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An Evaluation of At-Sea Handling Practices: Effects on Sea Scallop Meat Quality, Volume and Integrity

William D. DuPaul
Virginia Institute of Marine Science

Robert A. Fisher
Virginia Institute of Marine Science

James E. Kirkley
Virginia Institute of Marine Science

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William D. DuPaul, Robert A. Fisher and James E. Kirkley

College of William and Mary, School of Marine Science
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

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EXECUTIVE SUMMARY

Weight changes in shucked sea scallops during vessel stowage was determined for three commercial fishing trips during the summer of 1989 and 1990. Bags (N=576) of scallop meats (36-40 lbs.) were weighed prior to stowage in ice holds then reweighed at offloading. The holding (deck treatments) of shucked scallops on deck prior to bagging had a significant impact on weight changes of scallop meats both on deck and during stowage. Deck treatments tested included ice:seawater (1:2), seawater at ambient temperatures, ice:freshwater, dry at ambient temperatures and a soak in sodium tripolyphosphate (STP). Temperatures were determined for on-deck conditions, deck treatments and the internal core of filled scallop bags.

Weight gains for scallops held in various deck treatments ranged from 0% for seawater and dry holding conditions to 22% for ice:freshwater. Scallops held on deck prior to bagging in an ice:seawater (1:2) mix resulted in more conservative weight gains ranging from 9.4 to 12.6% on average for the three fishing trips. Subsequent weight changes during stowage ranged from 3.6 to 5.4% for ice:seawater deck treatment, 2.1 to 6.0% for seawater, 1.8 to 4.1% for dry and 1.0 to -0.3% for ice:freshwater deck treatments.

On-deck thermal abuse of sea scallops resulted in diminished product quality and weight uptake during stowage.

Scallops held at temperatures above 72°F prior to bagging became "wafered" and were considered thermally abused. Temperature of scallops held in ice:seawater or ice:freshwater deck treatments averaged from 39.5 to 51.9°F at time of bagging. Temperatures of scallops held in dry or seawater deck treatments averaged from 72.1 to 78.6°F. The use of insulated totes and a 1:2 ice:seawater mix to hold scallops on deck is a recommended handling procedure to minimize thermal abuse during the summer. Results of processing of stowed scallops with a 2.5% STP and 1% NaCl solution indicated that variables such as stowage time, deck treatment and the degree of thermal abuse were significant. Data on weight changes due to water uptake, thaw drip loss and cooked loss indicated that processors should set predetermined objectives for their processing operations.

INTRODUCTION

The sea scallop, Placopecten magellanicus, supports a valuable commercial fishery throughout much of its range from Newfoundland to north of Cape Hatteras. Over 33 million lbs. of sea scallops with an ex-vessel value exceeding $132 million was harvested in U.S. waters during 1989. In the mid-Atlantic region, commercial harvesting activity has increased dramatically since the mid-to-late 1970's with Cape May, New Jersey and Hampton Roads, Virginia, the major ports for sea scallop landings. Vessel activity in Hampton Roads increased rapidly from 5 full-time scallop vessels in January 1977 to over 51 vessels by the end of 1978. The number of scallop vessels operating out of Virginia ports reached an all-time high of 115 vessels during the Fall of 1979. The number of vessels have stabilized at around 50-60 vessels since 1979.

Sea scallops are Virginia's most valuable landed seafood exceeding $24 million for the past several years. The mid-Atlantic region has become an important sea scallop resource area contributing to over 50% of the U.S. landings and consequently supports a valuable fishery with an important regional economic impact.

Vessel operations in the mid-Atlantic have some difficult challenges during the summer months. The combination of warm sea water temperatures, hot weather and the tendency for extended trips, often exceeding 15 days, has the potential to create problems relative to product quality. Under such conditions, handling practices on deck and in the ice-hold have to be under fairly rigid control and there is little room for careless attitudes.

The impetus for this project was based on industry's concern about product quality and the need to improve handling practices on board fishing vessels. As seafood quality and safety issues become increasingly important both in the marketplace and for regulatory considerations, the industry must constantly seek improvements in the handling, processing and transportation of seafood.

PURPOSE

Sea scallop fishing operations in the mid-Atlantic region are conducted on a year-round basis from east of the Virginia Capes to northern New Jersey and southern Long Island in water depths of 22-37 fm. Seasonal changes in biological parameters, water temperature and temperatures on deck during shucking and handling operations can vary widely. During July and August, sea water surface temperatures between 70-78^{o}F are common and can exceed 80 degrees F for short periods of time. Air temperatures can range from 70-78^{o}F in the protection of shucking houses to over 90^{o}F on surfaces exposed to the sun.

On occasion, harvested scallops are allowed to accumulate on deck, sometimes with little shelter or an occasional spraying with seawater in an attempt to cool the scallops before shucking. This happens when the harvesting capacity of the vessel exceeds the shucking capability of the crew. Invariably, these scallops are exposed to warm temperatures and drying wind and the shucked meats are subject to poor quality characteristics consistent with thermal abuse. However, some vessels make an effort to match harvesting capability with shucking capacity to avoid these problems during the summer months.

Nonetheless, shucked sea scallop meats have been observed to be held on deck in plastic trash cans or stainless steel wash tanks, some with sea water and some without, for 6, 8 or 12 hours prior to bagging and icing in the hold. This time interval is generally determined by the watch schedule as bagging is done at the end of each watch.

Preliminary data indicated that internal bag temperatures at the time of bagging often exceeded 70^{O}F and were recorded as high as 76^{O}F. Little or no information was available on the internal cooling rates of scallop bags once stowed in the ice hold. No documentation was available as to the best way to chill scallop bags as several different procedures were used depending upon the vessel and what the captain or crew members believe. An obvious solution to the problems caused by thermal abuse is to keep scallops cool during shucking operations and pre-chill scallops just prior to bagging. However, how to best accomplish this without totally disrupting on-deck fishing operations and using excessive amounts of ice has not been examined. Any solution has to be reasonably compatible to normal fishing operations and be readily accepted by captain and crew.

During the summer, particularly from June through September, the incidences of thermal abuse and product mishandling are becoming more frequent. These abuses, manifested by product and bag discoloration, noxious odors, wafering of scallop meats, the inclusion of grit, or the loss of textural qualities and shelf life are becoming a source of concern within the scallop industry.

The product quality problems associated with thermal abuse and careless handling practices are sometimes compounded as the result of soaking and mixing scallops meats on-board vessels to comply with the regulatory constraint of meat count restrictions. The current study does not attempt to directly address these problems as they are beyond the scope of the proposed work. However, because of the potential interaction between the at-sea practices to improve or maintain quality and the indirect concerns with regulatory compliance, one cannot totally separate the issues in deciding how to best approach a solution to product quality and at-sea handling.

At-sea handling practices have profound effect on some of the physical parameters of quality and meat integrity. Little or no information is available with regard to changes in weight during stowage nor was there a good understanding as to how on-deck handling affects these changes. There is a strong suspicion that factors such as thermal abuse, wafering, soaking in fresh water or the use of ice on deck were important, but no quantitative information is available to industry.

In addition to weight changes during stowage, other parameters such as product discoloration and textural changes have to be evaluated relative to on-deck handling procedures and pre-chilling strategies. Scallop quality at off-loading is often determined by coloration, odor, the percentage of meat pieces and texture. Consequently, any modifications of handling procedures should be evaluated relative to the perceptions of product quality at off-loading.

The evaluation of at-sea handling practices as they affect sea scallop quality, volume (weight) and meat integrity cannot stop at the point of offloading. The performance of scallop meats during retail marketing of fresh product or processing to frozen product must also be considered. The questions relating to at-sea handling practices as they affect shelf-life and appearance is poorly understood. A large portion of sea scallop landings are frozen and stored for future use. Quality control issues such as drip loss and the effectiveness of processing aids such as sodium tripolyphosphate (STP) are poorly understood as they relate to what happens on deck and in the ice holds of fishing vessels. Obviously, even seemingly small effects would probably be immensely important to plants processing large quantities of sea scallops, however, no quantitative information is available to industry. Interestingly enough, buyers and processing operations often discount ex-vessel prices based on the perception that product abuse or adulteration occured on the fishing vessel, even without full knowledge of what actually occurred.

PROJECT OBJECTIVES

* Document existing scallop vessel handling and stowage practices common to the mid-Atlantic region.

* Determine changes in sea scallop meat weight, quality and integrity relative to existing commercial practices, fishing area and biological parameters.

* Develop and test alternative handling practices which minimize temperature abuse and improve scallop meat quality and integrity.

* Determine the effects of at-sea handling practices and stowage time on quality control parameters of processed (frozen) sea scallops.

* Determine actual or potential economic benefits resulting from modified scallop vessel handling and stowage practices.

* Develop a series of recommendations and reports for sea scallop vessels.

APPROACH

General Considerations

Because the primary intent of this project was to evaluate and modify, if necessary, commercial at-sea handling practices, work was conducted on commercial sea scallop dredge vessels during normal fishing operations. Minimal interference was imposed on fishing areas, vessel operations and crew size. However, strict control was exerted on product handling practices but these controls were well within the capability of the vessel and crew to adopt with minimal inconvenience. Invariably, captains and crews were helpful and cooperative beyond reproach and without their assistance, the success of the at-sea work would not have been possible.

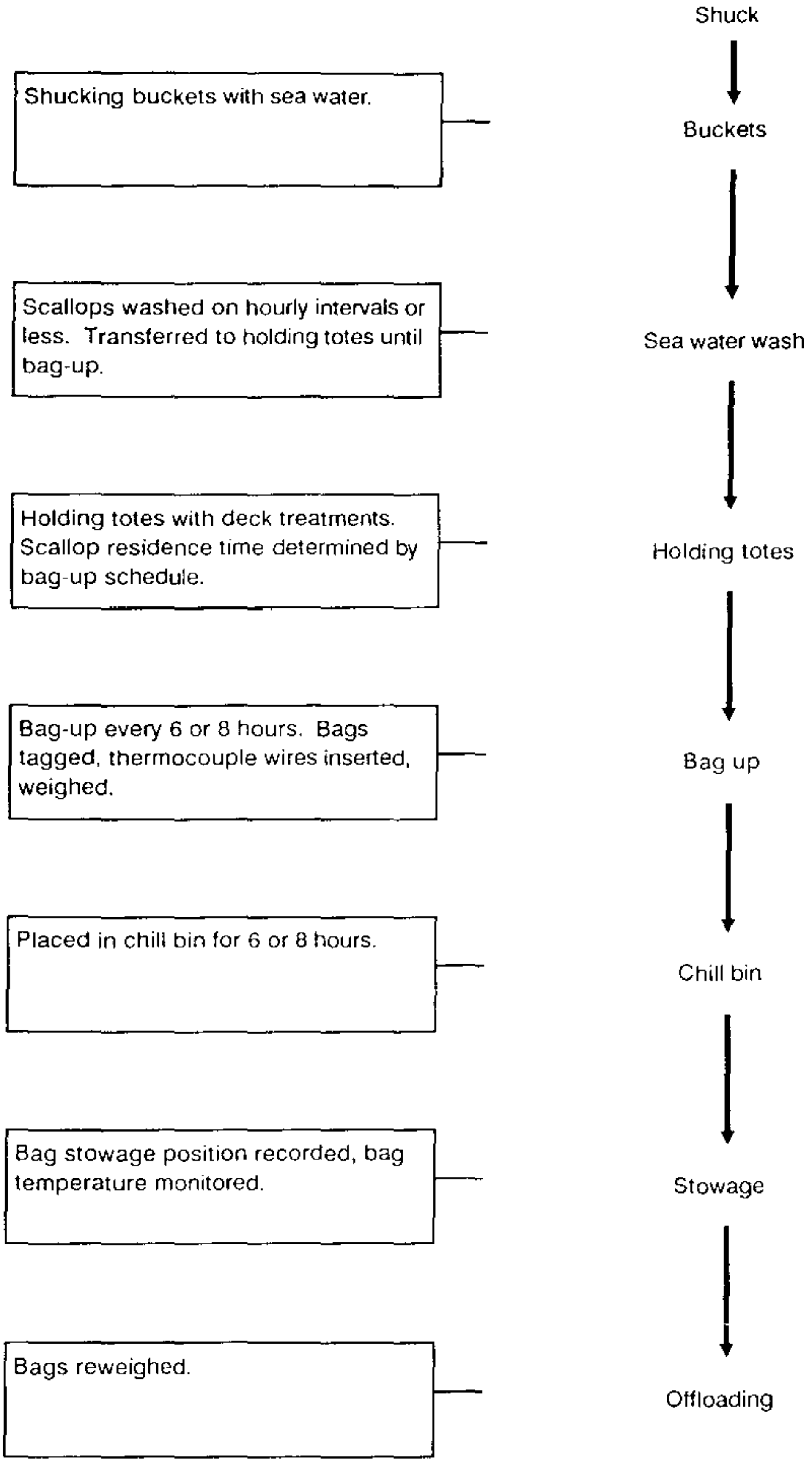
Three sea scallop fishing trips were conducted during the months of July and August. Data from these three trips comprise the primary basis for this report; however, some preliminary data which was used to formulate experimental designs was obtained on one preliminary trip not directly associated with this project. Fishing vessel operations were conducted in the mid-Atlantic region from Virginia to northern New Jersey in water depths ranging from 22-37 fm. Trips varied in duration from 12-21 days dock-to-dock. Exemption from the Federal meat count standard was obtained from the National Marine Fisheries Service, Northeast Fisheries Center, in cooperation with the New England

Fisheries Management Council. This exemption facilitated the necessity of altering normal sea scallop handling and stowage. Vessels were not allowed to mix scallop meats to obtain a legal average count nor were they allowed to disturb bags of scallops once iced and stowed. Shucking, bag-up times, bagging practices, icing and stowage were strictly controlled to insure conformity to experimental designs and to minimize sources of variability of test results.

Deck Operations

Sea scallops were landed on deck, culled, shucked and processed in accordance with normal industry practices (Figure 1). Scallops were shucked into buckets with sea water. Hourly, individual buckets were emptied into plastic baskets which facilitated washing with sea water both from the deck hose and in 55 gallon circular trash cans. Care was taken to wash the scallops thoroughly as no further washing of the scallops would be done beyond this point. Scallops were evenly divided and placed into two insulted totes containing ice:seawater (1:2), sea water, ice; freshwater, a solution of 2.5% sodium tripolyphosphate and 1% sodium chloride by weight, or nothing (dry) until bag-up. These are, hence, referred to as "deck treatments." Generally, two deck treatments were used for each deck watch and various combinations of treatments were used throughout

Figure 1. Sea Scallop Vessel Operational Diagram.



the trip (i.e. seawater vs. dry, ice seawater vs. seawater, etc.). Scallop meats were held in insulated totes until bag-up and were not rewashed with seawater prior to bagging. Scallops from different deck treatments were not mixed and were bagged separately.

