusks (Webb, 1935). Bivalves are characterized by having two opposed shells hinged together. The ocean quahog, which reaches

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Published September 1970.

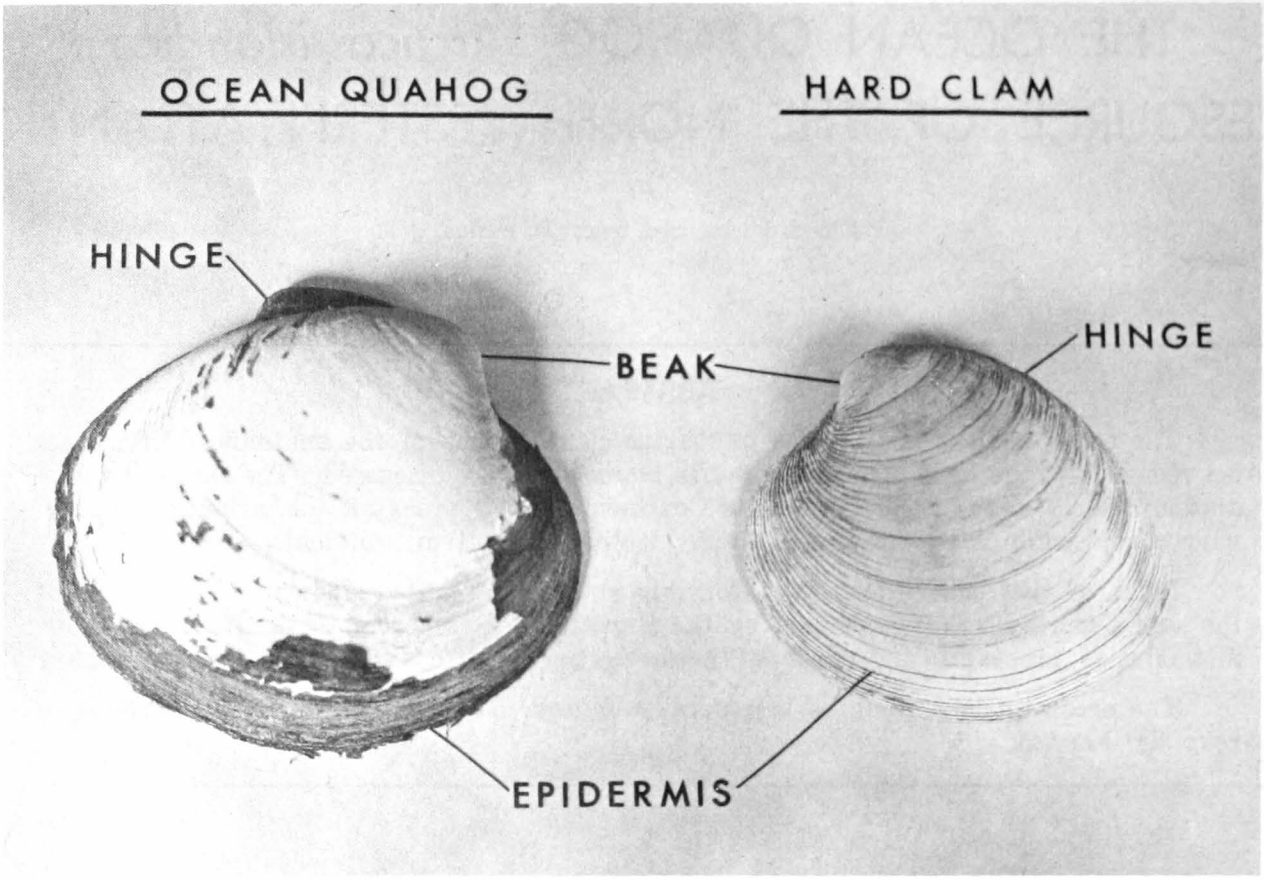

Figure 1.—Outer surface of shells of the ocean quahog and the hard clam. **The periostracum (labeled "epidermis" in photo) of the ocean quahog is nearly black; the periostracum of the hard clam is straw colored. The ligament or external part of the hinge is shown on the ocean quahog shell but is out of view on the hard clam shell.**

a length of 4 to 5 inches and a width of 3 to 4 inches, has nearly identical shells, with conspicuous "beaks" or umbos. An umbo forms initially from the embryonic shell and enlarges as the clam grows. The chitinous layer, or periostracum, on the exterior of the shell is wrinkled and is dark brown or black. Because of the distinctive color of the ocean quahog, it is often called "mahogany quahog" or "black quahog."

