Techniques for Live Storage & Shipping of American Lobster

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Second Edition

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Introduction

This public information booklet is intended as a concise guide for prospective commercial lobster dealers in the construction, operation, and maintenance of American lobster holding systems, and in the proper technique for shipping live lobster. It does not cover every operational design in use today, but concentrates on the major and basic points which must be addressed in order to maintain a successful operation.

Much has been written about the subjects of lobster holding and shipping methodology; however, the lack of a single, updated comprehensive treatment of these subjects prompted the drafting of this treatise. Considerable research has been carried out with marine recirculating systems, thereby improving our knowledge of the changes which can occur in a captive body of water. Effective procedures for dealing with these changes in order to maximize lobster survival and minimize impact on business overhead are discussed. Although live lobster shipping methodology has not changed much over the years, the major considerations necessary to minimize losses are also reviewed.

This booklet was not intended to "re-invent the wheel" but to facilitate "its" use. Much of the enclosed information was condensed from other published documents which are listed in the literature section and melded for easy reading. Specific reference to these documents was omitted from the text in order to simplify the presentation.

Live Storage

A. System Design Options

Live storage of American lobster for extended periods may be accomplished by several methodologies. Commercial dealers located in coastal vicinities may utilize floating crates, wooden "cars," dammed-off coves (common in State of Maine and Canada) or sheltered holding tanks, which are continuously supplied with running sea water pumped directly from the ocean (open system). Systems which are located further inland are limited to using recirculated-refrigerated tanks with a transported sea water or artificial sea water medium (closed system).

Each system has its advantages and disadvantages. Open seawater systems are the least complex to operate. If the source of seawater is high in quality, filtration may be unnecessary. However, the coastal environment is subject to periodic appearance of pathogens and toxicants which may be harmful to lobster. Under extreme conditions complex filtration and ultraviolet sterilization systems may be necessary. Pressure sand filters or cartridge filters will enhance the ultraviolet treatment process.

Major problems in a flow-through system are the presence of fouling organisms and silt. Sets of oysters, barnacles, or mussels can severely restrict water flow through the pipes and must be removed. This requires shut-down and mechanical cleaning and/or periodic back flushing. Construction of a back-up system would allow commercial operation to continue if the primary system fails or is shut down for cleaning.

The intake pipe should be placed in deeper water which is normally cooler and has a more constant salinity than the surface. The opening of the intake pipe should be covered by a removable screen or run from a filter box containing shells or gravel to remove suspended solids and hamper fouling (Figure 1). Such structure will require periodic maintenance.

The decision to use a submersible or non-submersible pump may depend on the distance between the tank and water source. A submersible pump may be more effective over a long distance, however, maintenance and electrical installation are simplified when the pump is land-based.