The use of insulated totes on-deck as holding containers for scallops prior to bagging facilitated the need to control and standardize handling procedures as much as reasonably possible. The totes provided cover and protection from the sun and other undesirable elements. They also provided a mechanism by which to keep scallop meats at relatively constant temperatures whether the scallops were kept in sea water or other deck treatments not entailing the use of ice. In the case when ice was used in conjunction with sea water or fresh water, it was desirable to use as little ice as necessary as during extended trip during the summer months, ice is at a premium. Generally one basket of ice was used per tote for the duration of a 6 or 8 hour watch and was sufficient for at least 240 lbs. of scallop meats. In order to maintain a consistent 1:2 ratio of ice to seawater, a permanent reference mark for seawater was made on the inside of the tote.

The insulated totes used were obtained through Polar Industries of Baltimore, Maryland. The totes measured 43 X 24 X 28 inches with a capacity of 9 cubic feet and weighed 66 pounds. The totes are constructed of one-piece polyethylene with a polyurethane foam core. The totes can be kept covered with easily removable tops with corner tie-downs to secure the tops during rough weather. The totes were of sufficient durability to be used on deck without undue concern.

Bagging was done on 6 or 8 hour intervals depending upon watch schedules but remained consistent for the duration of a particular trip. Scallop meats were bailed from the totes and bagged according to normal procedures. Approximately 38 pounds of scallops were placed in linen bags and secured with galvanized metal twist ties. Bags to be weighed were labelled designating deck treatment, date and time.

Bag Weight Determination

In order to determine the change in weight of scallops during stowage, bags of scallops from each deck treatment had to be weighed prior to icing in the hold. Bags were weighed to the nearest 0.1 lb. using a Micro Weigh (R) Series 540 Seagoing Scale with an accuracy of ± 0.2%. The Micro Weigh Seagoing Scale was used for two of the three trips. The scale used for the other trip proved unsatisfactory for the needs of the project design. Bags were then rinsed with seawater and immediately placed in the ice hold. Upon offloading, bags were reweighed using the same scale. During the course of the project, weight changes were determined for 576 bags.

Meat Count Determination

Meat count (meats per pound) were determined using a one pint frosting cup which is commonly used aboard commercial vessels. Five counts were made for each determination. Meat counts were determined at time of bag-up for each deck treatment and immediately after shucking prior to deck treatment. These data were used to assess changes in meat count (weight) attributed to the various deck treatments.

Temperature Determination

Temperatures were determined using an Omega (R) HH-51 Digital Thermometer with Type K Chromel-Alumel Thermocouples (connectors and wire) with a resolution of 0.1°C. Temperature data was obtained during each watch for which tests were being conducted. During the watch and at the time of bag-up, temperatures were determined for (1) shucking house, (2) surface sea water and (3) scallops held in totes. An additional thermocouple was located in the ice hold to monitor temperatures during the course of the trip.

At least once during each trip, the internal temperature of 4-6 bags of scallops were monitored from time of bagging, placement in the chill-bin and for the duration of the trip in the ice hold. During the course of the project internal bag temperatures were determined for 24 bags of scallops originating from the various deck treatments. Thermocouple wires were placed in the center of the filled scallop bags at time of bagging. Connector lead wires were of sufficient length to allow temperature determinations after stowage in the ice hold for the duration of the trip. Generally, bag temperatures were taken just prior to placement in the chill-bin and then on an hourly or frequent basis until temperatures stabilized after 24 hours. For the duration of the trip, bag temperatures were monitored daily.

Ice-Hold Operations

Icing and stowage of scallop bags were under the strict control of project personnel. Bags were received from deck and placed in chill bins for 6 to 8 hours prior to permanent stowage. Chill bins were prepared with a 3 ft. bed of ice. Scallop bags were placed on the bed of ice and then loosely covered with ice from another bin. The purpose of the chill bin is to cool the scallop bags before permanent stowage and subsequently to avoid excess ice meltage and the formation of air pockets in the stowage bin.

Scallop bags were stowed according to normal industry practices. Bag stowage positions were recorded, noting the layer of the bags in the bin. Generally there are 4-5 layers of bags in a 4 X 4 or 4 X 5 arrangement in each bin.

Off-Loading Procedures

Prior to off-loading, scallop bags were "broken-out" of the ice layers with care taken to remove thermocouple wires and noting unusual circumstances. Bags were brushed free of clinging ice and passed on deck for final weighing prior to delivery to the loading dock. In cases where samples of scallop meats were needed for further laboratory work, the linen bags were split and the sample extracted from the lower half of the bag. Scallop meats were placed in plastic storage bags, labeled, iced and immediately transported to the laboratory.

Sodium Tripolyphosphate Treatment

To test the effectiveness of phosphate on sea scallop meats of various age and from various deck treatments, scallop meats were recovered at off-loading from 32 bags previously tagged at-sea. Four deck treatments were represented which included: ice-seawater, seawater, dry, and ice-freshwater. Scallop meat age ranged from 2-17 days post-harvested. Scallop meats from laboratory shucked live shellstock served as age zero, and also representing no treatment. Replicate half pound samples from each of the 32 bags, plus shellstock meats, were weighed out. Optimum phosphate treatment duration was also investigated by sacrificing samples at 3 hour intervals up to hour 27 (10 sample periods including time zero). A total of 20 half pound samples (10 samples plus one replicate of each) per bag of scallops were weighed and loosely placed within 1/4 inch mesh polyethylene clam bags.

In conforming to current industry practices, light density, granular, food grade sodium tripolyphosphate (STP) was utilized. A solution of 2.5% STP by weight (specific gravity 1.023 at 15.5%) plus 1% food grade NaCl was prepared with tap water (pH 7.2) and chilled to 11-12^{o}C. The phosphate solution (pH 8.9) was distributed to 9 polyethylene fish totes (representing soak hours 3, 6, 9, 12, 15, 18, 21, 24, 27) to a predetermined amount equalling a 2:1 ratio by weight of solution to scallops. The totes were then kept on ice for the duration of the processing study. Two half pound samples (replicates) from each bag of scallops and from shellstock meats were placed in each of the nine totes, while time zero samples were frozen at this point. At each determined soaking time interval, the respective tote of scallop samples were processed while the other scallops were stirred within their totes and allowed to continue soaking until the next sampling time interval. Therefore, mixing of scallop meats occurred every three hours.

Post treatment processing included drained weights, freezing, thawing, cooking and organoliptic evaluation. Once removed from phosphate solution, each scallop sample was drained on a half inch plastic grid drain rack for 2 minutes, pat-dried with a 100% cotton towels, weighed, placed in a plastic freezer bag, commercially blast frozen to a temperature of -34°C, then placed in commercial cold storage at -23°C. After 30-35 days of frozen storage, samples were thawed by water submersion. Tap water at 20-22°C was introduced to the trough at a rate of 2 gpm. Complete thaw of samples was attained within 2 hours and 15 minutes. Thawed samples were emptied onto cotton towels, pat dried, reweighed, and placed back into freezer bags for cooking. Cooking was performed by the boil-in-the-bag method. Trial cookings monitored with thermocouples indicated an average cooking time of 4.5 minutes, for the center of various size scallop meats to reach 73°C as prescribed by AOAL methods. Therefore, all cooking was performed for 4.5 minute durations. Upon cooking, scallop odor was initially evaluated with the opening of each sample bag. Scallops were drained for 2 minutes on 1/2 inch plastic grid, weighed and then further evaluated in regards to appearance, texture and taste.

Methods of Analysis

Data collected from the vessel experiments were analyzed via several quantitative methods. Analytical procedures included analysis of variance and covariance, linear and semi-parametric regression, and non-parametric statistics (Mann-Whitney and Kruskal-Wallis). Analyses were restricted to determining changes in weight associated with the entire product cycle (i.e., harvesting, shucking, on-deck processing, stowing, and shore-side processing). Primary emphasis of the at-sea research was on determining the influence of deck treatments and stowage time on changes in product weight at offloading. Emphasis of research on shore-side processing was on determining the influence of deck treatments, vessel stowage time, and various soak times in evaluating the effectiveness of sodium tripolyphosphate (STP) as a processing aid.

In addition, economic analyses of the benefits and costs of various at-sea procedures were conducted. At-sea benefits were measured in terms of marginal revenues associated with the three types of at-sea deck treatments. The economics of shoreside processing were not examined because a wide array of procedures are used to process scallops. It was concluded that an economic analysis of shoreside processing would be biased unless the various procedures used by industry were examined.

Weight Changes and at-sea Processing Methods

Analysis of changes in weight associated with at-sea processing procedures was primarily accomplished by regression and analysis of variance. Conventional linear regression and semi-parametric regression models relating percent change in product weight to stowage time were specified and estimated:

$$PERCENT_i = f_i(\text{constant, stowage time}) \quad (1)$$

$$PERCENT_i = f_i(stowage_1, stowage_2, \ldots, stowage_n) \quad (2)$$

where $PERCENT_i$ is percentage change between off-loaded and initial bag-up weights from the ith deck treatment, stowage time is a continuous valued measure of hours stowed or product age, $stowage_n$ is a dummy variable for the nth stowage interval (e.g., $stowage_n = 1$ for product stowed 424 hours and 0 for all other stowage times). Equation (2) is the semi-parametric model.[1]

[1]Detailed discussions of semi-parametric regression are available in Goodrich (1989) and Robinson (1988).

A wide array of functional forms via Box-Cox (1962) were examined to determine functional form. Evaluation of logarithmic specifications required indexes of off-loaded weight relative to initial weight in lieu of percent; logarithms of negative values are not possible. Conventional Chow, F, and likelihood ratio tests were used to detect differences in at-sea methods of processing. In addition, equality of mean rates of percent uptake over all stowage times and treatment methods were examined by analysis of variance and covariance, Mann-Whitney, and Kruskal-Wallis tests. A summary of hypotheses examined is presented in Table 1.

Changes in Weight Associated with Shoreside Processing

A critical consideration of the research was to determine how at-sea treatments and stowage or product age affected the uptake or change in weight of scallop meats soaked over various time intervals in a solution of 2.5% STP and 1% sodium chloride. This solution is thought to be adequate for processing frozen product. Analysis of the influence of at-sea treatments and stowage on weight change of scallop meats soaked over various intervals of time was accomplished via regression analysis using data obtained from the August 1990 trip.

Table 1. Null hypotheses examined for changes in weight associated with at-sea treatment

Hypotheses examined
Mean percent change in weight $_{it}$ = 0 (does average uptake of product subjected to a particular treatment and stowed various hours equal 0)
Mean percent uptake$_{it}$ = Mean percent uptake$_{jt}$ (does the average uptake of product subjected to one treatment and stowed for a particular period of time equal the average uptake of product subjected to another treatment and stowed the same amount of time)
Regression relation$_{i}$ = Regression relation$_{j}$ (is the relationship between uptake for one treatment and various stowage times equal to the relationship between uptake for another treatment and various stowage times)
Regression relation$_{it}$ = Regression$_{it+1}$ (is the relationship between uptake and a given stowage time interval for one treatment equal to the relationship between uptake and another stowage time for the same treatment)
Functional form: linear vs. logarithmic vs. polynominal (which mathematical form of the relationship between uptake and stowage time provides the best statistical relationship)
i,j = method of at-sea treatment
t = stowage time interval of product age in hours

A quadratic regression model was specified and estimated for each treatment:

$$PERCENT_i = ao + a_1 \text{ SOAK} + a_2 \text{ SOAK}^2 + a_3 \text{ STOWAGE} \qquad (3)$$

where $PERCENT_i$ equals percent change in weight associated with 3 hour increments of soaking (SOAK = 0,3,6,...,27) for the ith at-sea treatment and STOWAGE equals days stowed or product age (1,2,...,18). Equation (3) was estimated using four 5-day intervals of time (STOWAGE = 1-5; STOWAGE = 6-10, STOWAGE =11-15, and STOWAGE = 16-18), data pooled over all stowage intervals (STOWAGE = 1-18), and daily data (STOWAGE was omitted from Eq. (3) and the equation was estimated for each day of stowage).

Estimates of Eq. (3) formed the basis for examining the influence of at-sea treatment, stowage duration, and soak time on percent weight gain during shore-side processing. Differences in percent weight gain associated with deck treatment, stowage time or product age, and soak times were also examined by analysis of variance and covariance (dummy variables for treatment were added to Eq. (3)) and F and likelihood ratio tests (Table 2).

Drip loss from thawed or previously frozen product was examined via simple two and one-tailed tests of the change

Table 2. Null hypotheses examined for shore-side processing

Hypotheses examined
Mean uptakes associated with 3,6,...,27 hour soaks are equal for ice and sea water, ice and fresh water, sea water, and dry at-sea treatments
Mean uptake for any one treatment and soak time is equal to mean uptake for the same treatment and a different soak time
The relationships between uptake, soak time, and stowage time or product age are equal for all treatments, soak times, and stowage times

in the weight of thawed relative to soaked product. Because of the voluminous nature of these data, however, it was necessary to primarily restrict the analyses to examining mathematical changes in weight and differences associated with on-deck treatments, stowage time, and hours soaked.

Economic Evaluation: At-Sea Treatments

Examination of the potential economic benefits of various at-sea or deck treatments was restricted to evaluating the marginal product and revenue associated with various deck treatments and stowage time relative to dry or sea water deck treatments.

The benefits were calculated by applying deck treatment gains and daily weight changes during stowage to assumed daily harvests of 800 and 1000 pounds for 14 and 21 day trips. Marginal product was estimated in terms of dockside weights of product treated with ice and sea water and ice and freshwater less dockside weights of product that was either processed dry or soaked in sea water. Marginal revenues were calculated by multiplying the marginal product of each treatment by $4.35 per pound, which is the current ex-vessel price for sea scallops in the mid-Atlantic.

FINDINGS

Weight Changes of Scallop Meats During Deck Treatment and Stowage

The weight change (gain) of sea scallop meats during stowage is the result of ice melt water being absorbed by scallop meats which are hyperosmotic to the their environment. The degree to which water is absorbed by scallop meats is affected by several factors, some relating to the biological state of the animal and some factors which are man-made. Clearly, the most obvious biological factors are related to the reproductive state of the animal, annual and seasonal environmental changes, fishing area and depth of water. During the course of this project, vessel operations for each trip were conducted over wide geographical areas and water depths which is normal for the mid-Atlantic fishery. As such, no attempt has been made to segregate the data relative to these variables at this time. Previous research has determined that water absorption by scallop meats is highly dependent upon season, water depth, geographic area and reproductive state and subsequently may be directly linked to the physiological state of the scallop.