The ocean quahog can be distinguished from the hard clam (Figure 1), or quahog, which it closely resembles, in several ways. The first is the presence in the ocean quahog of one posterior lateral tooth in each valve; this tooth is missing in the hard clam (Miner, 1950). The second means of distinguishing between the two clams is by the presence or absence of a pallial sinus[1] (Figure 2) (Abbott, 1954). This sinus is absent in the ocean quahog but is present in the hard clam. The third means of distinguishing between the two clams (and probably the easiest way to differentiate fresh unpreserved specimens of the two species) is by the presence or absence of a distinct purple border around the edge of the shell on its inner surface (Figure 2). The purple border is absent in the ocean quahog but is present on the shell of the hard clam (Miner, 1950). The fourth means of distinguishing between the two clams, and probably the most characteristic, is the black or dark brown color of the outer layer of the ocean quahog (Figure 1). This character at once separates the ocean quahog from all other mollusks of a similar size and shape (DeWolf and Loosanoff, 1945).

[1] The pallial sinus is a V-shaped depression on the inner surface of the shell at the posterior end. Its presence indicates that the clam has a retractile syphon.

Originally, the ocean quahog was thought to be strictly a European species. Now, however, its known range includes also the U.S. side of the North Atlantic Ocean. Abbott (1954) gives the range of this species as being from Newfoundland to off Cape Hatteras in areas of sandy-mud bottom and in depths of 5 to 80 fathoms. Miner (1950) states that it ranges from the Arctic Ocean to Cape Hatteras in 6 to 90 fathoms. Medcof (1958)[2] has reported large stocks in the Southern Gulf of St. Lawrence; other beds have been reported along the coasts of Scandinavia, Greenland, and Newfoundland. In all probability, the full range of this clam has not as yet been accurately defined. It probably is present on much, if not most, of the Continental Shelf of the North Atlantic.

I. HISTORY OF RESOURCE

The presence of ocean qualog in the waters of Rhode Island and Massachusetts has been known for some time prior to World War II; however, ocean quahogs were not used as a food resource until May 1943 (Arcisz and Sandholzer, 1947). At that time, the war food program stimulated the commercial use of the ocean quahog.

A. QUANTITY PRODUCED

The annual catches of ocean quahogs have varied widely from the 720,000 pounds of meats taken in 1943. The outputs during the following years greatly exceeded this amount (Loosanoff, 1946) though the higher rate of production was not maintained for long (Table 1). This decrease in production probably was the result of several causes: (1) at about the same time a parallel industry was being developed off the coast of Long Island which used what seemed, at the time, to be an almost unlimited surf clam resource, (2) the strong flavor and aroma of the meats, the high processing cost, and storage instability of ocean quahogs, and (3) the availability of other clam species. Today, production is once again increasing with the 1969 catch estimated at

[2] J. C. Medcof. 1958. Mechanized gear for shellfish harvesting and shellfish culture. Fisheries Research Board of Canada, Manuscript Report Series (Biological) No. 644, 20 pp. [Unpublished.]

