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NMFS scientists find a more efficient and less costly way to transport live crabs to market.

The Overland Shipment of Live Dungeness Crabs by Self-Contained Van

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ABSTRACT

The concept of delivering live Dungeness crabs to out-of-the-way markets by truck has been considered from time to time. Because it is difficult to keep the crabs alive beyond 1 or 2 days out of their natural environment, the idea has never proven to be workable. Described here are the results of laboratory experiments to develop such a method. The most successful laboratory method—designed around a system of vertically stacked trays fed by recirculated, chilled seawater—was scaled up and field tested. In two over-the-road tests, one lasting 3 days and the other 4 days, crab losses averaged less than 10 percent.

Live seafood marketing in the United States has been limited mainly to the northern lobster. In other countries retailing live fish and shrimp has been common practice. In Denmark for instance the consumer may choose a live plaice or other fish from a holding tank in a retail fish market. In Japan live shrimp are in great demand. Recently, the possibility for extending live retail marketing in the United States to include Dungeness crab has been investigated for several firms.

A retail market for live Dungeness crab began to develop in 1968 when air shipping techniques were successfully applied. The research leading to this development was reported by Barnett et al. in 1969.

Following the air shipping success the potential for live crab sales in areas not served by airlines became of interest. Some of the small California communities were especially good possibilities since fish markets in these areas had saltwater holding tanks that were being used for holding lobsters. One company tried shipping live crabs by truck to take advantage of such factors as: (1) accessibility to remote areas for processing live crabs and for delivery to the markets; (2) reduced cost; (3) ability to handle a large quantity in a single shipment; (4) and the convenience of delivery to numerous locations along a single route. Using an obsolete refrigerated meat transporting trailer, the company attempted several shipments of live crabs using a technique in which refrigerated seawater was sprayed onto the crabs through common garden sprinklers located throughout the inside of the trailer. The shipments originated in northern California and terminated in Los Angeles. However, after several disastrous attempts at shipping the crabs live, the procedure was abandoned as unworkable. It was at this point that the company heard of the work that the National Marine Fisheries Service had done in shipping live Dungeness crab by air and asked for assistance.

From previous experience in shipping live Dungeness crabs by air it was known that they can be held out of water for about 2 days under ideal conditions. The conditions include: the maintenance of low-storage temperatures, relative humidity of over 90 percent, and the elimination of unnecessary handling. Of these conditions, low temperature and high humidity are of primary importance. Low temperatures are known to make crabs torpid (Roach, 1956) and have been used successfully to produce the same physical effect in other marine species (Rodman, 1963; McLeese, 1958, 1965). The net result of this inactivity is to reduce the animals' apparent need for oxygen (Tomura et al., 1967; Waterman, 1960) because of reduced metabolism. The retention of moisture is necessary to prevent dehydration of the crabs' gills. Dehydration prevents the crab from breathing normally and ultimately will cause death. In conducting the study reported here, particular attention was paid to the prevention of dehydration.

LABORATORY STUDIES

Two methods of live holding were studied in small scale experiments at the laboratory using the trailer as a

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test unit. The purpose of these experiments were: (1) to test fog as a method of maintaining a high level of moisture on the gills and (2) to test partial immersion as a method of maintaining the gills in a moist condition.

Trailer Test Unit

To facilitate our research, a 28-foot trailer belonging to the crab-shipping company was brought to Seattle where the laboratory experiments were made. Because it had already been used to transport live crabs, the interior of the trailer had been covered with fiber glass. Three floor drains were connected by 2-inch polyvinylchloride (PVC) pipes to a 400-gallon capacity reservoir located under the trailer. A centrifugal pump, powered by a 5-hp gas engine (also beneath the trailer), pulled water from the reservoir via three Cuno[1] filters and recirculated it back into the trailer. Refrigeration was supplied by a Thermo-King, front-mounted, butane-powered unit.