Sea scallops in the mid-Atlantic area during the months of July and August are "recovering" from the spawning episode in May and June. Comments are often heard that the scallop meats are "poor" during the summer months. This may be true to a greater or lesser extent depending upon water depth and area. Future work will concentrate on an attempt to isolate these factors of variability. However, for the present study, statistical estimates were used for the graphic presentation of the data and are used to present our findings and recommendations.

Man-induced variations on vessels are likely the result of uneven production (i.e. baskets of scallops/hour or lbs. of scallop meats per hour). In addition, variable rate of production were responsible for unshucked scallops remaining on deck from 1-4 hours because harvesting capacity on occasion exceeded the shucking capabilities of the crew. Often the amount of scallops shucked was not distributed evenly throughout the watch. Consequently the rate at which shucked scallop meats were placed in the totes varied widely. As a result, the residence time of scallops in various deck treatments was not proportionate. This effected the rate at which ice in totes melted and thus the relative exposure to 2/3 strength seawater. As such, the rate at which scallops absorbed freshwater in the totes was variable. However, these conditions are the realities of commercial fishing operations.

Data on the average, minimum and maximum weight change of sea scallop meats incurred during holding in deck treatments prior to bagging demonstrate differences related to the type of deck treatments and its duration (Table 3). Weight gains were larger for similar deck treatments with longer holding times and were the highest for ice:freshwater. The range of minimum and maximum values are indicative of the variation caused by irratic rates of production as mentioned previously. However, it is evident that irrespective of quality issues, the type and duration of deck treatments can greatly alter the weight (volume, and thus meat count) of scallops from the time of harvesting to bagging and stowage.

Man-induced variations in the on-deck handling procedures would hypothetically affect the rate at which water was absorbed during stowage in the ice-hold. It stands to reason that what happened on deck relative to the degree of exposure to fresh or less saline water and to the degree of thermal abuse or mishandling would ultimately affect what happened to the scallops in the ice hold.

The degree of thermal abuse on deck became immediately evident. Scallop meats held in seawater or dry where temperatures exceeded 72-74^{o}F for more than two hours began to show signs of becoming "wafered." Wafering is the rapid onset of a rigor mortis type reaction during which the scallop meat changes from a cylinder shape to that of more of a wafer. Concomitantly the scallop meat loses its

Table 3. Average, Minimum and Maximum Percent Weight Change of Sea Scallop Meats as the Result of Holding in Deck Treatments

<u>Bag-up at 8 hour intervals; August 1990</u>	
Ice:Seawater (1:2)	12.6% (5% min.-18% max.)
Ice:Freshwater	22.0% (19% min.-29% max.)
2.5% STP 1% NaCl	15.5% (11% min.-22% max.)
<u>Bag-up at 6 hour intervals; August 1989</u>	
Ice:Seawater (1:2)	7.0% (5% min.- 9% max.)
Ice:Freshwater	12.2% (9% min.-16% max.)
<u>Bag-up at 6 hour intervals; July-August 1990</u>	
Ice:Seawater (1:2)	9.4% (6% min.-14% max.)

flacidness and becomes rubbery. This phenomenon has been observed frequently, especially after the spring spawning cycle is completed. It has been hypothesized that wafered scallops "behave" differently during stowage with regard to water uptake and subsequent processing on-shore. During the trip conducted in August 1990, air and surface sea water temperatures and temperatures for sea water and dry deck treatments were well above 72^{o}F and the degree of wafering and thermal abuse was described as severe.

Average temperatures at the time of bag-up (Table 4) indicate that the highest temperatures were observed for seawater and dry deck treatments with those during the August 1990 trip reaching above 78^{o}F. Temperatures recorded for the seawater and dry deck treatments closely paralleled air (shade) and surface sea water temperatures. Final temperatures in the ice:seawater and ice:freshwater deck treatments depended upon the quantity of shucked scallops, duration of the deck watch and ultimately the rate at which the ice melted. Ice melt was complete at time of bagging for nearly all for 6 hour deck watches and for all occasions for 8 hour deck watches. It is obvious that despite elevated sea water temperatures and sometimes abnormally high deck temperatures above 90^{o}F, common during July and

Table 4. Average, Minimum and Maximum Temperatures (F) of Sea Scallops Held in Various Deck Treatments at Time of Bag-up

<u>August 1990</u>	
Ice:Seawater (1:2)	48.7 (37.6 min.-58.0 max.)
Ice:Freshwater	50.1 (39.8 min.-57.7 max.)
Seawater	78.6 (77.5 min.-79.8 max.)
Dry	78.3 (75.6 min.-81.3 max.)
<u>July-August 1990</u>	
Ice:Seawater (1:2)	39.5 (32.6 min.-48.2 max.)
Seawater	72.6 (66.4 min.-75.4 max.)
Dry	72.1 (68.8 min.-74.2 max.)
<u>August 1989</u>	
Ice:Seawater (1:2)	44.2 (34.0 min.-53.8 max.)
Ice:Freshwater	51.9 (42.4 min.-61.0 max.)
Seawater	73.1 (69.4 min.-75.6 max.)

August, the insulated totes with ice treatments were fully capable of maintaining cooler temperatures in the 40-50°F range.

Summary Data

Weight changes as a result of various deck treatments and length of stowage for the three trips are summarized in Table 5. Ice:seawater and seawater deck treatments were employed during all three trips where as dry and ice:freshwater deck treatments were employed for only two of the three trips. The use of 2.5% sodium tripolyphosphate as a deck treatment was used on only one trip. The greatest weight changes can be attributed to how the scallops were handled on deck with lesser weight changes attributed to time in stowage. It follows true to the concept that the greater the weight gain achieved on deck the less the gain (even or loss) will be during stowage. However, there are several factors that must be considered when reviewing these results:

(1) Thermal abuse. In the case of extreme thermal abuse, wafering occurred (August 1990) during the dry and seawater deck treatments; average weight change during stowage was minimal (1.8 to 2.1% gain) and statistically different for the 18 day stowage period. During the two

Table 5. Average weight change (%) of scallop meats as a result of deck treatment and stowage time.

	Ice: Seawater	Seawater	Dry	Ice: Freshwater	STP
	8 hr. bag-up interval; 18 day stowage; Aug. 1990				
Deck Treatment	12.6	0	0	22.0	15.5
Stowage	3.6	2.1[a]	1.8[a]	-0.3[b]	1.9[a]
Total[c]	16.6	2.1	1.8	21.2	16.5
	6 hr. bag-up interval; 14 day stowage, Aug. 1989				
Deck Treatment	7.0	0	-	12.2	-
Stowage	5.4	6.0	-	1.0	-
Total[c]	12.8	6.0	-	13.3	-
	6 hr. bag-up interval; 10 day stowage, July 1990				
Deck Treatment	9.4	0	0	-	-
Stowage	3.9[d]	3.1	4.1[d]	-	-
Total[c]	13.6	3.1	4.0	-	-

[a]Statistical tests indicate weight changes from stowage for seawater, dry and STP are equal.

[b]Percent weight change is not statistically different than zero between day 4 and 18.

[c]Total weight change from shucking to offloading based upon original weight of shucked scallops. Stowage gains are imposed upon deck treatment gains and are not additive.

[d]Statistical tests indicate weight changes from stowage for ice:seawater and dry are equal.

trips (August 1989 and July 1990) where thermal abuse was considered as low to moderate with little or no wafering, average weight gains for seawater or dry deck treatments ranged from 3.1 to 6.0% even with shorter stowage periods of 14 and 10 days. Thermal abuse and/or wafering while scallops are shucked and handled on deck can adversely effect product quality and weight gain while in stowage.

(2) Deck-chilling. The use of a ice:seawater (1:2) mixture to hold and chill scallops before bagging conveys two benefits in that (1) of a reasonable weight gain both on deck and in the hold and (2), minimizing or eliminating the occurrence of thermal abuse and its associated adverse consequences. Weight gains were consistent with bagging intervals and the length of stowage time. For two trips (August 1989 and July 1990) with bagging intervals of 6 hours and stowage times of 14 and 10 days, ice:seawater deck treatment resulted in offloading weight changes of 12.8 to 13.6%[2]. The August 1990 trip with an 8 hour bagging interval* and 18 days of stowage resulted in a 16.6% weight change.

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[2]Residence time of scallops in various deck treatments depended upon bagging intervals. For 6 hour intervals, residence time range from 30 minutes to at least 5 hours. For 8 hour intervals, residence time ranged from 30 minutes to at least 7 hours.

The use of ice:freshwater to chill and hold scallops on deck prior to bagging results in large weight gains of 22.0% for an 8 hour bagging interval. However, subsequent weight changes during stowage were minimal for both trips. In fact, the percent weight change during stowage was not statistically different than zero between days 4 and 18 for the August 1990 trip. The use of ice:freshwater as a deck treatment resulted in the greatest weight change compared to other deck treatments. However it also resulted in questionable or less desirable quality and meat integrity characteristics.

(3) Processing aids. The use of processing aids such as sodium tripolyphosphate (STP) as a deck treatment resulted in weight changes comparable to that of the ice:seawater deck treatment totaling 16.5% and 16.6% respectively. The testing of STP was prompted by questions as to the effectiveness of processing aids at sea and does not constitute an endorsement of use.

Estimated percent weight changes over the time course of each trip are presented in Figures 2-4[3]. The rate at

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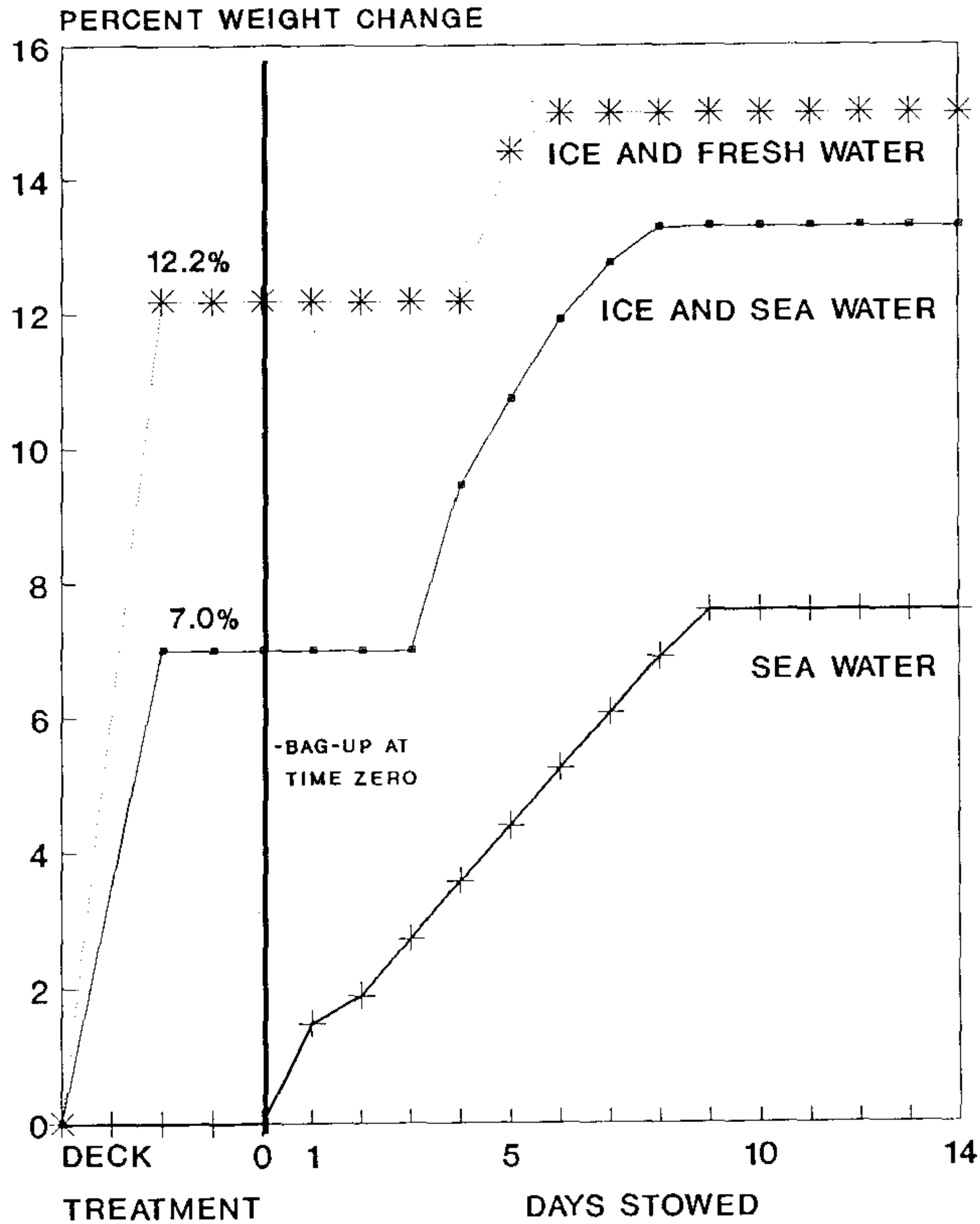
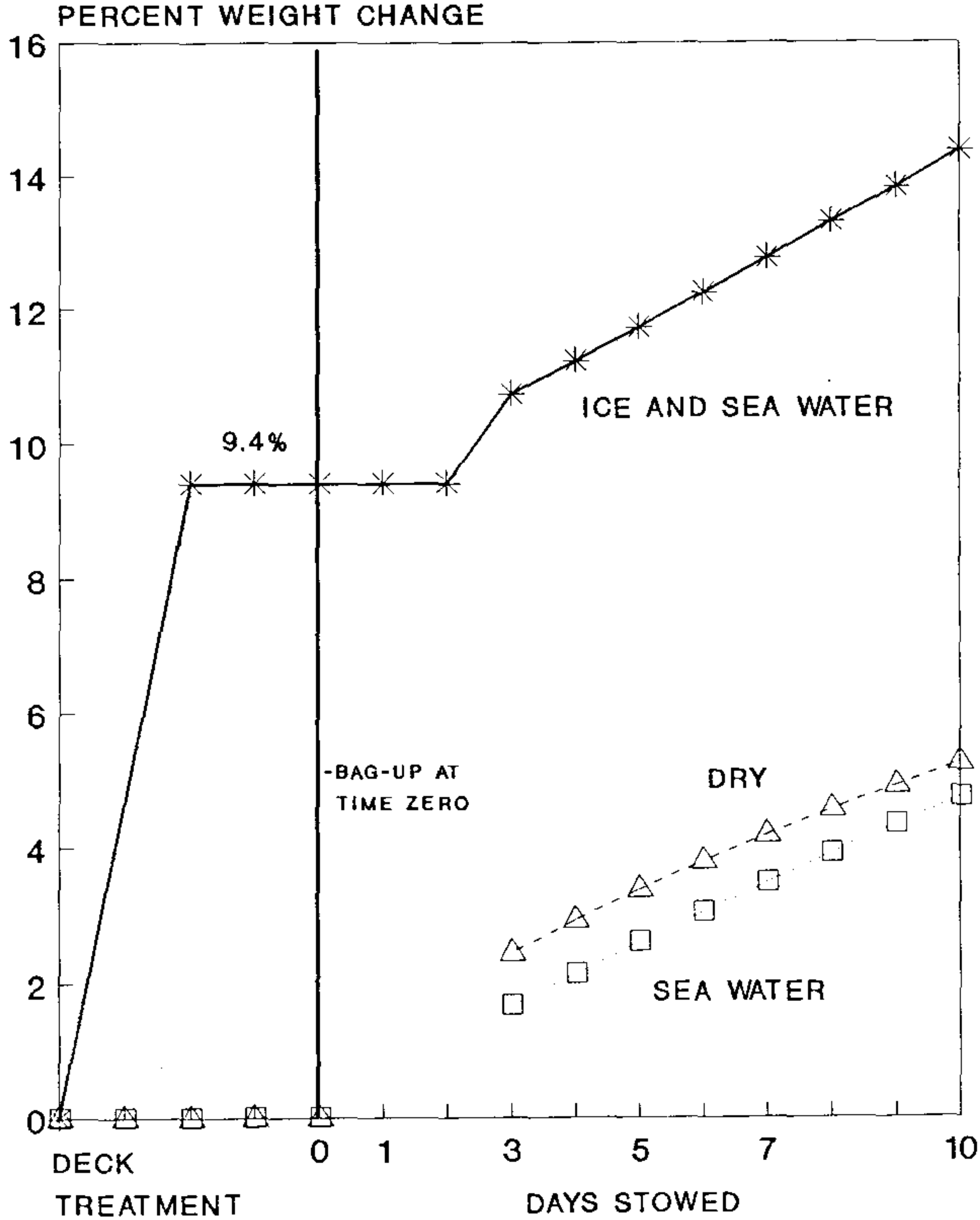
[3]Percent weight change due to stowage was estimated by several linear and semi-parametric regression models and related statistical tests. Given the voluminous nature of the estimates, they are omitted from the report. The estimates, however, may be obtained from the authors on request.