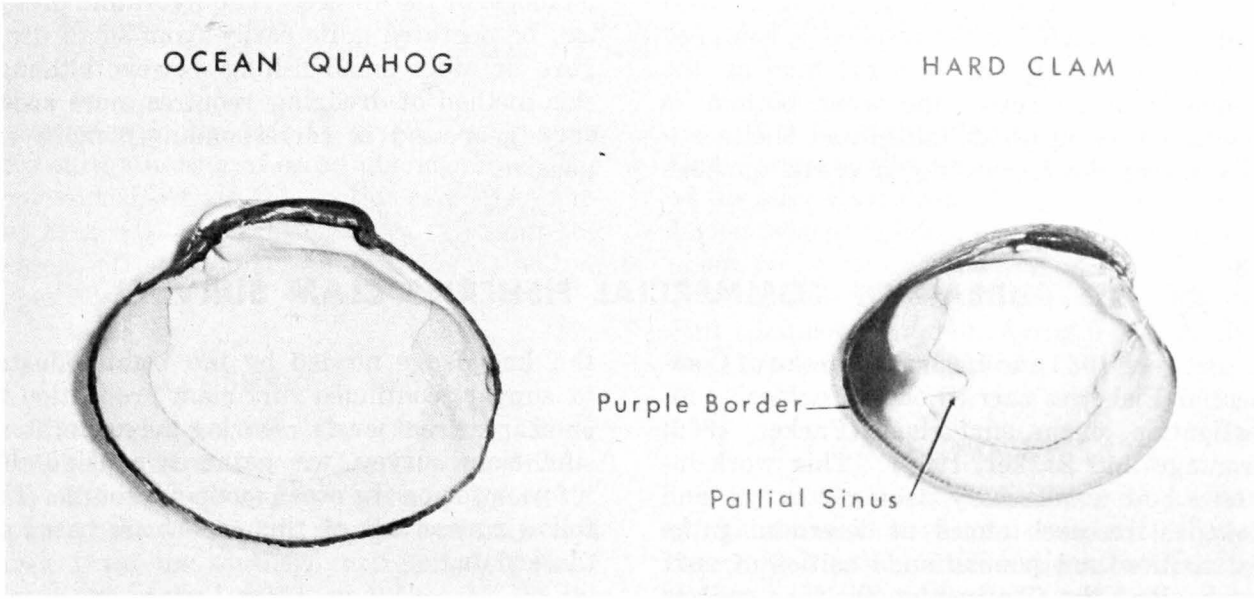

Figure 2.—Inner surface of shells of the ocean quahog and the hard clam. Note lack of pallial sinus and purple border on ocean quahog shell.

Table 1.—Annual catch and value of ocean quahogs harvested in Rhode Island and Massachusetts, 1956-68[1]

Year	Rhode Island production		Massachusetts production		Total production	
	Weight of shucked meats	Value	Weight of shucked meats	Value	Weight of shucked meats	Value
	Thousands of pounds	*Thousands of dollars*	*Thousands of pounds*	*Thousands of dollars*	*Thousands of pounds*	*Thousands of dollars*
1956	187	19	199	23	387	43
1957	127	13	262	35	389	48
1958	109	11	154	25	263	36
1959	95	10	--	--	95	10
1960	187	19	--	--	187	19
1961	124	12	--	--	124	12
1962	67	7	--	--	67	7
1963	104	10	--	--	104	10
1964	113	11	--	--	113	11
1965	93	11	--	--	93	11
1966	91	11	--	--	91	11
1967	45	6	--	--	45	6
1968	205	31	--	--	205	31

[1] Estimated catch for 1969 was 488,000 pounds of shucked meats valued at $73,000 for the State of Rhode Island and 72,000 pounds of shucked meats valued at $11,000 for the State of Connecticut.
Source: Fishery Statistics of the United States (figures rounded to the nearest thousand).

560,000 pounds of shucked meats. Increasing demand for ocean quahogs is the result of industry and Government solutions to many of the objectional processing problems and development of new products from the meats. These products are finding a favorable public acceptance.

B. HARVESTING METHODS

Ocean quahogs can be harvested by rakes and tongs in shallow water, but the commercial fisherman ordinarily uses some form of steel dredge. A simple boxlike steel cage, equipped with teeth for digging into the mud as the dredge is towed across the ocean bottom, is generally used in Rhode Island and Massachusetts where the harvesting of ocean quahogs originated. This type of dredge is commonly called a "dry" dredge; it contrasts to a "hydraulic" dredge, which uses jets of water to wash clams from the substrate. Historically, the dry dredge has also been called the Nantucket-type dredge, rocking-chair dredge, or queer dredge (Arcisz and Sandholzer, 1947).