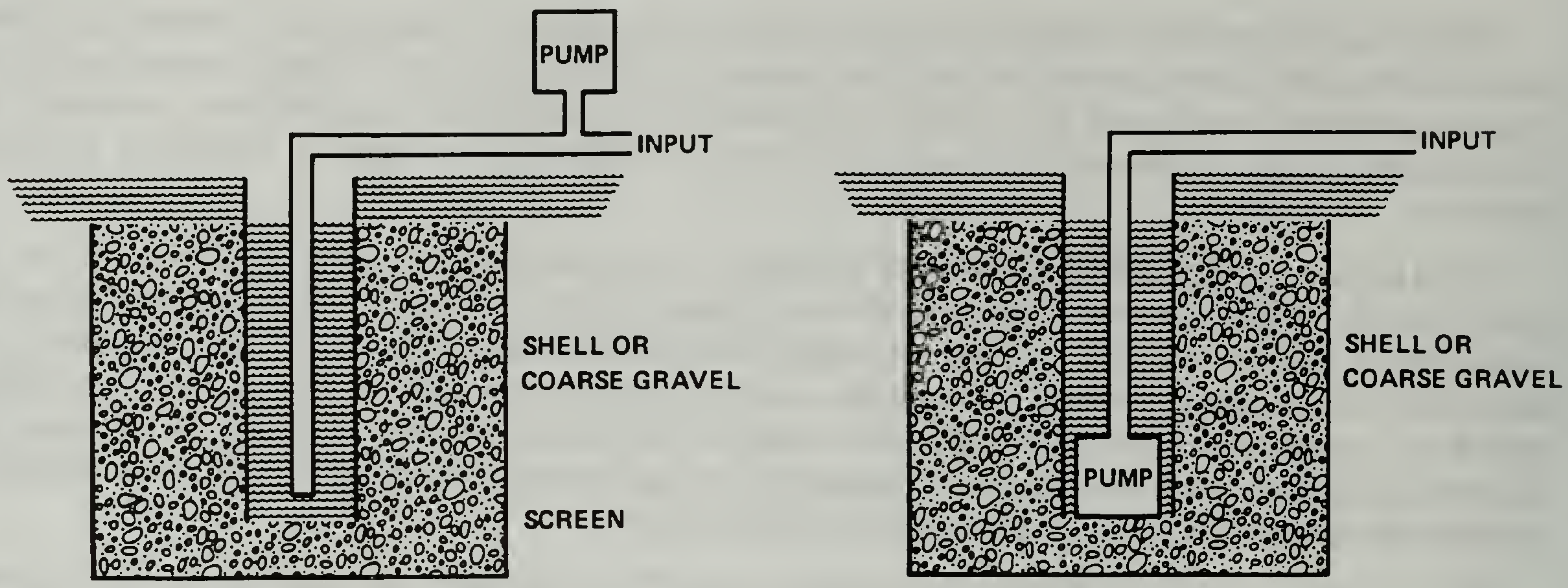

Figure 1. *Mechanical filter box and alternate placement of pumps for flow-through system. (From Perry et al. 1979)*

A closed recirculating system will reduce pumping costs and exposure to the marine environment and thereby allow better control over pathogen entry, particularly if an artificial medium is used. Gravity or biological filters are two water cleansing options used in closed systems. Figure 2A depicts a simplified closed recirculating system.

B. Tank Construction

The size and shape of a tank may vary depending upon space restrictions and needs. Keeping in mind a suggested loading ratio of 1 to 2 lbs. of lobster to 2 gallons of water, the tank capacity in gallons yielded by contemplated tank dimensions can be easily computed using the following formula:

gallons = (desired water depth x tank length x tank width) ÷ F

If measurements in inches, then F = 231 cubic inches/gallon

If measurements in feet, then F = 0.13368 cubic ft./gallon*

*(1 cubic foot = 1728 cubic inches = 7.48 gallons).

Tanks constructed of glass and aluminum or stainless steel are convenient for display but costly. A less expensive and commonly used construction material is pine planking. Most other woods, including plywood, have been used successfully although the toxicity of oak, cedar, and redwood is suspected. Wooden, concrete, or cinder block tanks can be coated with fiberglass or epoxy resin to seal them, enhance their longevity, and facilitate cleaning. The rounding of corners aids water circulation, and eliminates sites of debris collection and low dissolved oxygen. Commercially produced molded fiberglass and plastic tanks as well as glass display tanks are available from several firms (Appendix A).

The plumbing layout must not contain any copper or copper alloys (brass, bronze, Monel Metal, etc.) which are in contact with the water. The leaching of copper ions into the water will readily occur and is extremely lethal to lobster. Consequently, a pump with a bronze impeller should not be used. Zinc and lead are also toxic and should not interface with system water. PVC piping is the preferred choice for plumbing. The use of capped "T's" in place of elbows will facilitate cleaning.

Water entering the tanks may be sprayed through holes in a capped pipe or through a series of holes in an overhead pipe. This will achieve aeration by breaking the surface tension of the water and trapping air. Air pumps which force air through diffusers, or mechanical agitators may also be used.

Tank drains should be at least 1¼ inches in diameter and may be placed in the side or bottom of the tank. Since the water level is controlled by the height of the drain opening, the water level in a bottom drained tank may be simply adjusted by fitting a particular length of pipe (standpipe) into the drain hole. This pipe should be removable to allow complete drainage if necessary. A self-flushing tank can be easily made by placing a notched pipe of larger diameter over the bottom standpipe (Figure 3). This causes water to be drawn from the bottom of the tank, thereby pulling some debris with it. If the tank's water supply is stopped for any reason, lobster will quickly use up available dissolved oxygen in the standing water and suffocate faster than they would in moist air. If such conditions are expected to be prolonged, tanks should be drained. A ¼ inch hole at the base of the standpipe will allow drainage.