Prior to initiating the experiments, the interior of the trailer was modified with a fogging system. The system consisted of an electrically powered, high-pressure pump capable of delivering 6 gpm at 200 psi and two Spraying Systems Company type 7-N fog-jet nozzles. The nozzles were connected about 12 feet apart to a 1½-inch diameter PVC pipe attached to the ceiling of the trailer. A high-pressure hose joined the pipe to the pump beneath the trailer. In these experiments, the floor of the trailer was used as the reservoir. A garden hose from the floor drains connected to the suction end of the pump completed the system.

Fog Experiments

In each of three replicate experiments, 24 live Dungeness crabs were divided evenly among three plastic-webbed baskets (Figure 1). The baskets were stacked three high in the trailer to determine if the spray mist would reach all of the crabs and keep them moist. A second group of 24 crabs divided among three baskets was placed, without stacking, adjacent to the stacked groups. Each experiment lasted 4 days, during which time the temperature of the environment was maintained at 43° F. Because of the mechanical condition of the refrigeration unit, 43° F was about the lowest temperature that could be achieved with any dependability. The crabs were examined daily during the experiments.

Results and Discussion

Even though the atmosphere was saturated by the mist, the crabs in these tests began to succumb by the end of the second day. Maximum mortalities occurred by the beginning of the last day of the experiment. Total losses, based on the number of crabs lost in each test, averaged about 30 percent (Table 1). Mortalities appeared to be evenly distributed among the baskets. Mortalities in the unstacked groups were not significantly different from those sustained in the stacked group.

During each experiment, the pH of the chilled seawater was measured periodically with a pH meter. No significant changes from the normal pH of the brine (7.5 to 8.5) were noted. This indicated, for the conditions described here, that ammonia was not being formed. Crabs surviving these experiments were frequently in a weakened condition. When relocated in the laboratory's live-holding facilities, these crabs usually succumbed quickly.

Although the fog spray technique increased the holding time of the crabs over that of the initial spray method used by the crab shippers, losses were unacceptably high.

Partial Immersion Experiments

Because the fog method resulted in high mortalities, a different approach was tried in which live crabs were held in trays continually flushed with recirculating refrigerated seawater.

Two trays (4-ft x 3-ft x 4-in deep) were made from marine plywood and painted with a nontoxic coating. Openings (18- x ⅜-in) were cut into the short ends and 1 inch above the floor of the trays. The openings were used to regulate the water level in the trays. The 1-inch depth was selected on the basis of previous tests made at the laboratory in which crabs were exposed to different water depths to determine the smallest amount of water in which they could survive without difficulty. It was determined that average-size (1.5 to 2.5 lb) crabs did well in water deeper than half an inch. A frame with supporting glides was made to hold the trays in a vertical or stack configuration. Water was supplied to the top tray by an epoxy-clad submersible pump delivering water at a rate of about 350 gph. The water spilled through the openings in the top tray, to the bottom tray and then onto the floor of the trailer. Vertical stacking of the trays prevented the crabs in the bottom tray from escaping and a screen held the crabs in the top tray. The temperature of the water was maintained at 43° F during the test. The experiment was repeated three times.

Results and Discussion

Between 30 and 50 live crabs were used in each test and to the degree possible crabs were evenly divided among the trays. All crabs selected for the experiments were in apparent good condition.

Despite their condition, however, small but unexplained losses occurred at the 2-day interval in each experiment (Table 2). Additional mortalities occurred near the completion

[1] Mention of trade names does not imply NMFS endorsement; they are used only to simplify descriptions.

Figure 1. (above)—Live crabs in webbed basket prior to holding in fog-spray experiment. Fog-jet nozzles are shown top-center of photograph mounted between two rows of garden sprinklers.

Figure 2. (below)—Arrangement of rails and vertical stanchions to support the holding trays.

Figure 3.—Live crabs arranged in holding trays. Bales for nesting trays are shown hooked in place.

of the studies. Average total losses after 6 days were about 17.0 percent. Surviving crabs were almost always strong and when returned to the laboratory's live-holding facility, they resumed normal activities without difficulty.