We have found that a properly rigged hydraulic dredge (Figure 3) is an efficient way to harvest ocean quahogs. This type of gear, or some modification of it, will doubtlessly become the standard method of harvesting ocean quahogs in the future. The hydraulic dredge can be operated quite easily from small draggers or other small fishing vessels, although this method of dredging requires more accessory gear and is correspondingly more expensive.

II. BUREAU OF COMMERCIAL FISHERIES CLAM SURVEY

Between 1963 and 1967, the Bureau of Commercial Fisheries carried out an extensive investigation of the surf clam (Parker, 1966; Groutage and Barker, 1967). This work included both exploratory fishing surveys and biological research aimed at determining the distribution and population densities of surf clams along the Continental Shelf as well as the life history, ecology, and biology of that clam. The purpose of this work was to gain the knowledge needed by the clam industry to support continued surf clam production at or near current levels. During the exploratory surf clam survey, we gathered considerable information on the ocean quahog resource. The following sections of this report are based on those data.

Parker (1966) has described fully how the surf clam survey was made, so only a cursory

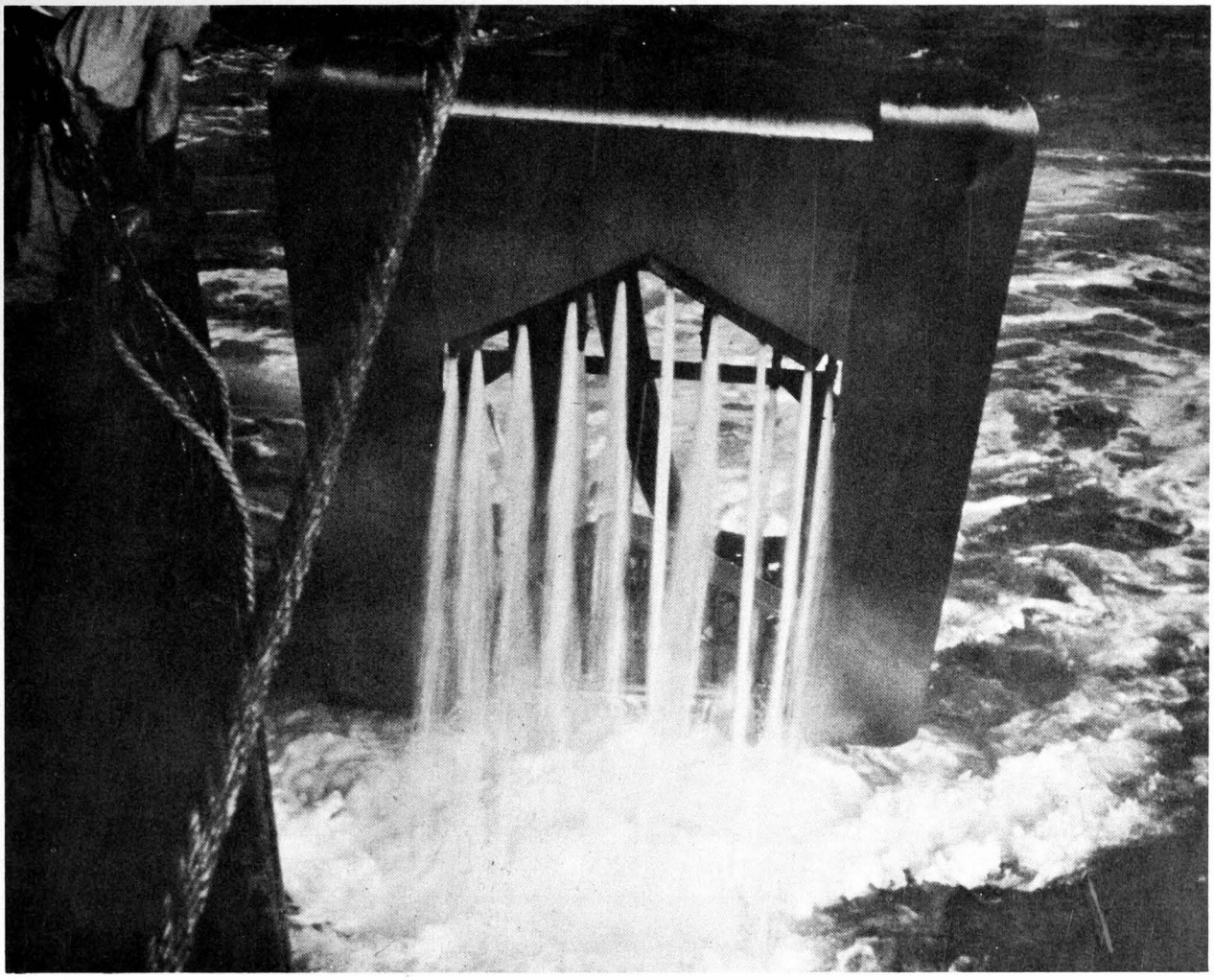