Figure 2. Estimated Percent Weight Change given Deck Treatment and Stowage Time, August 1989



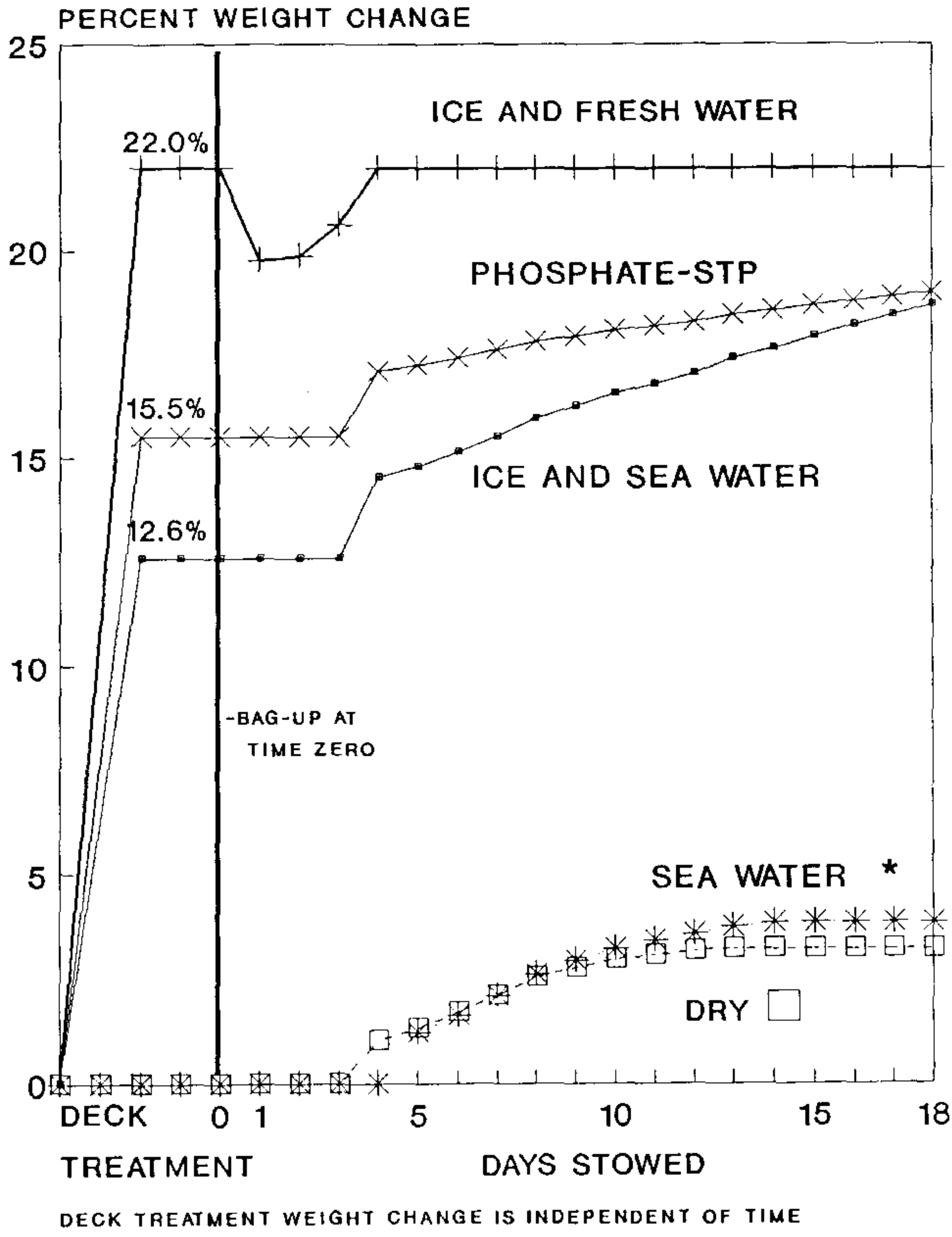
DECK TREATMENT WEIGHT CHANGE IS INDEPENDENT OF TIME

Figure 3. Estimated Percent Weight Change given Deck Treatment and Stowage Time, June-July 1990



DECK TREATMENT WEIGHT CHANGE IS INDEPENDENT OF TIME

Figure 4. Estimated Percent Weight Change given Deck Treatment and Stowage Time, August 1990



which weight changes occur during stowage was variable depending upon duration of trip, deck treatment and the degree of thermal abuse and scallop meat wafering. However, weight changes during stowage for ice:seawater deck treatment were generally greater than or equal to weight changes for dry or seawater deck treatments. This is an important consideration relative to the objectives of this project as it clearly demonstrates the value of pre-chilling and the prevention of thermal abuse during the summer months.

Temperature Records

A primary objective of this project was to document temperatures of scallop meats from shucking to stowage during commercial operations and to alter normal handling practices to minimize the potential for thermal abuse. A series of four temperature records of scallops from shucking to offloading are depicted in Figures 5-8. For each series, one temperature record is for scallops from ice:seawater deck treatments and the other is from a seawater or dry deck treatment at ambient temperatures. In each of the four series, several commonalities which are worth noting, are evident.

Figure 5. Mean Temperature of Scallops from Shucking to Offloading, August 5-16 1989

Seawater temperature 74.2 F, air (shade) temperature 76.6 F

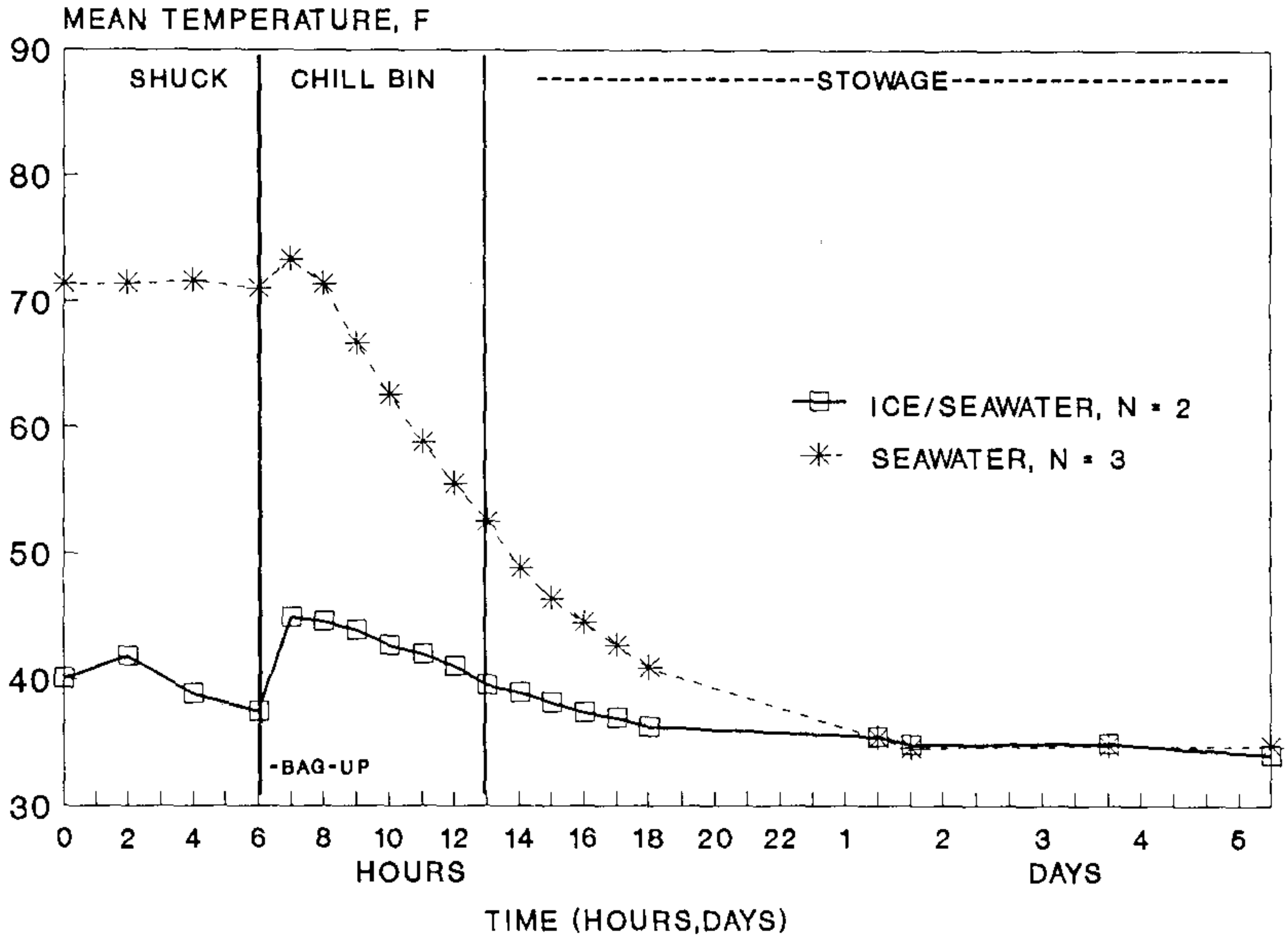


Figure 6. Mean Temperature of Scallops from Shucking to Offloading, August 10-16 1989