Summary of Laboratory Experiments

The laboratory experiments indicated that a seawater fog technique was not a satisfactory method for maintaining Dungeness crabs in live conditions beyond 2 days. Even though the fog constantly bathed the exterior of the crabs, apparently the gills were not kept sufficiently moist under this condition. On the other hand, partial immersion in seawater resulted in a lower rate of mortalities and successful live holding for 6 days. Based on these results we decided to expand the experiments using the partial immersion technique in over-the-road tests using the trailer.

FIELD EXPERIMENTS

The purpose of the field experiments was to determine if the results obtained in the laboratory scale tests could be repeated under conditions more like those found in actual shipments. In addition, large-scale tests would be useful in assessing factors such as: loading and unloading the trailer, scheduling, and other problems that might be encountered (aside from those involved in maintaining crabs in live conditions). The tests were arranged by the owners of the trailer, using suppliers and outlets that the company had made prior to our involvement in the experiments. All costs and obligations associated with the field tests were borne by the company. Our responsibility was limited to recommending the procedures to be used and in making an objective evaluation of the results.

Trailer Modification

All pipes, hose, and nozzles were stripped from the van and replaced by a system of aluminum channel tracks. The tracks ran the length of the trailer's walls and were attached to vertical stanchions located at intervals along the length of the trailer and about 21 inches in from the walls (Figure 2). The spacing allowed for suspending 18- x 24- x 4-in (deep) polyethylene trays made with 1½-

Figure 4.—View of stacked trays loaded with crabs.

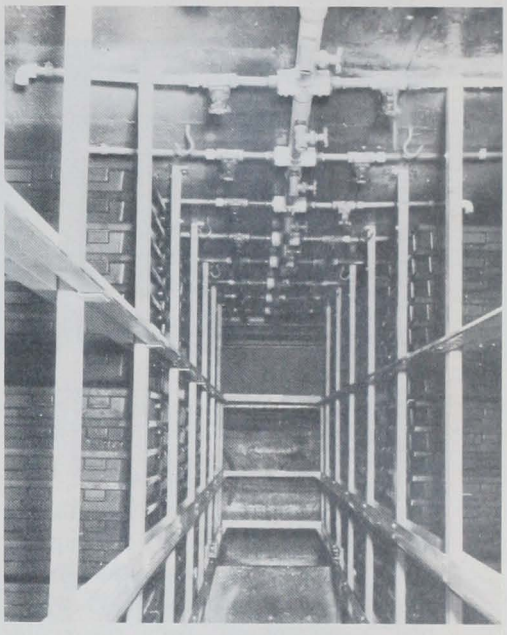
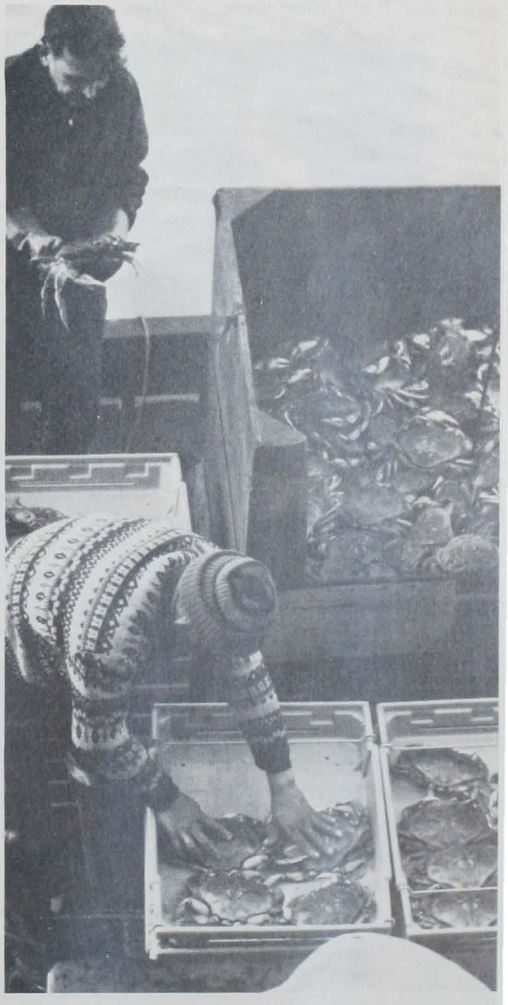


Figure 5. (above)—Arrangement of PVC distributor pipes (top, center) feeding chilled seawater to trays loaded with crabs.