Figure 3.—Hydraulic jet dredge. This view shows the underside of the dredge with water flowing through the jets. An after section, called the "cage," is hinged to the trailing end of the dredge and, in this photo, is still submerged. The cage, with an attached chain bag, holds the catch.

description is included to provide an insight into our gathering of ocean quahog data. The topics considered in this section are: (A) survey area, (B) sampling stations, (C) sampling vessels, (D) sampling results, and (E) bottom types.

A. SURVEY AREA

The region between Cape Hatteras, North Carolina, and Eastport, Maine, was divided into 10 separate survey areas (Figure 4). Some work was done in all of the areas except Area 1 (at the southern extremity), Area 7 (near the central part), and Area 10 (at the northernmost extremity). The major survey effort was concentrated in Areas 2 through 6, along the Virginia, Maryland, Delaware, and New Jersey coasts, generally within the range of the surf clam fleet. In Areas 2 and 3, the survey was completed. In Area 4, it has been about 50-percent completed; in Area 5, about 40-percent completed; in Area 6, about 25-percent completed; and in Areas 8 and 9, about 5- to 10-percent completed.

B. SAMPLING STATIONS

Within the individual survey areas, sampling stations were positioned at locations determined by the intersections between predetermined Loran (Long Range Aid to Navigation) gridlines. The gridlines were selected so that the stations were located about 1 mile