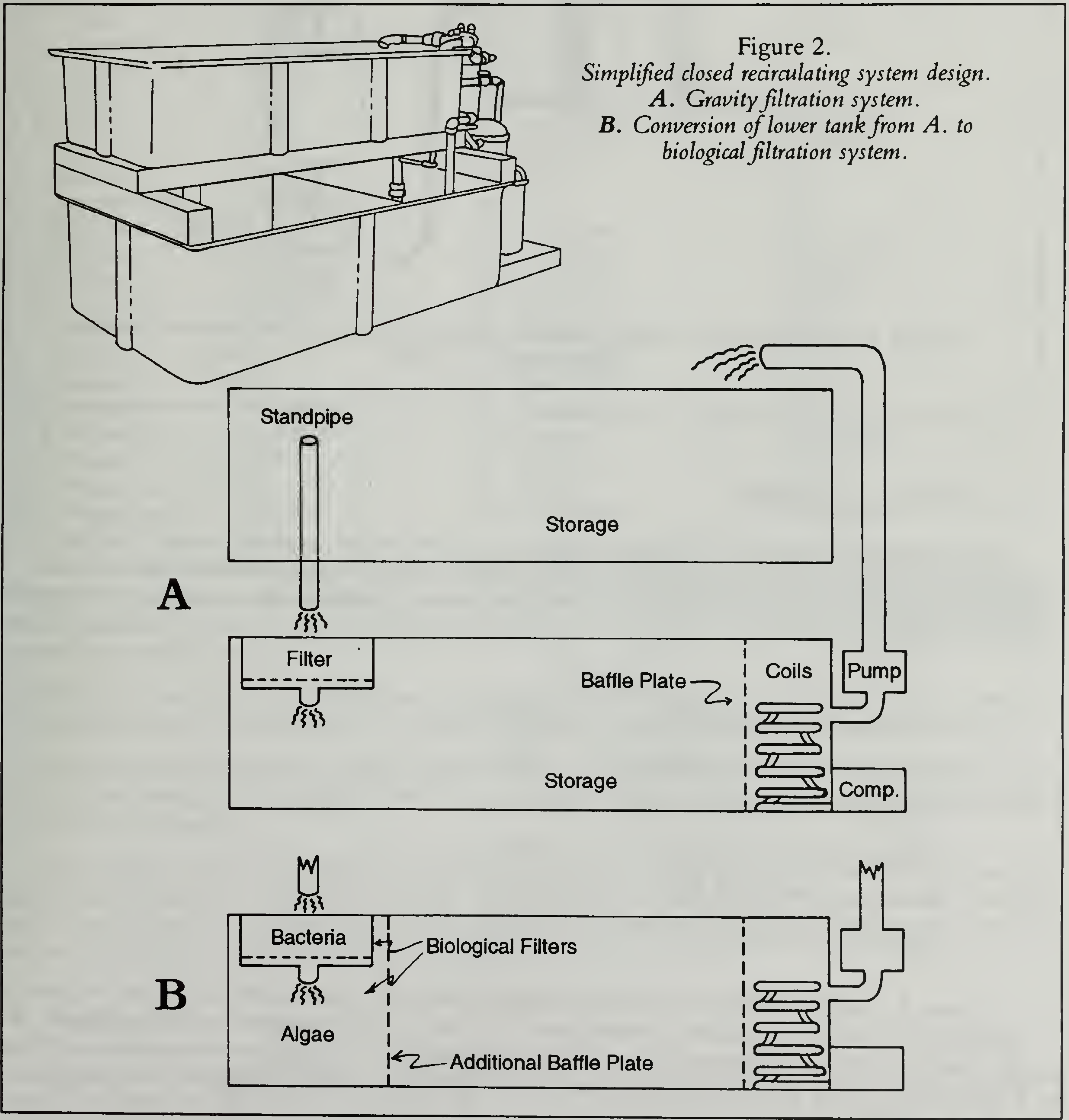

Figure 2.
Simplified closed recirculating system design.
***A.** Gravity filtration system.*
***B.** Conversion of lower tank from A. to biological filtration system.*

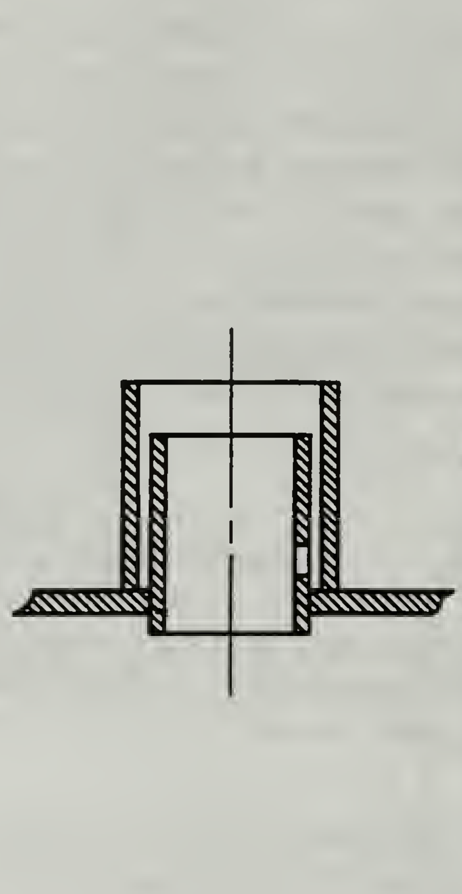

Figure 3. *Self flushing drain showing placement of notched pipe over smaller diameter standpipe. (From Perry et al. 1979)*