Figure 6. (below)—Live crabs being loaded into trays without the aid of restraints.



inch rims between the tracks. When completed, each side of the trailer had a system of three sets of tracks vertically spaced to accommodate trays nested one on top of the other. Special bales prevented the trays from nesting in each tray deeper than 1 inch (Figure 3). The overhanging rim of the bottom trays in each stack rested on the tracks and supported the other four trays in the stack. Each side of the trailer accommodated 10 stacks of 15 trays or a total of 300 trays (Figure 4).

Water was carried to the trays through 1-inch PVC distributor pipes teed from a 1½-inch PVC pipe attached to the ceiling of the trailer. The flow of water through the distributor lines to the trays was regulated by plastic hand (gate) valves. Water from the distributor lines was pumped into the top trays of each stack, overflowed through ⅜- by 12-inch openings cut into the short ends 1 inch above the floor of the trays and down into each succeeding tray (Figure 5). Water was drained from the trays by means of five ¼-inch holes located in the floor of each tray. The holes were placed in each corner about 2 inches in from the sides and one in the center of the tray floor. When in operation, water flowed into the trays at 6 gpm. Each tray held about 2 gallons of water. Water dropped from the bottom trays to the floor where it was pulled down the floor drains into the reservoir through the filters and recirculated by the gas-driven centrifugal pump. Baffles on the floor of the trailer reduced the problem of surging water when the trailer was in motion. The temperature of the trailer was maintained at 43°F. All water used in the trucking experiments was pumped from local saltwater bays. Two experimental shipments were made.

First Road Experiment

Procedure

The first shipment was made from a crab-buying station located on the Washington coast. Thirty-six hundred pounds of sea-run[2] crabs were hauled via Seattle, Washington, to Portland, Oregon. The trip was purposely kept short (about 300 miles) to enable us to observe the effects of road vibra-

[2] Sea-run crabs have not been culled for damaged, broken shell and missing legs but are taken "as is" when unloaded from the boat.

Table 1.—Daily mortalities (%) occurring in Dungeness crabs held in stacked and unstacked basket containers exposed to a 43°F. fog-spray[1]

Days held	Crab mortalities (%/day)[2] in stacked baskets (Test) 1	2	3	(Avg.)	Crab mortalities (%/day) in unstacked baskets (Test) 1	2	3	(Avg.)
1	0	0	0	0	0	0	0	0
2	4.2	0	4.2	2.8	0	6.5	0	2.2
3	8.3	8.3	16.6	11.0	0	12.5	6.5	9.7
4	16.6	12.5	16.6	15.2	18.8	12.5	25.5	18.9

[1] Results are based on data collected from three separate experiments.
[2] Figures are based on the number of crabs lost in each experiment compared to the number of live crabs used initially.

tion on the crabs and evaluate the effectiveness of the trailer's life-support system. The crabs were individually placed by hand in the trays which had been removed from the trailer for the loading operation (Figure 6). Because the crabs were not restrained in the trays, considerable time was used to complete the task of loading. As the trays were filled (eight crabs per tray) they were weighed and loaded into the trailer. When a vertical stack was completed, a flow of seawater, pumped into the trailer prior to loading, was started to prevent the gills of the crabs from drying. The time required for 9 men to complete the loading operation was about 7 hours.

Results and Discussion

Part of the trip to Portland was made over secondary roads which were rough in spots. During this segment of the trip, several members of the crew rode with the crabs in the trailer to observe their reaction to the ride. As far as could be determined, the crabs were not unduly excited by the occasional jarring and bumping. Although some water spilled from the trays when the truck moved up or down steep grades, the crabs were never without water very long during the trip. The crabs were restricted from moving freely because of the nested tray configuration and their close proximity to each other. The darkened interior of the trailer and cool temperatures also contributed to the crabs' relative inactivity. Examination at the time of delivery showed that physical damage was minimal.