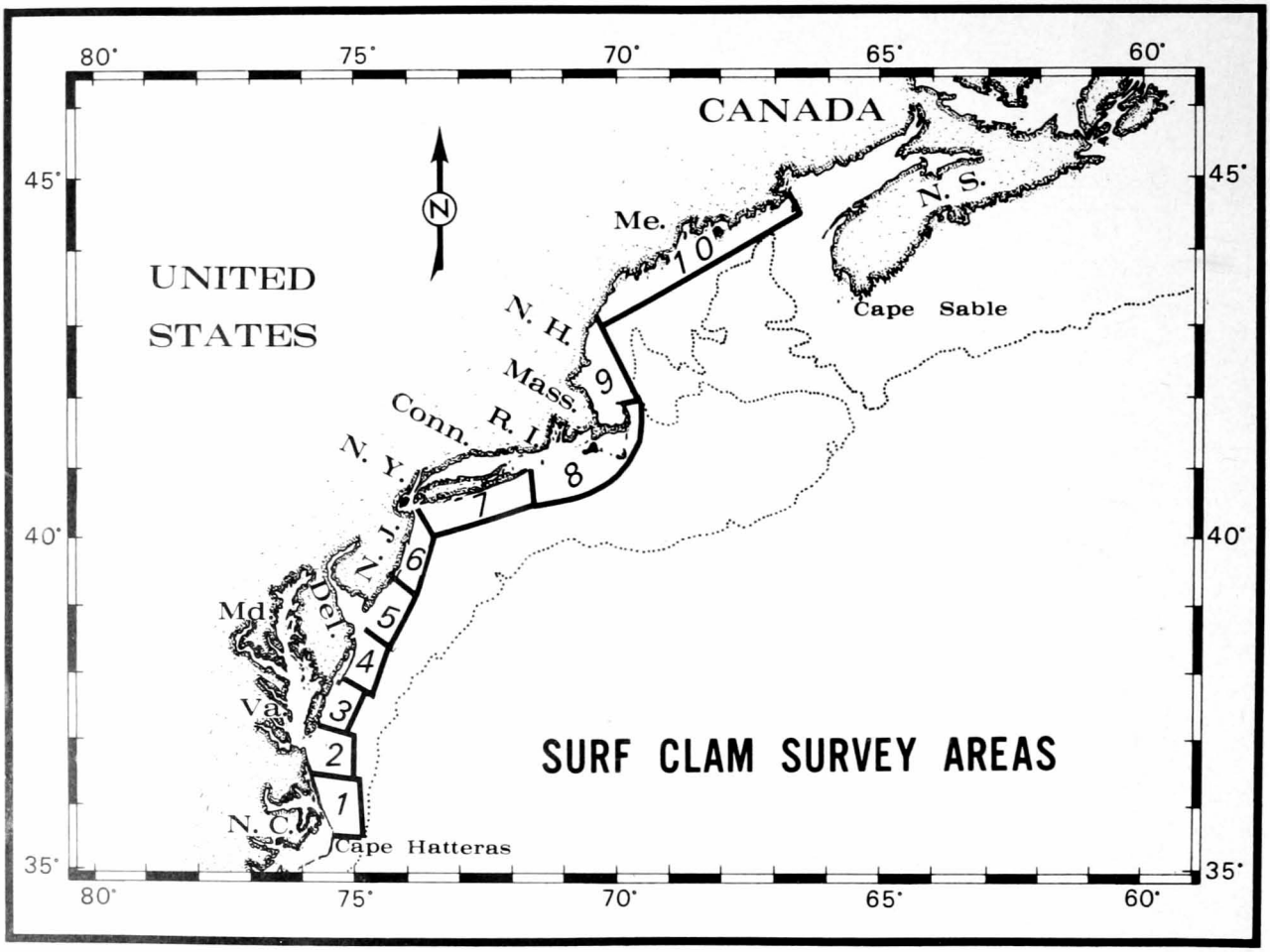

Figure 4.—Areas designated as "survey areas" for planning purposes as well as use during field operations of the Bureau's surf clam survey.

apart. This method provided the most precise means for positioning the vessel. Sampling tows lasting 4 or 5 minutes were made at each survey station. The data recorded from each sample included a tally of the number of ocean quahogs in the catch as well as the size measurements from a representative sample. We analyzed collectively and estimated the standing crop of ocean quahogs within the survey areas.

C. SAMPLING VESSELS

During the survey cruises, various vessels and sampling gear were used. We have adjusted to compensate for the differences in the various sampling gear. Specific data collected during the summer of 1963 aboard the commercial vessel *Mabel Susan* have been included in length frequencies and in other related biological analyses but have not been included in the calculated estimates of the population. During the 1964 work aboard the Bureau's research vessel *Rorqual,* a 40-inch "standard" hydraulic jet dredge was used. Since 1965, all work has been carried out aboard the Bureau's research vessel *Delaware* (I).[3] A 48-inch hydraulic clam dredge (Figure 5), of a design similar to that now used by the commercial clam fishermen, was used during the *Delaware* (I) cruises. The data collected aboard the vessels *Delaware* (I) and *Rorqual* have been used in all the analyses presented here.

D. SURVEY RESULTS

During the surf clam survey by the Bureau of Commercial Fisheries, 3,915 tows were made

[3] The *Delaware* (I) has been retired from service and replaced by the *Delaware II.*

Figure 5.—Complete hydraulic jet dredge as viewed from the stern. The bag and the cage (to which the bag is attached) were submerged in Figure 3. Note the "blade" of the dredge extending below the runners of the dredge. The blade is spring-mounted and will ride over the surface of the bottom when the dredge is being towed with the jets turned off. When the jets are on and cutting a trench, the blade will follow and retain contact with the bottom of the trough.

in 6 of the 10 survey areas. In Area 9, an additional 54 tows were made in which two hydraulic dredges of different design were compared (one of these dredges used a vessel-mounted pump, whereas the other used a dredge-mounted submersible pump). The results of the Bureau explorations indicate that the ocean quahog inhabits extensive areas of the Continental Shelf between Gloucester, Massachusetts, and Cape Hatteras, North Carolina.