C. Water Quality

If cost and/or inconvenience prevent shipping sea water inland, artificial sea salt mixtures can be prepared. Six major salts which are easily purchased from chemical supply firms can be dissolved in 100 gallons of tap water at the following proportions and provide a medium with a salinity of 34 o/oo (parts per thousand):

	Ounces
Sodium chloride (Na Cl)	376.66
Magnesium sulfate (Mg SO_4)	92.50
Magnesium chloride (Mg Cl_2)	73.33
Calcium chloride (Ca Cl_2)	19.17
Potassium chloride (K Cl)	9.17
Sodium bicarbonate (Na HCO_3)	2.85

Although somewhat effective at keeping lobster alive, such mixtures which do not include trace elements are generally considered unsatisfactory for culture and long-term use. It is difficult, if not impossible, however, to duplicate all trace elements available in natural sea water since the contributing proportions of many are infinitesimally small. The following table should emphasize the complexity of natural sea water:

Element	Amount, ppm	Element	Amount, ppm
Ag, Silver	0.003	Ar, Argon	0.6
Al, Aluminum	0.01	As, Arsenic	0.003
Au, Gold	0.000011	Mo, Molybdenum	0.01
B, Boron	4.6	N, Nitrogen	0.5
Ba, Barium	0.03	Na, Sodium	10,500
Be, Beryllium	0.0000006	Nb, Niobium	0.00001
Bi, Bismuth	0.000017	Ne, Neon	0.00014
Br, Bromine	65	Ni, Nickel	0.0054
C, Carbon	28	O, Oxygen	857,000
Ca, Calcium	400	P, Phosphorus	0.07
Cd, Cadmium	0.00011	Pa, Proctactinium	$2x10^{-9}$
Ce, Cerium	0.0004	Pb, Lead	0.00003
Cl, Chlorine	19,000	Ra, Radium	$6x10^{-11}$
Co, Cobalt	0.00027	Rb, Rubidium	0.12
Cr, Chromium	0.00005	Rn, Radon	$6x10^{-16}$
Cs, Cesium	0.0005	S, Sulfur	885
Cu, Copper	0.003	Sb, Antimony	0.00033
F, Flouride	1.3	Sc, Scandium	<0.000004
Fe, Iron	0.01	Se, Seleniem	0.00009
Ga, Gallium	0.00003	Si, Silicon	3
Ge, Germanium	0.00007	Sn, Tin	0.003
H, Hydrogen	108,000	Sr, Strontium	8.1
He, Helium	0.0000069	Ta, Tantalum	<0.0000025
Hf, Hafrium	<0.000008	Th, Thorium	0.00005
Hg, Mercury	0.00003	Ti, Titanium	0.001
I, Iodine	0.06	Tl, Thallium	<0.00001
In, Indium	<<0.02	U, Uranium	0.003
K, Potassium	380	V, Vanadium	0.002
Kr, Krypton	0.0025	W, Tungsten	0.0001
La, Lanthanum	0.000012	Xe, Xenon	0.000052
Li, Lithium	0.18	Y, Yttrium	0.003
Mg, Magnesium	1350	Zn, Zinc	0.01
Mn, Manganese	0.002	Zr, Zirconium	0.000022

Even though trace elements comprise less than one percent of the total salts in natural sea water, their importance in providing an ionically balanced medium is not diminished. Such a medium has nutritive and life supportive properties and is particularly important when used for culturing delicate larvae and for scientific investigations.

There are numerous commercial sea salt mixtures available (Appendix A). Care should be taken to choose one which contains at least the essential elements in ratios approximating natural sea water.

Lobster can actively absorb ions from solution; consequently, an unbalanced salt mixture may be toxic. It is the ionic antagonism resulting from a balance of ingredients which cancels the poisonous potential of individual elements.

The buildup of ammonia excreted by lobster is a common problem in a closed system which can upset this chemical balance and cause mortality. Consequently, biological and physical water treatment procedures become a necessity for removing nitrogenous wastes and other metabolic by-products. This will be discussed in more detail in another section.

1. Parameter Limits

Optimum salinity for lobster ranges from 29 to 35 o/oo. Acclimation to salinities outside this range is possible if other conditions are favorable. For example, survival can occur at 11 o/oo at 40° F, or at

26 o/oo at 70° F. The upper tolerance is at 45 o/oo while survival at lower salinities is enhanced if the temperature is low.