The shipment was held overnight in Seattle then trucked to Portland, Oregon, where 2,500 pounds were delivered to a retail market. Prior to unloading, the water was drained from the trays. Draining took about 20 minutes and was accomplished by closing appropriate valves and allowing the water to drain from the trays through the holes drilled into the bottoms. The crabs were then unloaded, carefully examined and weighed. A 10-percent allowance was made for entrapped water that did not drain off. Accordingly, this was deducted from the total unloaded weight. Four percent of the delivered crabs were dead. The survivors were lively and in excellent condition. They were placed in live display tanks for sale.

The remaining crabs were returned to Seattle where they were held an additional 48 hours in the trailer. Seven and one-half percent of the remaining crabs died during this time. The surviving crabs, which were lively and in good condition, were delivered to a local crab processor. Overall losses in this experiment, based on total weight, were 4 percent.

Table 2.—Daily mortalities (percent) occurring in Dungeness crabs held in vertically-stacked trays partially flooded with 43° F. recirulated sea water.[1]

Days held	Crab mortalities (%/day)[2] (Test) 1	2	3	(Avg.)
1	0	0	0	0
2	4.0	3.0	4.0	3.7
3	0	0	0	0
4	0	0	0	0
5	0	6.1	7.9	4.7
6	10.0	6.1	13.1	9.7

[1] Results are based on data collected from 3 separate experiments.
[2] Figures are based on the number of crabs lost per day in each experiment compared to the number of live crabs used initially.

Second Road Experiment

Procedure

Because the life-support system performed well during the first experiment, a second trip of longer duration and larger numbers was initiated. As in the first experiment, the crabs were obtained from the coast of Washington. Forty-two hundred pounds were taken directly from the live well of a crab boat, weighed (after draining) and placed in the plastic trays. The problem of placing the crabs in the trays was eliminated by using aluminum separators (Figure 7) made especially for this experiment. The separators, resembling egg carton separators, divided the trays into eight separate compartments, one crab per compartment. In this way, the crabs were kept relatively quiet. When full, the separators were carefully removed and an empty tray placed on top, loaded, and so on. When enough trays were filled with crabs, they were weighed and loaded into the trailer. Using this technique seven people handled and loaded the crabs in about half the time required in the first experimental road test. As soon as the crabs were loaded and the life-support systems operating, the crabs were trucked to southern California. The trip covered a distance of about 1,500 miles and lasted 4 days.

Results and Discussion

Deliveries of crabs weighing from 500 pounds to 1,000 pounds were

made to six live seafood markets during the trip. Except for weak crabs, which were immediately cooked, all active crabs were placed in live display or storage tanks when unloaded (Figure 8). Dead crabs could not be sold and were disposed of. Mortalities for this experiment, based on the total weight shipped, was 5 percent. Dealers were very impressed by the liveliness of the crabs and absence of broken shells and lost legs. Damage was not considered to be significant. Delivery of the crabs direct to the market also pleased the dealers since air shipment of live crabs requires that they pick them up at an airport or have them delivered by an air-freight forwarder. Either operation is expensive and time-consuming.

Special handling procedures used to remove air trapped beneath the shell of the crab were not necessary in this or the first trucking experiment. Because the crabs were partly submerged during the trips, the water displaced the air sometimes trapped under the shell of dry packed crab.

Air causes the crabs to float when returned to live holding facilities. The problem is usually eliminated by holding the crab partly submerged in water until the air is displaced and the crab can sink. The procedure requires considerable time, especially when large numbers of crabs are involved.

Although pH measurements were not made during this and the first experiment, bacteria did not appear to be a problem as evidenced by the absence of off odors, including that of ammonia. Dissolved oxygen, also not measured in these experiments, did not appear to create a problem with respect to the crabs in that they were always active and alert when examined.