Seawater temperature 73.2 F, air (shade) temperature 72.2 F

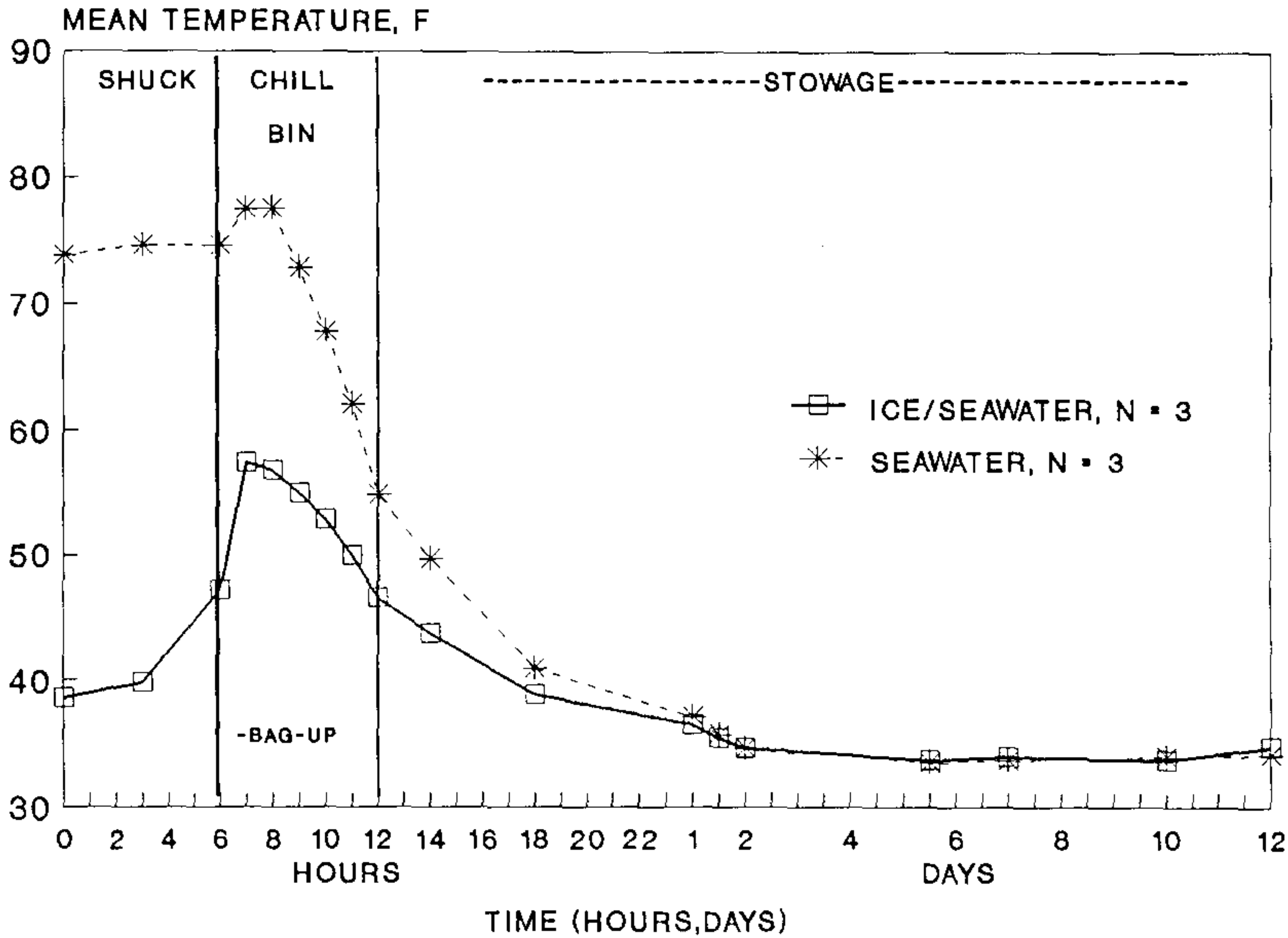


Figure 7. Mean Temperature of Scallops from Shucking to Offloading, July 1990

Seawater temperature 71.2 F, air (shade) temperature 73.0 F

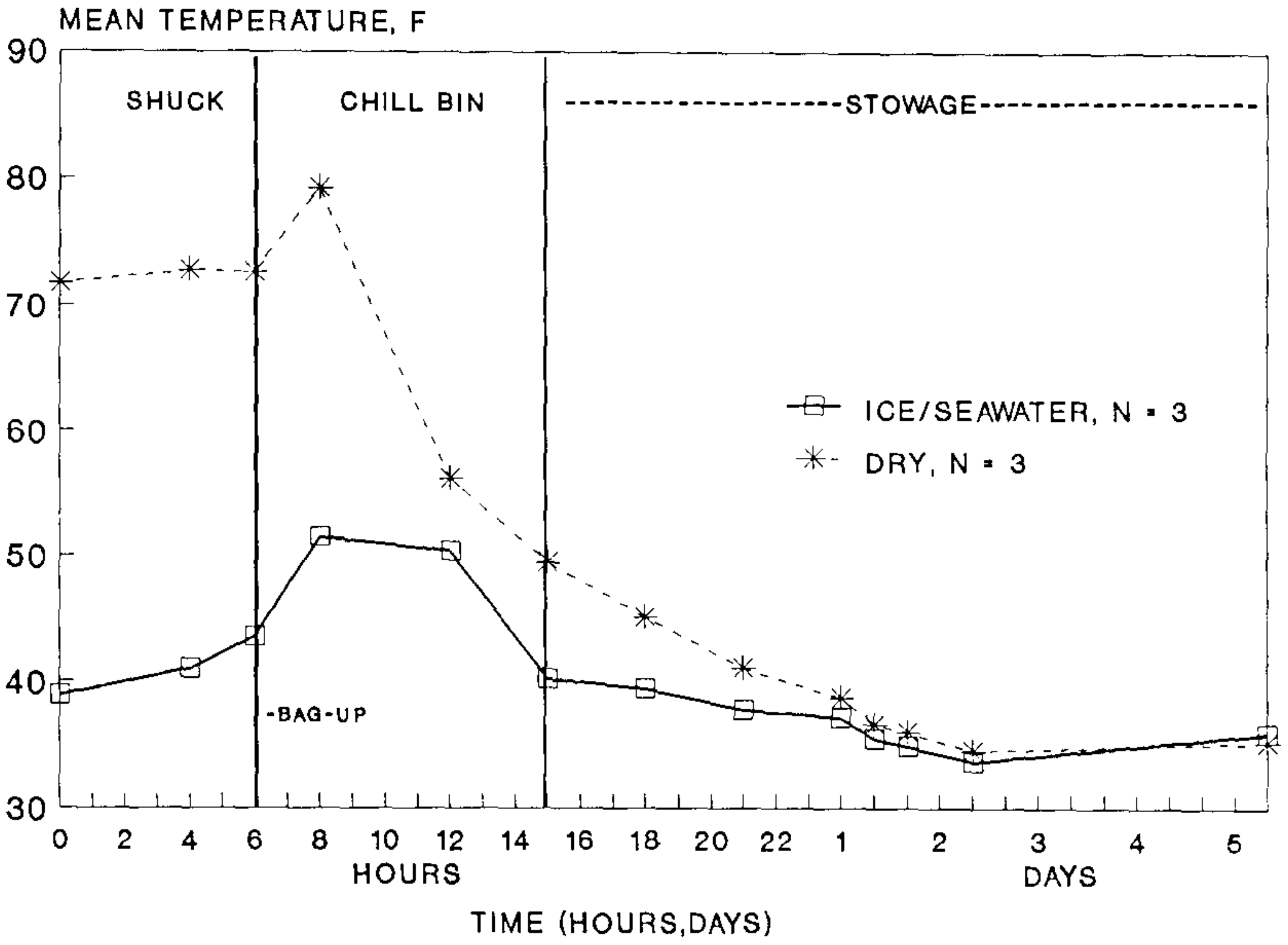
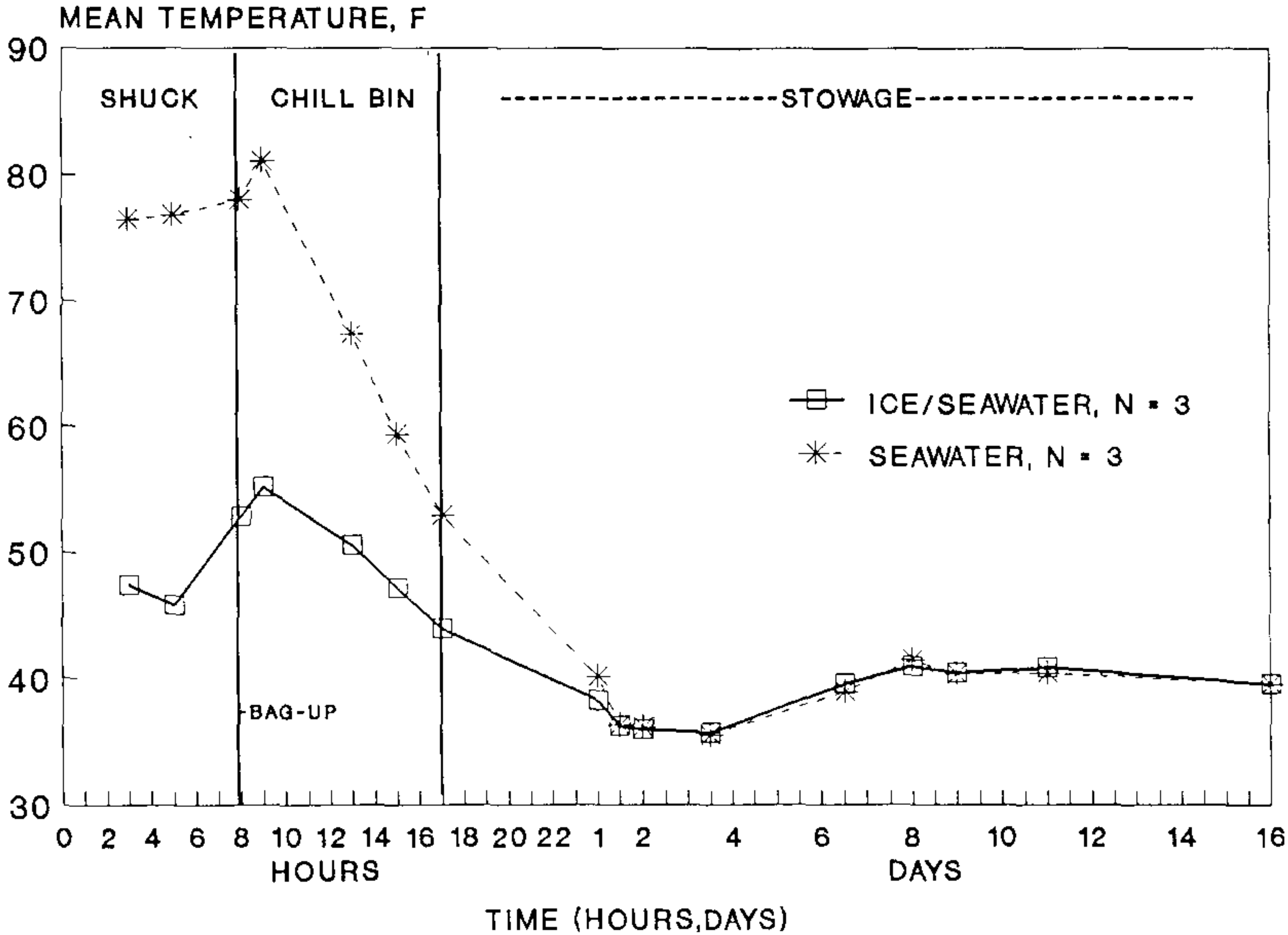


Figure 8. Mean Temperature of Scallops from Shucking to Offloading, August 1990

Seawater temperature 78.6 F, air (shade) temperature 77.0 F



(1) Deck treatments without ice resulted in bag-up temperatures ranging from 72.1° to 78.6°F whereas deck treatments with ice resulted in bag-up temperatures ranging from 39.5° to 51.9°F. The use of ice:seawater in conjunction with insulated totes proved to be very effective in maintaining scallops at low temperatures for the duration of the deck watch.

(2) Despite wide temperature differences between deck treatments with and without ice, internal bag temperatures were nearly the same after 24 hours regardless of the method of deck treatment.

(3) Temperature increases on the order of 3°-10°F were noted for all treatments during the process of bagging and handling scallop bags for placement into the ice hold. These increases were generally larger for pre-chilled scallops but still were in an acceptable temperature range. However, any temperature increase for unchilled scallops could further compromise quality.

(4) The use of chill-bins as described earlier in this report, was very effective in rapidly reducing internal bag temperatures. During a 6 or 8 hour period, internal temperature decreases on the order of 20°-32°F were observed for bags of scallops from un-iced deck treatments.

(5) The internal bag temperatures became fairly stable after 48 hours and temperatures between 33°-35°F were

frequently observed for the duration of the trip. On one occasion (August 1990), internal bag temperatures increased 4^{o}-5^{o}F after four days of stowage. This increase was the result of improper icing practices where insufficient ice was used to separate one layer of bags from another. Upon offloading, some bags from one layer were in contact with the bags in the layer below.

Economic Evaluation of Vessel Performance

As previously stated in this report, post-harvest weight changes can occur as the result of how scallops are handled on deck and during stowage over the duration of the trip. Weight changes (gains) on deck may be intentional and motivated only by the opportunity to increase revenues and/or conform to meat count regulations. However, weight changes on deck can also be the result of legitimate efforts to minimize temperature abuse by chilling scallops in an ice:sea water mixture. Consequently, both motives have to be considered in evaluating the effects of various deck treatments on weight changes. The use of ice:fresh water or STP as a deck treatment can be considered as an intentional effort to gain weight and scallop quality may be only a secondary consideration. The use of an ice:seawater deck treatment with the intent to minimize temperature abuse and maintain good scallop quality has an additional benefit, namely the associated weight gains documented in this report. Holding scallops in warm seawater or dry imparts no benefits to the aspects of product quality or an increase in revenues as the result of an increase in weight.

Analyses of weight changes associated with deck treatments suggest that it may be financially advantageous to subject harvested product to one or more of the deck treatment methods. However, financial gains may be short lived or not significant if deck treatments adversely affect quality. Buyers may discount the ex-vessel price or refuse to buy scallops that have been abused. In addition, there is considerable variation in weight changes associated with the various deck treatments. Some changes appear to be related to spatial, temporal, and physical conditions of the resource and may be unpredictable or inconsistent.

Evaluation of the economic aspects of the various deck treatments is limited to evaluating changes in landings and revenues associated with deck treatment. No attempt is made here to carry the economic analysis beyond the point of offloading. The analysis assumes that 800 pounds of meats are harvested per day, and the ex-vessel price equals $4.35 per pound--the current average price in the mid-Atlantic region.

Given daily harvests of 800 pounds and 10, 14, and 18 fishing days, the largest gains in weight are calculated for product treated with ice and freshwater (Table 6). The second highest gains are calculated for product treated with ice and seawater except for the 18 fishing days in which STP was used at-sea. Although ice and freshwater provide the largest weight gains, two aspects need to be considered in the economic evaluation: (1) weight changes for product treated with ice and freshwater are extremely variable--the coefficient of variation was 142.6 and 223.2 for August 1990 and 1989, respectively; (2) buyers frequently reduce or discount the ex-vessel price for scallops that have been subjected to excessive soaking in ice and freshwater.

Consider the two periods of August 1989 and 1990 and the current market price of $4.35 per pound. Vessels fishing 14 and 18 days and harvesting 800 pounds per day would realize revenues of $55,467 and $75,899 for product treated in ice and freshwater (Table 7). These vessels would harvest 11,200 and 14,400 pounds. In comparison, product treated with ice and seawater would yield approximately $54,201 and $73,054 for 14 and 18 fishing days, respectively. The marginal revenues--incremental revenues from a given deck treatment--of using ice and freshwater would be approximately $5,968 and $13,781 for the August 1989 and 1990 periods, respectively. The marginal revenues of using ice and seawater would be $3,410 and $7,891 for the two periods.

Table 6. Harvests, landings, and changes in product weight associated with fishing days and deck treatment given daily harvest rate of 800 pounds

Trip and at-sea processing stage	Ice and sea water	Ice and fresh water	Sea water	Dry	STP
	-------------Pounds of meats-------------				
August 1989/14 fishing days					
Harvest	11,200	11,200	11,200		
Deck treatment	784	1,372	0		
Stowage	476[a]	179[a]	688[a]		
Landings	12,460	12,751	11,888		
June-July 1990/10 fishing days					
Harvest	8,000		8,000	8,000	
Deck treatment	750		0	0	
Stowage	285[b]		212	264[b]	
Landings	9,035		8,212	8,264	
August 1990/18 fishing days					
Harvest	14,400	14,400	14,400	14,400	14,400
Deck treatment	1,814	3,168	0	0	2,232
Stowage	580	-120[c]	269[d]	269[d]	286[d]
Landings	16,794	17,448	14,669	14,669	16,918

[a]Percent weight change from stowage is statistically different for each treatment.

[b]Percent weight change from stowage for ice and sea water is not statistically different than the weight change for dry.

[c]Statistically equals zero for days 4-18.

[d]Percent weight change from stowage is equal for sea water, dry, and phosphate.

Table 7. Ex-vessel revenues given different levels of fishing days, deck treatments, and an ex-vessel price of $4.35 per pound

Trip and at-sea processing stage	Ice and sea water	Ice and fresh water	Sea water	Dry	STP
	------------Ex-vessel revenues------------				
August 1989/14 fishing days					
Harvest	48,720	48,720	48,720		
Deck treatment	3,410	5,968	0		
Stowage	2,071[a]	779[a]	2,993[a]		
Landings	54,201	55,467	51,713		
June-July 1990/10 fishing days					
Harvest	34,800		34,800	34,800	
Deck treatment	3,262		0	0	
Stowage	1,240[b]		922	1,148[b]	
Landings	39,302		35,722	35,948	
August 1990/18 fishing days					
Harvest	62,640	62,640	62,640	62,640	62,640
Deck treatment	7,891	13,781	0	0	9,709
Stowage	2,523	-522[c]	1,170[d]	1,170[d]	1,244[d]
Landings	73,054	75,899	63,810	63,810	73,593

[a]Percent weight change from stowage is statistically different for each treatment.