Commercial sea salt mixtures are available for mixing with tap water. However, precautions should be taken to insure that any chlorine present in the tap water has dissipated before lobster are added. A concentration of 0.1 ppm chlorine is toxic to lobster. If present, recirculate water for two to three days (depending upon concentration) or pass water through an activated charcoal filter. Commercial dechlorinators such as sodium thiosulfate are available from aquarium stores.

A pH level between 5 and 9 should be maintained. The use of calcareous materials in the filter such as broken mollusc shells will aid in buffering against a usually declining system pH. The pH of natural sea water ranges from 7.5 to 8.4. The addition of activated carbon to a biofilter wil help to maintain a pH level above 7.5 because it also inhibits a buildup of acid substances in the system. Its use has been found to reduce mortality by approximately 10%.

Ammonia is quite toxic to lobster and will build to high levels in the holding system unless it is controlled by nitrifying bacteria in a biological filter. These bacteria will convert ammonia to nitrite which is less toxic and then convert nitrite to nitrate. The system is considered to be balanced when the bacterial colony has grown large enough to keep the ammonia and nitrite levels under control. When this happens, a test for ammonia should read < 10 ppm while nitrite drops to <5 ppm. Under these circumstances nitrate levels will continue to build and should be kept below 100 ppm by a regular schedule of water changes.

The toxicity of copper ions to lobster cannot be overstated. The normal concentration of copper in sea water is 0.003 ppm. The lethal threshold of copper established for lobster is 0.056 ppm.

2. Refrigeration

An optimal system water temperature should fall between 40°F and 50°F and may vary depending upon individual needs. For instance, lobster held at 48° F are fairly active and appealing to a customer. At 40° F they are markedly less active but will last longer under stressful conditions due to a slower metabolic rate. Also, waste production will decrease as the temperature decreases. Consequently, a refrigeration unit consisting of a compressor and coils which are of proper capacity for the size of the system must be installed. Special construction is necessary because cooling coils are normally made of (toxic) copper tubing. Safe coil materials are black iron, galvanized iron, plastic, titanium, and stainless steel. Black iron and galvanized iron will eventually rust, and plastic is impractical due to poor heat conductivity. Stainless steel may not be a useful choice for cooling coil construction; it is non-toxic and corrosion resistant, but it is greatly susceptble to electrolysis. Titanium tubing is efficient at heat conduction and resistance to corrosion and as a result is commonly found in modern commercially manufactured systems.

A general rule of thumb is to use eight square feet of black iron coil surface per ton of refrigeration. The square footage per ton would have to be increased by 60-80% if plastic coils are used (although it is probably more accurate to relate coil surface area to horsepower). The use of a pump to agitate water flow over the cooling surface enhances the water-to-coil friction and is far more efficient than allowing cooling coils to passively chill water.

The compressor and cooling coil or heat exchanger surface area should be capable of maintaining a water temperature between 40° F and 50° F. Placement of air cooled condensers is critical since they give off excessive heat. A refrigeration specialist should be consulted for proper installation. Suggested compressor sizes are:

Compressor Size (horse power)	System Size (gallons)
⅓	75-125
¾	200-250
1	275-400
1½	425-700
2	800-1100
3	1200-1500

A temperature of 45° F approximates the body temperature of lobster when they are unpacked from an iced shipping container and minimizes temperature shock. Although lobster can adapt to a wide range of temperatures, exposure to sudden extreme changes should be avoided. Lobster should be protected from direct contact with cooling surfaces by using a baffle plate (Figure 2) or maintaining refrigerant coils in a separate tank. Death may ensue when lobster are exposed to a rapid rise in temperature while reaction is less violent to decreases in temperature. Lobster can adjust satisfactorily to a temperature differential of 15° F, although complete acclimation may take nearly three weeks. Differentials greater than 15° F may lead to mortality. Lobster captured during the summer months are acclimated to warm ocean temperatures; they should be gradually adjusted to holding tank temperatures to avoid temperature shock.

3. Circulation

Oxygen is another important requirement which must be available at optimal levels for proper holding conditions. Oxygen level varies with water temperature. As the temperature rises the oxygen holding capacity drops. When water holds all that it can at a given temperature it is said to be saturated as in the natural environment. At 32° F saturated sea water contains 12 ppm (parts per million) oxygen but at 77° F it contains 7 ppm. The oxygen concentration of the storage system should be kept at or near saturation level.