Ocean quahogs were generally concentrated in beds rather than being uniformly distributed over the bottom. The density and size of the beds varied considerably within the areas explored. Some of the beds produced ocean quahogs at a rate of 20 bushels per 4-minute tow with the 48-inch hydraulic clam dredge, but many of the tows took no ocean quahogs. The size of individual beds was quite variable.

Within the Continental Shelf areas surveyed between Cape Hatteras and Massachusetts, the best catches were made in depths of 18 to 24 fathoms (Table 2).

Data were collected on the size range of ocean quahogs in the catches during all cruises; however, each of the sampling dredges was selective because of design and construction features. Many of the small size ocean quahogs could pass through the dredges; however, this escapement was not the same for each dredge. In the dredges used during the early explorations, the spacing of the dredge slats was less than that on the dredges used during later cruises. For this reason, the smallest size of clams that could be retained was variable; that part of the data is correspondingly incomplete. Very few ocean quahogs under 2.4 inches long were taken (Table 3). Most of the ocean quahogs were about 2.8 to 4.3 inches. Data in Table 3 indicate that the percentage of clams retained by all dredges increased rapidly with an increase in the size of clams from about 2.4 to 3.1 inches long; most of the clams over about 3.1 inches long seem to have been retained, and perhaps all of them were. This selectivity of size is very similar to that found with the surf clams.

Table 2.—Depth distribution of ocean quahog in selected survey areas

Depth of water	Average catch of ocean quahogs taken per tow in:					
	Area 2	Area 3	Area 4	Area 5	Area 8	Area 9
Fathoms	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
6	0	0	0	0	0	0
7	0	0	0	0	0	55
8	0	0	0	0	0	51
9	0	0	0	0	1	0
10	0	0	0	0	1	52
11	0	0	0	0	3	41
12	1	1	0	0	11	191
13	2	1	0	1	23	90
14	1	1	0	1	25	--
15	3	1	11	4	117	--
16	2	1	1	41	67	--
17	2	2	24	92	162	--
18	3	1	38	147	190	--
19	4	2	43	212	296	--
20	5	29	181	323	210	--
21	5	6	191	420	92	--
22	7	48	179	240	52	--
23	5	44	221	267	2	--
24	3	41	142	--	0	--
25	1	86	64	--	--	--
26	3	23	138	--	--	--
27	--	11	--	--	--	--
28	--	14	--	--	--	--

Note: The dashed spaces in the columns indicate depths not surveyed. All tows were 4 minutes in duration for some of those made in Area 3, which have been adjusted for their differences.

Table 3.—Number of ocean quahogs, in 10-millimeter length intervals, taken in all survey areas

Length interval		Ocean quahogs taken
Millimeters	*Inches (approx.)*	*Number*
20-29	0.8-1.1	2
30-39	1.2-1.5	28
40-49	1.6-1.9	48
50-59	2.0-2.3	154
60-69	2.4-2.7	501
70-79	2.8-3.1	2,515
80-89	3.1-3.5	7,873
90-99	3.5-3.9	10,191
100-109	3.9-4.3	4,028
110-119	4.3-4.7	673
120-129	4.7-5.1	50

Table 4 shows the numbers of ocean quahogs taken from each survey area according to length, in 10-millimeter intervals, without regard to depths of occurrence. This table indicates that the length-frequency curves would be slightly different for different areas. Because data have not been collected yet on the entire depth range of the ocean quahogs in these areas, statistical conclusions cannot be drawn at this time. We should point out that, although no ocean quahog taken in Area 9 was longer than about 3.9 inches, this length limitation may possibly have occurred either because the beds sampled in Area 9 were located in the shallower inshore waters or be-

Table 4.—Number of ocean quahogs, in 10-millimeter length intervals, taken in each of the seven survey areas