[b]Percent weight change from stowage for ice and sea water is not statistically different than the weight change for dry.

[c]Statistically equals zero for days 4-18.

[d]Percent weight change from stowage is equal for sea water, dry, and phosphate.

If dealers discounted the ex-vessel price of product treated with ice and freshwater by $.10-$.15 per pound, however, ex-vessel revenues for the 14 and 18 fishing days during August 1989 and 1990 would be as follows: (1) $54,192--$.10 discount and 14 fishing days, (2) $53,554--$.15 discount and 14 fishing days, (3) $74,154--$.10 discount and 18 fishing days, and (4) $73,282--$.15 discount and 18 fishing days. For the 14 day August 1989 period, product treated with ice and freshwater yields less revenue than product treated with ice and seawater if the price is reduced $.10 per pound. Revenues for product treated with ice and freshwater during the August 1990 period are higher than revenues for product treated with ice and seawater even with the $.15 per pound reduction in ex-vessel price.

Scallop meats treated with seawater would generate approximately $51,713 and $63,810 in ex-vessel revenues for 14 and 18 fishing days, respectively. On deck weight gains are zero for seawater and dry treatments; all gains are associated with stowage and are approximately equal.

Ice and freshwater offer the greatest economic return to the vessel provided ex-vessel price is not reduced. However, use of ice and freshwater provides very unpredictable changes in weight. In comparison, use of ice and seawater, although not providing as much an increase in weight as provided by ice and freshwater, offers a more consistent or predictable change in weight than any of the other deck treatments. Ice and seawater also yields larger increases in weight than typically obtainable from seawater or dry treatments.

Analyses of changes in weight suggest that the influence of deck treatment and stowage on ex-vessel revenue is greatly affected by the physiological condition of the scallop meats. However, use of ice and seawater appears to offer the most consistent or predictable weight changes. Moreover, product treated with ice and seawater is likely to receive the full market value. Relative to the use of seawater and dry treatment methods, product treated with ice and seawater appears to offer higher ex-vessel revenues (approximately 10%).

Phosphate Processing on Stowed Scallop Meats

Currently, the majority of the sea scallop processors utilize certain phosphate solutions during processing. Phosphates are important processing aids which influence pH, ionic strength, water binding, color, rancidity and texture of scallop muscle. As part of this project, processing with a phosphate solution was evaluated relative to various deck treatments and the duration of stowage in the ice-hold of the fishing vessel. Results from this study were somewhat different from expectations and in certain cases difficult to interpret, although they realistically reflect variables in vessel operations, resource conditions and processing practices common in the sea scallop industry. In order to evaluate the results, it is important to understand the following: (1) basic functions of phosphate which influence meat hydration and water holding capacity, (2) the potential for scallop muscle hydration, and (3) at-sea variables which may effect shoreside processing.

Phosphate Effect on Muscle Hydration

Phosphates are salts of phosphoric acid. There are two classes of phosphates; orthophosphates, which contain a single phosphorus atom, and polyphosphates which contain two or more phosphorus atoms. Polyphosphates are widely used in the food industry. Sodium tripolyphosphate (STP) is commonly used in the sea scallop industry and was therefore utilized in this project. STP is an alkali polyphosphate (ph 9.8) which significantly influences water holding capacity by both controlling pH, and increasing the ionic strength of solution by providing polyvalent anions.

The primary objective in raising pH is to extend pH further from the myosine and actomyosin isoelectric point of pH 5.0. At the isoelectric point (IP), maximum salt cross-linkages between positively and negatively charged groups of proteins exist. Therefore, the net charge of the myosine and actomysine molecules are at a minimum, resulting in minimal water holding capacity. By increasing pH away from the IP, a raising of the net charge of the protein occurs which weakens the salt cross-linkages between peptide chains, resulting in a loosening of the protein network. Loosening the protein network creates additional interfilament spacing which increases muscle swelling and water holding capacity.

Polyphosphate also provide polyvalent anions to the processing solution. Polyvalent anions are ions that have more than one negative charge. These ions can attach one end of their chain to a positively charged site on a protein, and the result of the chain can attract water molecules from the solution. The binding of these anions bring about an increase of the electrostatic repulsion between adjacent protein filaments to such an extent, that more water can be immobilized within the loosened protein network. The ionic strength of the processing solution is also increased by the addition of NaCl. The addition of NaCl increases the electrostatic repulsion between protein charges which results in an increase in water holding capacity. There exists a synergism between alkali polyphosphates and NaCl.

Fresh scallop meat contains 76-78% water during the summer. Only a fraction of this water is tightly associated with muscle proteins. The rest of the water is considered "free" unbound water which may be immobilized within the microstructure of the tissue by the use of STP. The rate, or degree of fresh held drip loss, freeze-thaw loss, and cooked loss is, in large part, determined by the effectiveness of these salts to immobilize tissue water. However, the rate, or degree of weight change during processing with these salts, may also be a function of the amount of unbound water present in the muscle at time of processing.

The concentration of solutes within the scallop tissue is approximately that of seawater (34 ppt). In the presence of fresh of slight saline water, sea scallop muscle takes up water, increasing in weight from 15-33% depending upon a number of variables. This added weight is in the form of unbound water. Landed scallop meats have already experienced a degree of weight change, or swelling due to onboard practices and stowage (refer to Table 5). The ability of the meat to retain unbound water decreases as the total amount of water increases. Scallop meats shucked and stowed in ice from the beginning of the 18-day trip would be subjected to more freshwater ice melt and for a longer period of time than those harvested from the last few days of a trip. Consequently, one could conclude that utilizing a phosphate solution on older scallop meats would not generate positive results as with fresher meats. This assumption is generally valid where shoreside operations are processing scallops from a single resource area. Inconsistencies in processing results are found when scallops from different resource areas are processed in similar ways. Future research is needed to better delineate the effects of different resource areas, season and reproductive cycle on processing parameters.

In addition to stowage time, the nature of deck treatments and the degree of thermal abuse and other at-sea factors influence the results of shoreside processing. Various deck treatments of shucked scallops which used ice for chilling scallops on deck resulted in significant weight gains. Deck treatments which did not utilize ice resulted in scallop meats that became wafered. The implications of various deck treatments and wafering relative to weight changes during stowage have been discussed earlier in this report.

The data generated from the shoreside processing experiments are presented in two formats. Table 8 embodies data based on average weight changes of 100 lbs. of sea scallop meats at harvest as a result of deck treatment and variable processing times with tri sodium phosphate (STP).

Table 8. Estimated average weight change in lbs. and percent(%) based on 100 lbs. of scallop meats at harvest as a result of at-sea deck treatments and shoreside processing.

	Fresh	Ice and Seawater	Seawater	Dry	Ice and Freshwater	STP
Harvest	100	100	100	100	100	100
Deck Treatment	---	112.6 (12.6)	100.0 (0)	100.0 (0)	122.0 (22.0)	115.5 (15.5)
Stowage	---	116.6 (3.6)	102.1 (2.1)	101.8 (1.8)	121.6 (-.03)	117.6 (1.9)
Off-load Total	---	116.6 (16.6)	102.1 (2.1)	101.8 (1.8)	121.6 (21.2)	117.6 (16.5)
No Process[1]	100.0	116.6	102.1	101.8	121.6	117.6
Thawed	95.7 (-4.3)	107.6 (-7.7)	97.7 (-4.3)	98.6 (-3.1)	108.7 (-10.6)	110.5 (-6.0)
Cooked	78.8 (-17.6)	88.6 (-17.6)	83.0 (-15.0)	85.6 (-13.2)	87.2 (-19.7)	85.3 (-22.8)
Net of Harvest[2]	78.8 (-21.2)	88.6 (-11.4)	83.0 (-17.0)	85.6 (-14.4)	87.2 (-12.8)	85.3 (-14.7)
9 Hour Process	113.6 (13.6)	127.2 (9.1)	111.2 (8.9)	111.6 (9.6)	133.8 (10.1)	128.6 (9.4)
Thawed	108.1 (-4.9)	125.6 (-1.2)	110.0 (-1.1)	110.7 (-0.8)	131.2 (-1.9)	125.2 (-2.6)
Cooked	91.6 (-15.3)	108.0 (-14.1)	97.4 (-11.4)	97.4 (-12.0)	115.2 (-12.2)	99.4 (-20.6)
Net of Harvest	91.6 (-8.4)	108.0 (8.0)	97.4 (-2.6)	97.4 (-2.6)	115.2 (15.2)	99.4 (-0.6)
15 Hour Process	118.2 (18.2)	129.5 (11.1)	115.0 (12.7)	114.4 (12.4)	134.4 (10.5)	131.0 (11.4)
Thawed	111.0 (-6.1)	126.9 (-2.0)	114.0 (-0.9)	113.4 (-0.9)	130.6 (-2.8)	126.4 (-3.5)
Cooked	90.2 (-18.7)	109.6 (-13.6)	99.2 (-13.0)	101.2 (-10.8)	113.6 (-13.0)	108.8 (-13.9)
Net of Harvest	90.2 (-9.8)	109.6 (9.6)	99.2 (0.8)	101.2 (1.2)	113.6 (13.6)	108.8 (8.8)
21 Hour Process	121.6 (21.6)	133.2 (14.2)	118.6 (16.5)	119.0 (16.9)	140.8 (15.8)	136.6 (16.2)
Thawed	111.0 (-8.7)	129.6 (-2.7)	116.3 (-1.9)	116.7 (-1.9)	135.6 (-3.7)	131.8 (-3.5)
Cooked	87.4 (-21.3)	111.6 (-13.9)	98.2 (-15.5)	101.0 (-13.4)	117.8 (-13.1)	111.3 (-15.6)
Net of Harvest	87.4 (-12.3)	111.6 (11.6)	98.2 (-1.8)	101.0 (1.0)	117.8 (17.8)	111.3 (11.3)

[a]Processing times of 0, 9, 15, and 21 hours in 2.5% STP and 1% NaCl solution by weight.

[b]Net of harvest equals difference between cooked and harvested weight.

This data does not separate the effects of stowage time but accounts for these changes as an estimated average over 18 days in stowage (refer to Table 5 and previous discussion on stowage weight change). Weight changes as a result of shoreside processing are calculated from weight change data at offloading. Consequently, weight changes can be tracked for each stage of processing (STP process, thaw, cooked).

The results indicate certain benefits between processed and unprocessed scallops relative to weight loss during thawing and cooking. For all deck treatments, and for unprocessed scallops there was a significant weight loss from harvest to cooked product. The benefits or changes based upon using a 9 hour, 15 hour or 21 hour process time are not fully realized by extending processing time beyond 9 to 12 hours. The changes observed for weight gain, thaw loss and cooked loss by more than doubling processing time are not large and in many cases not significant. Processors therefore should establish a set of objectives based on desired levels of weight uptake, thaw drip loss and cooked loss in conjunction with plant processing capacity and schedule. For example, processing times to achieve different results vary widely and some set of predetermined objectives should be in place before processing begins (Table 9).

Table 9. Estimated processing time (hours) to achieve maximum weight gain, minimum thaw drip and cooked loss (%). Estimates are based on landed product for each deck treatment and independent of time stowed. Observations are not withstanding organoleptic evaluations. Scallop meats processed in a solution of 2.5% STP and 1% NaCl by weight.

Deck Treatment	Maximum Weight Gain (Hours)
Ice:Seawater	28.6
Ice:Freshwater	26.4
Dry	27.9
Phosphate	25.3
Seawater	28.1
Fresh	26.2

Deck Treatment	Minimum Thaw Drip Loss (Hours)
Ice:Seawater	16.0
Ice:Freshwater	16.9
Dry	15.7
Phosphate	15.2
Seawater	14.8
Fresh	3.0*

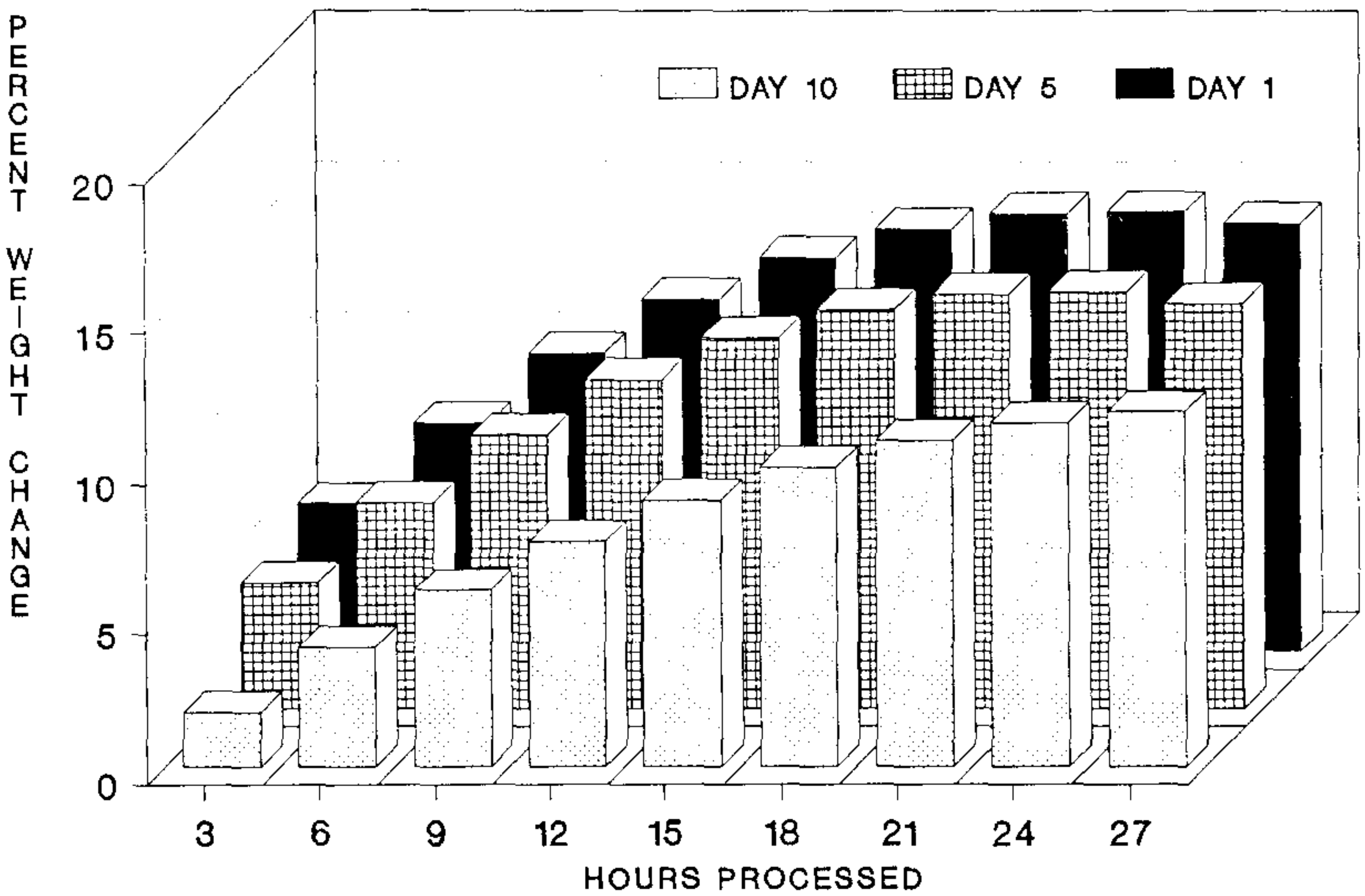
Deck Treatment	Minimum Cook Loss (Hours)
Ice:Seawater	14.6
Ice:Freshwater	17.2
Dry	10.9
Phosphate	18.8
Seawater	11.0
Fresh	3.0-9.0*

*from observed data.