The rate of oxygen going into solution is enhanced by breaking up the surface of the water through use of a recirculating pump, the size of which is an important consideration. Oxygen dissolves in water more readily when it is broken into small bubbles by an air stone or air breaker. If the return flow is directed through a perforated pipe overhanging the tank, the resulting spray will break the surface tension and facilitate the dissolving of oxygen. Minimum circulation requirements for a suggested loading ratio of 1 lb. of lobster to 2 gallons of water are:

Pounds of Lobster	55	110	220	660
Degrees (F)	Rate of circulation (gallons per minute)			
40	½	1	2	6
50	1	2	4	12
60	1½	3	6	18
70	2	4	8	24

Larger loading ratios will increase the rate of oxygen consumption and circulation requirements. The water flow requirement to maintain 1,000 pounds of lobster at 45°F where 50% of the dissolved oxygen is utilized is 10.8 gallons per minute.

The plumbing must be constructed properly to prevent supersaturation of the water which will cause a condition known as gas disease (which is similar to a pressure-related ailment called "the bends" experienced by divers). Supersaturation will occur when the pump is working against high head pressure and an air leak develops on the vacuum side of the pump. Death may result in a few hours to two weeks depending upon the acuteness of the problem. In order to prevent this the recirculating system should be operated under low head pressure by selecting a low speed pump (e.g.,1725 r.p.m. preferable to 3450 r.p.m.); avoid a deep well jet pump; minimize the height at which water must be pumped; make the outlet pipe diameter larger than the suction pipe; minimize the number of elbows or "T's" in the piping, the layout should be as straight as possible; give preference to a gravity filter rather than a pressure filter; and do not install a priming valve on the intake side.

The amount of oxygen present in sea water varies with salinity as well as temperature. Oxygen holding capacity increases as water temperature and salinity decrease. Oxygen consumption is directly related to temperature. At 60° F lobster consume about twice as much oxygen as they do at 40° F. If the salinity is below optimum the oxygen requirement is also increased. Also, after feeding, oxygen consumption nearly doubles and remains high for three or four days. Small lobster require appreciably more oxygen per pound than large lobster.

4. Filtration

Sanitation is an important aspect of holding system operation. Water which is cloudy and foul smelling is generally laden with organic material from not only waste products but from broken lobster parts. This organic matter breaks down into complex toxic by-products and in the process can utilize a large volume of oxygen. Water in this condition is aparently receiving inadequate filtration and should be changed to reduce its toxicity. Filtration will help to cleanse the water and reduce the need for water changes.

Large amounts of protein in the water will cause surface foaming. For these reasons, food should be omitted during short-term holding due to its pollution potential. Lobster have been held successfully for seven months without food. Although a slightly lower meat yield resulted, flavor was not affected.

4a. Gravity (Mechanical) Filter

Several options for filtration system construction are available. A simple gravity filter may be prepared by building a box with a plastic screen bottom and filling it with turkish toweling, burlap, cheesecloth, or cotton waste. Fiberglass insulation has been used successfully; however, it is not recommended because loose glass fibers will injure lobster, and may affect mortality in lobster held for long periods. Other filter materials such as 1/8" to 1/4" gravel or activated carbon may be used. This type of filter box, when placed in an accessible location allows easy inspection and replacement of the filter medium when needed. A polyester fiber pad may be placed on top of the filter material in order to screen large particulate matter. This "prefilter" can be periodically removed, flushed, and reused. A filter box size of 2' x 2' x 2' is suggested for a 200 to 400 gallon system.

4b. Pressure Filter

Commercial pressure filters, e.g. swimming pool filters, using charcoal or sand will also be effective at removing particulate matter, but are expensive and may cause gas disease. Generally, the volume of the filtrant material which these filters can hold is relatively small and therefore requires periodic backflushing to clean the medium. Such a filter should be shunted to a fresh water system for backflushing because backwashing into the saltwater system will release into the system all of the particulate matter which is trapped in the filter. This will require a complete water change.

4c. Biological Filter

A third filter type is the biological filter which has a multifaceted application. Normally commercial holding systems are designed for short-term lobster holding with filters intended mainly for removal of solid wastes. However, successful recirculating system operation requires an awareness of the changes occurring in a captive body of water. Even with a gravity filter in place, the buildup of nitrogenous compounds is a common problem. For example, ammonia, the major metabolic waste products of not only lobster but most aquatic animals is extremely toxic to all life forms and should be kept below 10 ppm. It can be controlled by employing a biological filter which is populated with nitrifying bacteria that metabolize ammonia and convert it to less toxic nitrite and then to nitrate. This is the nitrification segment of biological water treatment.