Time restrictions and limited experiments precluded considering the economics of the procedure. However, the relatively few crab losses, the enthusiasm of the retail buyers, and the success of the experiments indicated that this method of delivering live Dungeness crabs to market has considerable potential.

Figure 7.—Aluminum separators used to restrain crabs during tray-loading procedure.

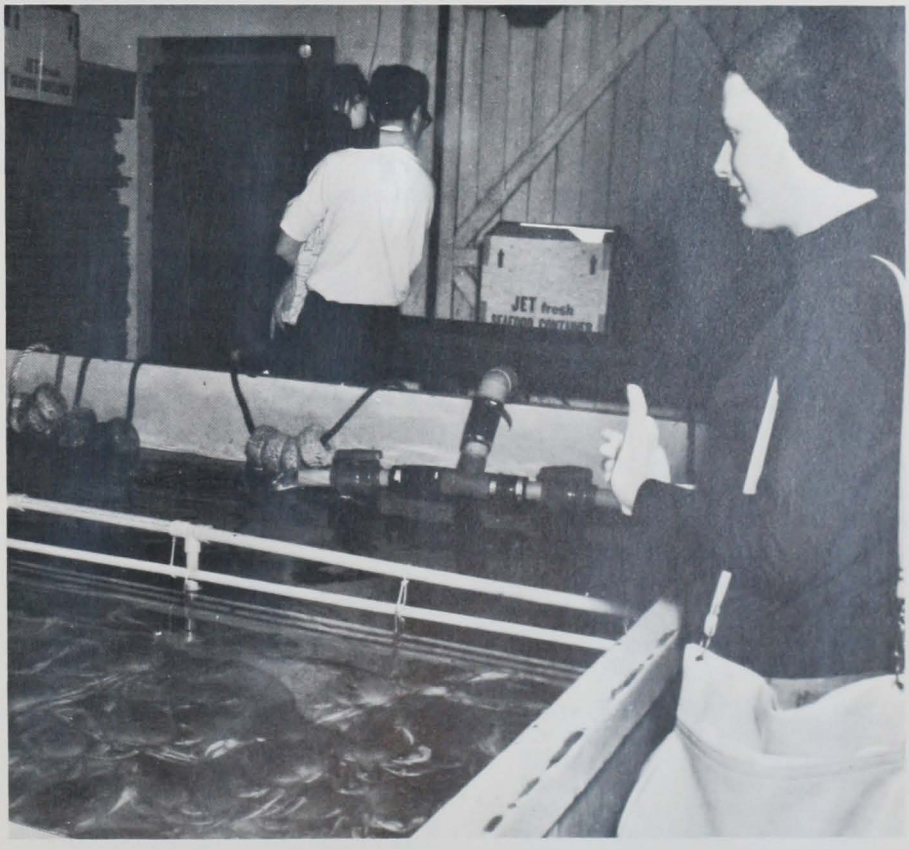


Figure 8.—Customer selecting a live crab from display tank.

SUMMARY AND CONCLUSIONS

Two experimental methods for keeping Dungeness crabs alive during long-distance hauling by truck were designed and evaluated in the laboratory. In the first experiment, a refrigerated seawater fog-spray, produced by a high-pressure pump and special fog-nozzle apparatus, was tested on crabs held in baskets. The technique resulted in mortalities of over 30 percent in a 4-day test period.

The second method was designed around a system of vertically-stacked trays supplied with a chilled, recirculated seawater that cascaded from tray to tray. Openings on the ends of the trays regulated the water level at a depth of 1 inch so that the crabs were continuously in enough water to maintain life without having to be completely submerged. Crab losses in replicate tests lasting 6 days were less than 17 percent.

Based on the results, the method was scaled-up for field testing in a truck-trailer combination. Crab losses in each of two over-the-road tests, one lasting 3 days and the other 4 days, averaged about 10 percent.

In conclusion, the method for handling and shipping live Dungeness crabs, as described above, appears to have considerable potential. Furthermore, the technique may have application to lobsters, fresh-water crayfish or other aquatic animals. However, if other animals are considered, experimental work is necessary to establish the efficacy of the method as it applies to each species.

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