Results indicate that deck treatment had generally minor effects on processing parameters. Weight gain, thaw loss and cooked loss expressed as percent (%) change were remarkably consistent. However, weight changes expressed as net of harvest (which incorporates changes due to deck treatment and stowage) were significantly different relative to the type of deck treatment employed. Essentially, weight changes realized on the vessel carried through to the results of processing. As anticipated, processing weight gains for fresh scallops were significantly greater than for scallops from various deck treatments utilizing ice or freshwater. However, processing gains were also greater than weight gains for scallops from deck treatments not using ice or freshwater (dry and seawater deck treatments). This could very well be due to the fact that these scallops were severely wafered. As previously mentioned, "wafering" is the result of a high temperature rigor mortis type reaction which theoretically alters the muscle fibers of the scallop meat.

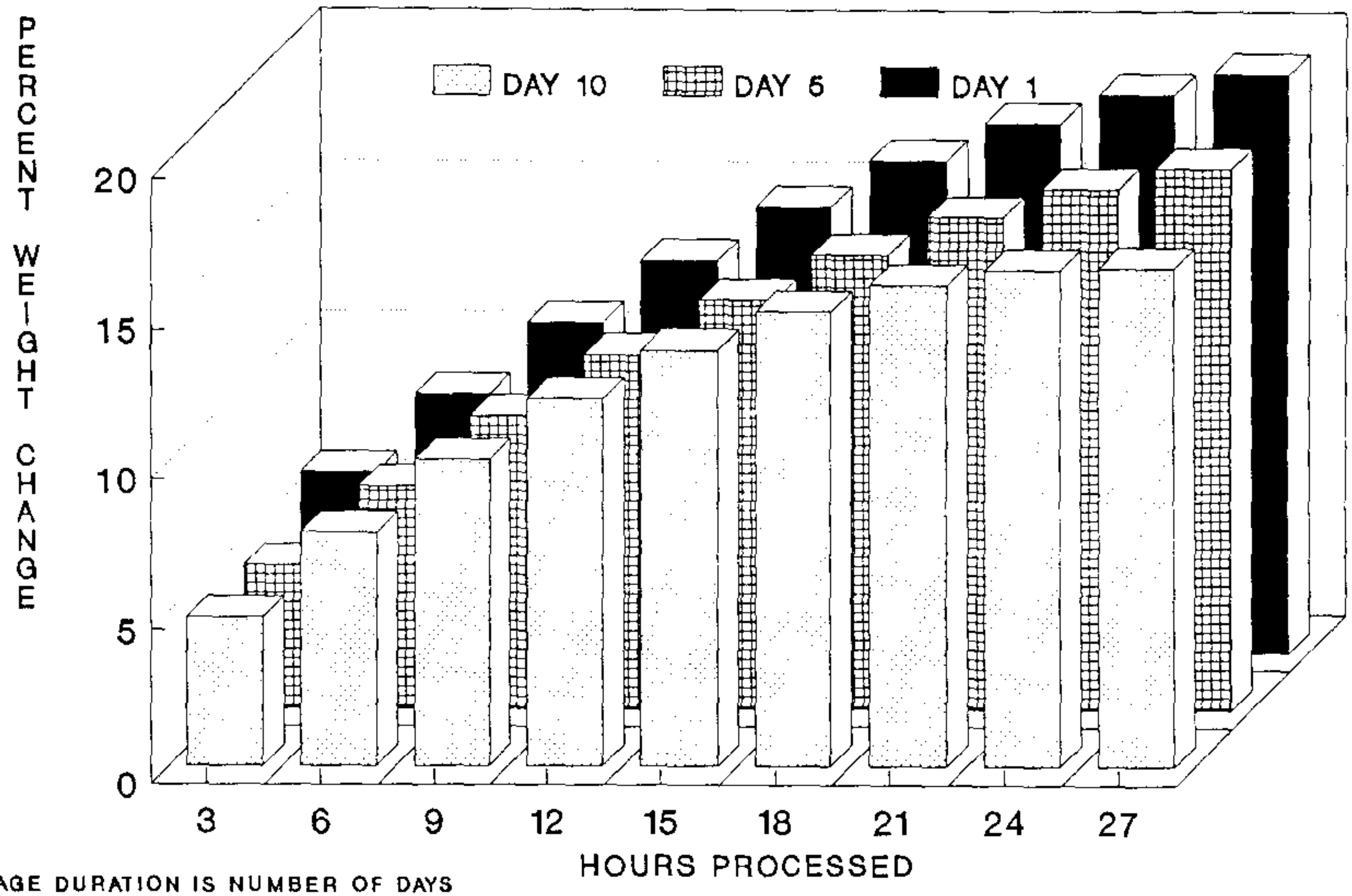
A second format used to demonstrate results of shoreside processing is presented in Figures 9-12. This data takes into account vessel stowage time on scallop processing parameters. Stowage time had the most pronounced effect on processing weight gains fro scallops held in ice:seawater and ice:freshwater deck treatments.

Figure 9. Estimated average percent weight change of scallop meats during processing for ice and freshwater deck treatment and stowage duration of 1, 5, and 10 days



STOWAGE DURATION IS NUMBER OF DAYS
SCALLOP MEATS HELD IN VESSEL HOLD

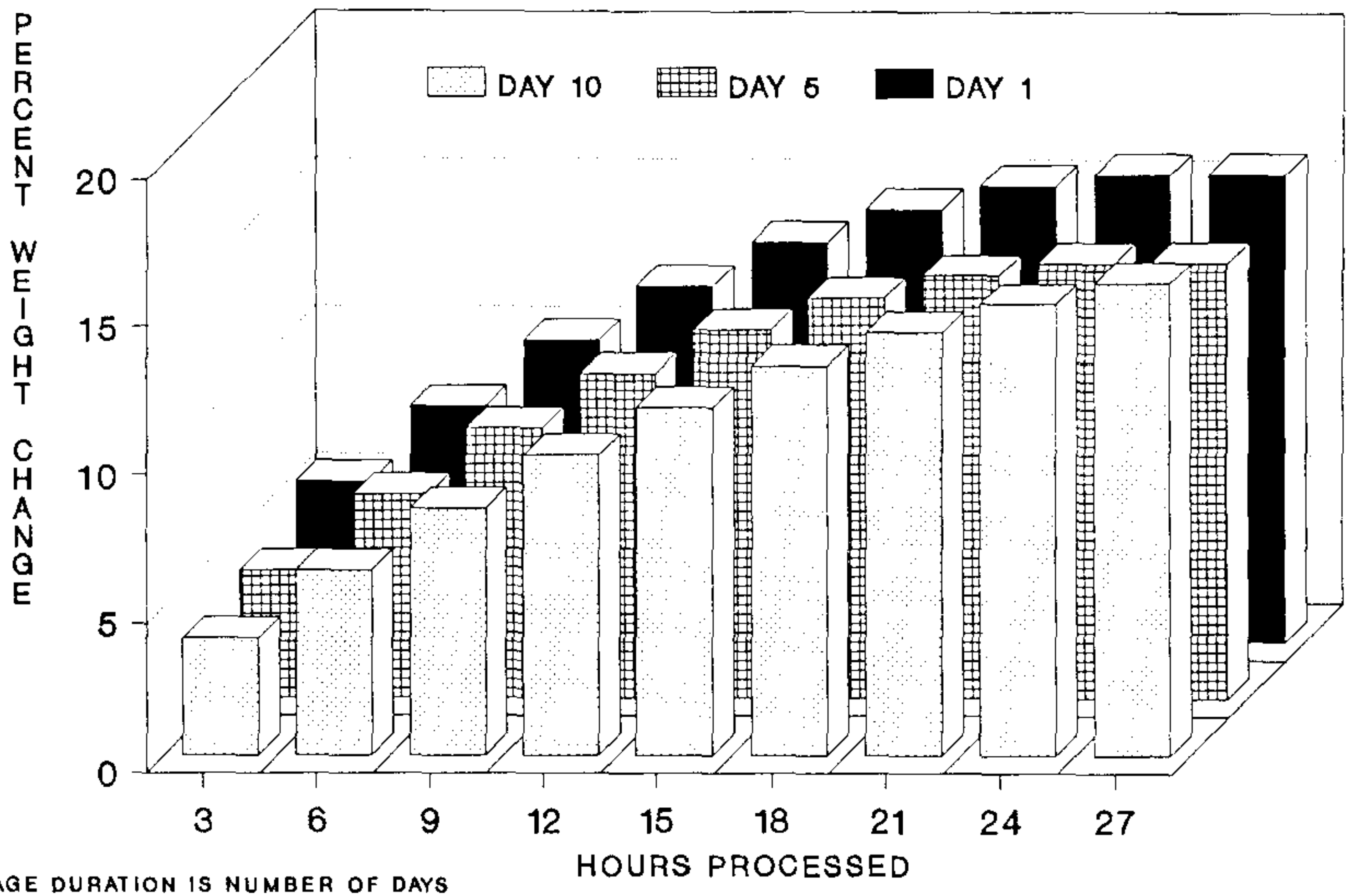
Figure 10. Estimated average percent weight change of scallop meats during processing for dry deck treatment and stowage duration of 1, 5, and 10 days



STOWAGE DURATION IS NUMBER OF DAYS

SCALLOP MEATS HELD IN VESSEL HOLD

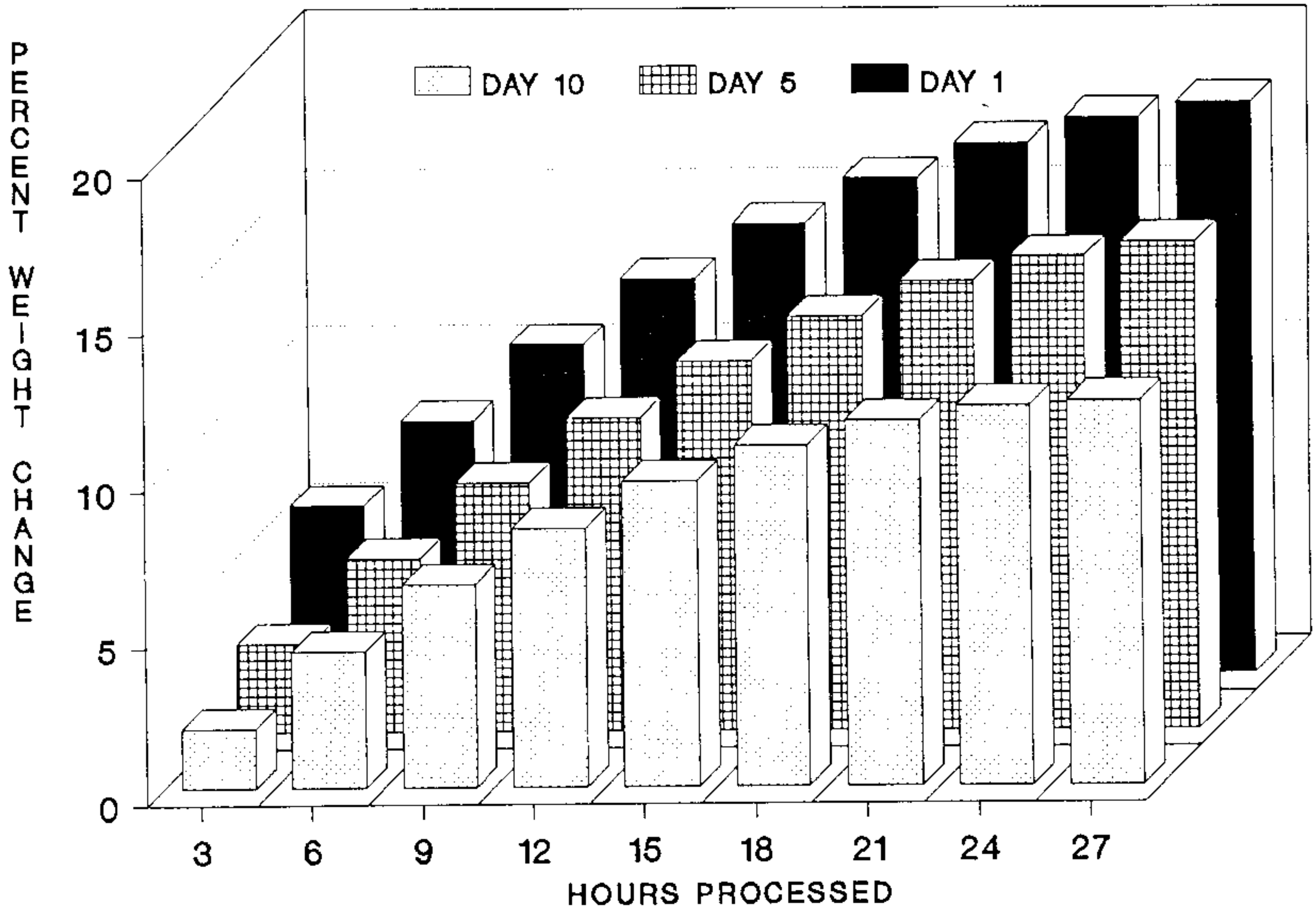
Figure 11. Estimated average percent weight change of scallop meats during processing for seawater deck treatment and stowage duration of 1, 5, and 10 days



STOWAGE DURATION IS NUMBER OF DAYS

SCALLOP MEATS HELD IN VESSEL HOLD

Figure 12. Estimated average percent weight change of scallop meats during processing for ice and seawater deck treatment and stowage duration of 1, 5, and 10 days



STOWAGE DURATION IS NUMBER OF DAYS SCALLOP MEATS HELD IN VESSEL HOLD

Preliminary data indicated that stowage time had a significant influence on the results of shoreside processing with STP. The present data indicates that the above statement is correct, but the nature of on deck handling (i.e., use of ice or freshwater) and the extent (or absence) of thermal abuse are also important considerations. Generally, scallops with the least amount of stowage time "perform" better compared to scallops held for extended periods of stowage relative to processing results. Within a given deck treatment, the "better performance" of scallops with less stowage time is more pronounced. However, as stated earlier in this report, within the given time frame of a single trip, variables due to different geographical fishing areas and depth, along with differences in the reproductive state of the scallops can result in data that are difficult to interpret.