If lobster are going to be held in closed systems for a long period of time, and particularly if they are fed, then ammonia production and buildup will be enhanced. Sudden overloading of a system with lobster (high lobster to water ratio) will have the same result and require regular complete water changes to mitigate the toxic effect. A high lobster to water ratio may be tolerated with fewer water changes if a biological filter is utilized. However, keep in mind that an effective biological filter is one in which the microbial population is in equilibrium with the waste produced by the lobster. Maintaining the recommended

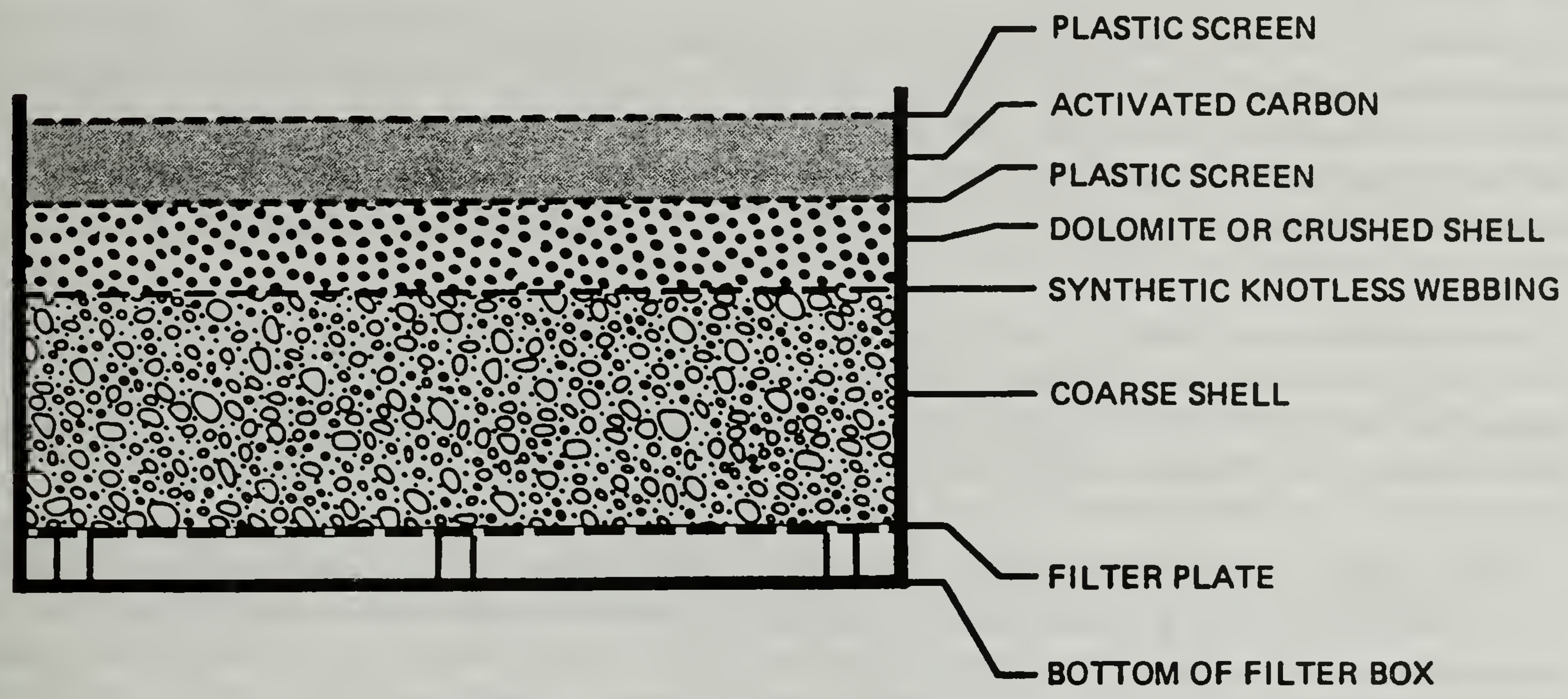

Figure 4. *Primary biological filter with filtrant materials resting on a suspended, perforated filter plate which provides under-drainage. (From Perry et al. 1979)*

system loading ratio of one pound of lobster to two gallons of water will reduce the water changing frequency and yet optimize use of the medium.