Length interval		Ocean quahogs taken in:						
		Area 2	Area 3	Area 4	Area 5	Area 6	Area 8	Area 9
Millimeters	*Inches (approx.)*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
20-29	0.8-1.1	--	2	--	--	--	--	--
30-39	1.2-1.5	--	20	--	--	6	1	1
40-49	1.6-1.9	--	21	--	1	12	14	--
50-59	2.0-2.3	2	19	3	1	13	90	26
60-69	2.4-2.7	20	180	29	43	9	122	98
70-79	2.8-3.1	33	1,046	347	619	70	309	91
80-89	3.1-3.5	201	1,886	1,853	1,806	301	1,763	63
90-99	3.5-3.9	284	1,607	3,543	1,933	594	2,213	17
100-109	3.9-4.3	98	489	1,572	825	558	486	--
110-119	4.3-4.7	32	35	183	162	238	23	--
120-129	4.7-5.1	--	--	2	10	38	--	--

cause the beds were located in areas outside of the optimum conditions for the growth of this clam.

E. BOTTOM TYPES

During surf clam surveys by the Bureau, bottom sediments were determined at each sampling station. The various bottom types were grouped into general categories. These data show that ocean quahogs were taken most often from sandy areas and that the largest average catches were made in sandy mud or in sediments that had a large proportion of sand. Catches were also taken from gravel, mud, clay, and "unknown" types of bottom (probably very hard) but with less frequency.

III. POTENTIAL OF THE OCEAN QUAHOG RESOURCE

As was stated earlier, ocean quahogs have been taken at the rate of 20 bushels per 4-minute tow from highly productive beds. This concentration of clams may be near the maximum density for this species in the region north of Cape Hatteras. For a square-mile bed with this density of clams (the area could either be a part of a large bed or parts of the necessary number of smaller sized beds needed to reach this total area), the standing population would be about 300,000 bushels of ocean quahogs. Because a bushel of whole ocean quahogs yields an average of 10 pounds of meats, an area containing this quantity of clams would produce 3 million pounds of meats. In other areas, the possible production of ocean quahogs would be less than the above-indicated maximum and could range downward to only a few bushels of clams or pounds of meats per square mile.

From the data compiled to date, a conservative estimate of the standing crop of ocean quahogs between Cape Hatteras and Canada would be between 100 and 150 million bushels. A sustainable rate of cropping would probably be at least as great as 10 percent per year, or an annual harvest of more than 100 million pounds of meats. Of course, the possible yield during the first few years of concentrated harvesting would be much greater.

CONCLUSIONS

The current yearly harvest for ocean quahogs in the United States is about 500,000 pounds of meats, although the reported annual catch fluctuated between 45,000 and 389,000 pounds between 1956 and 1968. This use of the resource is inadequate in comparison with its estimated potential sustainable yield.

In the near future, the production of surf clams will probably reach the level of nearly maximum sustainable yield. Production of the soft clam, *Mya arenaria*, will probably increase in some areas, particularly in the Middle Atlantic Coastal States; however, because of increasing pollution in other areas, total yields may remain at nearly the present level. The production of hard clams will probably remain at or about the same levels with only small chances for an increase of large proportion.

As a result of these circumstances, any future major expansion of the clam fishery in the Northwestern Atlantic area of the United States will probably depend upon increased use of underutilized clam resources. The ocean quahog is the largest known and unexploited clam resource available in this area. This resource occurs in great abundance along the Atlantic Coast and is within easy reach of present harvesting gear. It is waiting for anyone willing to harvest it.

SUMMARY

The ocean quahog is also known by the common names "mahogany quahog" and "black quahog." This clam closely resembles the hard clam, but the two species are fairly easy to separate.

The ocean quahog occurs extensively along the Atlantic Seaboard north of Cape Hatteras. Incomplete information is available on the abundance and distribution of this clam; however, additional knowledge of its distribution and occurrence was gathered incidental to the surf clam survey by the Bureau of Commercial Fisheries between 1963 and 1967.

In the past, ocean quahogs have been commercially harvested in small quantities, and production reached a peak in 1944. The current production is about 500,000 pounds of meats annually. The potential U.S. sustainable yield of this resource is estimated conservatively as being about 100 million pounds of meats annually.

The total production from other clam resources is not expected to increase markedly in the future. The use of the ocean quahog resource offers a good possibility for filling future increases in the need for clams.

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