A large amount of data was generated as a result of this part of the project and in particular, the exercise to determine the effects of at-sea handling on processing parameters. Much of this data has yet to be examined in detail which goes beyond the original intent and objectives of the proposal. The authors anticipate that additional technical reports will be forthcoming which will examine issues such as organoliptic ratings of processed and unprocessed scallops, differences in processing results relative to different resource areas, reproductive cycle and underlying economic ramifications.

RECOMMENDATIONS: VESSEL OPERATIONS
MID-ATLANTIC (JUNE-SEPTEMBER)

1. Scallops should be shucked into clean buckets containing seawater. When seawater temperatures exceed 70°F, a small amount of ice should be used.

Rationale: Shucking scallops into buckets with seawater minimizes the problem of grit or sand becoming imbedded in the scallop meat. When seawater temperatures exceed 70°F, the use of ice will prevent the scallop from wafering.

2. Scallops should be thoroughly washed and transferred to holding totes on an hourly basis.

Rationale: Scallops are most easily and effectively washed in small quantities and are less prone to wafering and damage. Scallops should be thoroughly washed at this point to minimize the necessity of another washing at time of bag-up.

3. Scallops should be held in insulated totes containing ice:seawater (1:2) until bag-up.

Rationale: The use of ice:seawater mixture will maintain scallop meats at low temperatures which will eliminate wafering and thermal abuse. A 1:2 ice-seawater ratio is sufficient to maintain low temperatures but is not considered to be an excessive amount of freshwater which can conceivably damage the scallop meats. The use of freshwater is not recommended. Adding more ice to the totes is not recommended.

4. Bag-up should be at 6 or 8 hour intervals.

Rationale: The insulated totes with a 1:2 ice-seawater mixture is sufficient to keep the scallops chilled for 6-8 hours. Often, the ice has melted after 4-5 hours but the water is still quite cold. Holding times beyond 8 hours could result is elevated temperatures and overloading the totes. Adding more ice to the totes is not recommended.

5. Scallop bags should be placed in a chill-bin, covered with ice, and stowed after 6-8 hours.

Rationale: Even though scallops have been pre-chilled on deck, further holding in a chill-bin will help insure proper stowage conditions. There will be less of a tendency to form air pockets in the ice which results from warm bags melting the surrounding ice. These air pockets are suspected of being a primary cause of "yellow" bags.

6. Bags should be scrubbed with clean seawater and a nylon bristle brush before permanent stowage.

Rationale: Cleaning the exterior of bags can minimize the occurrence of discoloration. Do not reuse seawater for scrubbing: the use of clean seawater is essential.

7. Sufficient ice must be used to insure that bags do not come in contact with bin boards or each other.

Rationale: Improper bagging or insufficient ice can cause elevated temperatures in scallop bags during stowage leading to discoloration or product loss.

8. Insulated totes, wash bins and other tools used on deck either to store or bag scallops must be thoroughly cleaned after each watch or bag-up.

Rationale: Product safety and quality are important considerations not only to the general public but also to the fisherman. Unsanitary and contaminated working conditions can lead to product loss.

PROJECT MANAGEMENT

Project management and coordination was under the direction of the principal investigator, William DuPaul. At-sea work was performed by W. DuPaul, R. Fisher and E. Heist. Data analysis was performed by J. Kirkley. All personnel are employed by the Virginia Institute of Marine Science, School of Marine Science, College of William and Mary.

The vessels used for the project were (1) F/V Neptune, D & B Fisheries, Inc., Cape May, New Jersey, (2) F/V Carolina Breeze, Wells Scallop Co., Seaford, Virginia and (3) F/V O'Neal's Pride, V. J. O'Neal and Co., Seaford, Virginia. Preliminary data was gathered on the F/V Ms. Margie, East Coast Fish & Scallop Co., Newport News, Virginia. Project support and industry coordination was obtained through consultations with the East Coast Fisheries Association, Virginia Beach, Virginia. Arrangements were made with each vessel owner in consultation with captains and crews with regard to project personnel on the vessels, the work that was to be done and the level of participation and cooperation expected from captain and crew. Agreements were secured from vessel owners, captains and crews to allow project personnel to alter or modify deck and ice-hold practices as necessary. In addition, upon off-loading, project personnel were permitted open use of deck space and off-loading areas.

Freezer space and processing facilities were open to project personnel and were provided by Seaford Scallop Co., Seaford, Virginia. In all cases, industry cooperation and support was beyond reproach. No problems were experienced and all industry cooperators provided excellent support to the project and project personnel beyond expectations.

EVALUATION

The overall project goals and objectives to document existing at-sea handling practices on sea scallop vessels and subsequently test alternative handling practices designed to minimize thermal abuse and loss of project quality were realized. The benefits to the sea scallop fishing industry was linked to the belief that thermal abuse and improper handling of scallops at-sea were responsible for direct economic loss to the vessel and diminished product quality and meat integrity with additional concomitant economic losses at the processing and market level. If these losses could be documented and consequently mitigated by altering handling practices, industry as a whole would benefit. In addition, any recommended changes in handling practices had to minimize interference with normal vessel operations. This project had to be designed in such a way so that vessel captains and crew members would be willing to implement changes and those changes would show a favorable benefit-cost ratio.

During the course of the project, there were no changes in project goals and objectives. The methodology used to obtain the project's objectives was subject to some alterations. As a result of some preliminary work, it was concluded that on deck practices had to be closely controlled to minimize possible biases in the data and experimental results. Consequently two project personnel were required to be on each vessel trip. Other sources of potential bias of the data attributable to area and depth fished and the changing nature of the resource could not realistically be controlled by modifications in methodology and were considered during data analysis.

The project will be successful in developing several informational products. The contract's final report, alone will be useful to industry as it is constructed in a useable manner. The final report will be the basis for developing several smaller documents or brochures addressing particular aspects of the project. These will include the proper use of insulated totes on vessels, proper icing and stowing of scallop bags and the economic benefits of proper handling of sea scallops. Of significance is the list of recommendations that are detailed in this report. These recommendations, made possible by the information and data collected during the project, provide the cornerstone for the success of the project as they (1) provide economic benefits, (2) solve handling problems and (3) may be easily adopted by captains and crew.

Printed informational projects will be valuable to industry and will be delivered to the industry through comprehensive computerized mailing lists. An important spin-off of this project will be the future development of a video on proper handling of sea scallops. Since many vessels have VCRs, the video format of this information will facilitate wide distribution to industry.

The project had an immediate impact on the practices of captains, crew and vessel owners. Since the project was carried out on three different vessels, three captains, three vessel owners and almost 30 crew members witnessed the visible improvement in product quality and appearance. Within a short period of time, an estimated 22 scallop vessels in Virginia had purchased insulated totes and adopted most of the procedures outlined in our recommendations. As the information becomes more widely distributed, it can be expected that more vessels will adopt the recommendations provided by this project.

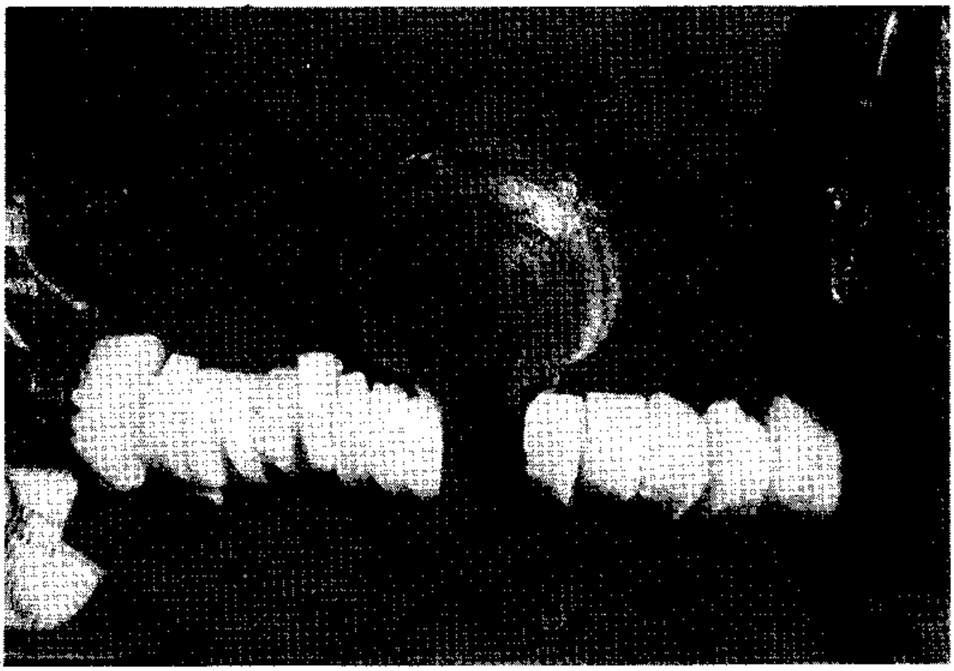
The results of this project will be presented at the December 1990 joint meeting of the Tropical-Subtropical Fisheries Technology and Atlantic Fisheries Technology Societies in Orlando, Florida. Two papers have been developed to describe the weight changes of scallops during stowage and the performance of aged scallops treated with the processing aid, sodium tripolyphosphate.

The benefits of this project are clearly associated with the warm temperatures of summer. Consequently, we would expect more visible and tangible benefits to be realized during the summer of 1991.

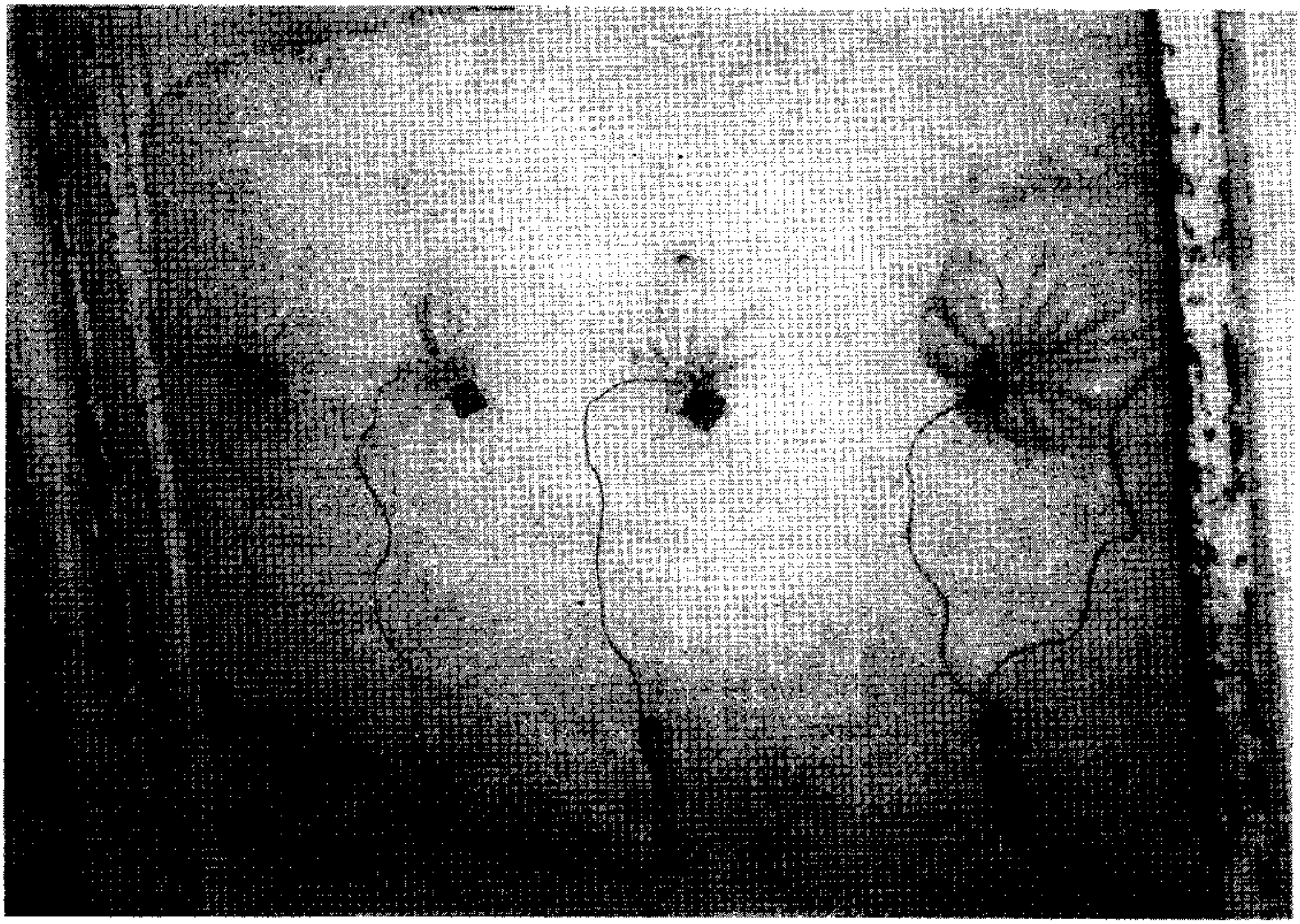
CONCLUSION

A critically important issue, that of the potential adverse effects caused by warm seawater and deck temperatures on sea scallop harvesting operations during the summer months was documented and a solution offered. Thermal abuse, as a result of traditional at-sea handling practices adversely affected the product quality, water retention characteristics and processing "performance" of sea scallops. The use of insulated totes at-sea, with a 1:2 ice seawater mixture as a holding container until bag-up effectively kept scallops chilled and prevented thermal abuse. The project was successful in offering a set of recommendations to improve the handling of scallops on vessels. The study further concluded that these recommendations were effective in improving the results of shoreside processing. The proper use of insulated totes during the summer when seawater temperatures normally exceeded 72°F translate to improve product quality and economic gains for the fishing vessel.

Utilization of ice on deck helps ensure sea scallop quality. Shucked scallop meats are held in insulated totes containing a 2:1 seawater to ice mixture.



This photo illustrates "wafering," a phenomenon which occurs when meats are subjected to elevated temperatures.



Bagged scallop meats being monitored for rate of temperature change during ice stowage.