A biological filter may simply consist of a box containing materials that provide surface area for bacterial growth. Ammonia-fouled water flowing through the filter is acted upon by the bacteria. Filter materials may include granular activated carbon, a layer of crushed oyster shell or dolomite, and a layer of coarse oyster or clam shells, all of which should be washed thoroughly before use. These materials also provide some mechanical filtration since particles will be trapped between the grains. A prefilter pad may also be used here to screen large particles. The bottom layer of coarse shell should rest on a perforated filter plate which suspends it above the floor of the tank to provide underdrainage (Figure 4). In addition to providing sufficient area for bacterial growth, the layer of granular activated carbon will absorb dissolved organic carbon, while the layers of shells provide a carbonate buffer against a declining pH resulting from a buildup of nitrates in addition to other factors: abundant nitrate ions readily replace carbonate and bicarbonate ions to form nitric acid. Successive layers of crushed shell and finally marine-activated carbon should each be sandwiched by nylon screening to keep the layers discrete and facilitate removal for cleaning. Phosphates will precipitate as calcium salts onto the filter bed and reduce its buffering capacity. This requires periodic stirring and/or rinsing of the filtrant materials. However, washing will remove most of the detritus which supports a large population of nitrifying bacteria. It also detaches bacteria from the filtrant surface. Consequently, if washing is absolutely necessary, it should be done directly in the system with clean water of the same salinity. The surface area of such a filter should approximate 25 percent of the total water area. Since microbial activity in a fine-grained filter diminishes with increasing depth due to declining oxygen availability, overall filter depth should not exceed one foot. Most of the nitrification will occur in the top several inches of the fine-grained segment of the filtrant material. The turnover ratio should be 2 to 3 tank volumes per hour.

Although the biological filter described has been proven to be successful, recent studies have shown that the use of a filtrant material size of 2-5 mm (1/16 - 3/8" dolomite, crushed mollusc shells, or coral gravel) will enhance uniform distribution of nitrifying bacteria throughout the filter. If used, this will decrease the size of the filter needed and allow more efficient utilization of space.

The filter can be placed above the holding tank or submerged in a separate tank. The latter maximizes filtration efficiency since the entire surface area will be covered with water.

It should be noted that the activity level of nitrifying bacteria will be drastically reduced when the medium temperature is below 50° F as is generally the case with commercial lobster holding systems. Consequently, caution should be taken if a biological filter is incorporated since its efficiency will be lowered. A change of from 10 to 30 percent of the water per month is recommended, particularly if the suggested loading ratio is exceeded. Nevertheless, a biological filter will increase the length of time that water can be recirculated for it mitigates lethal toxic buildup.

It is advisable to allow from one to two months for the bacterial medium in biological filters to develop, depending upon water temperature. Filter bacteria can be introduced into the system by the addition of natural bay water, soil nitrifying bacteria, or by inoculation from an established filter bed. In the latter two cases, one may vigorously mix well cultivated garden soil or filtrant materials with fresh water, allow the solids to settle out, then pour the liquid into the new filter.

The loading capacity of the system will vary according to the area of the filter's surface, the successful colonization and resulting density of nitrifying bacteria, and the health of the biological filter. The system parameters should be closely monitored to determine the holding capacity of the system. If the parameter limits are exceeded, the health of the filter's bacterial colony will suffer and the number of lobster it can sustain will diminish. The operator should seek to achieve a balanced system which is one in which the biological filter is in equilibrium with the waste production.

Secondary Water Treatment

Secondary water treatment is a necessary segment of the biological filtration system only if one wishes to control the buildup of nitrates and the resulting need for the previously described frequent water changes. This facet of biological filtration is seldom employed in commercial lobster operations. It is described here only to provide a comprehensive description of biological filtration. This is the dissimilation segment of biological water treatment where nitrates are reduced to free nitrogen and/or converted to plant tissue. It is accomplished by the culture of filamentous or leafy marine macroscopic algae. A separate tank must be provided with light either natural or artificial for the algae to conduct photosynthesis (Figure 2B). Keeping the rest of the system in dim light will help prevent spread of the algae throughout the system. The growth and viability of both the microbial and algal populations will depend upon the supply of available nutrients. Once bacteria and algae are introduced into the system, the nutrients (waste products) necessary for their growth and proliferation must be supplied. Lobster may be maintained in the tank with a mechanical or gravity filter until the biological filter is fully developed. Under such conditions the water chemistry should be regularly monitored and water changes made if necessary.

Portable test kits are available from a number of sources (Appendix A) which will determine dissolved oxygen, salinity (may be measured with a hydrometer), ammonia (NH_4), nitrate (NO_3), and pH. These parameters, in addition to temperature, should be major considerations of a system operator. (When deciding on which water analysis kit to purchase it may be helpful to consider the maximum number of tests which each kit allows).

D. Troubleshooting Causes of Mortality

It is obviously important to regularly monitor system parameters to avert excessive mortality, however, when evaluating system problems one should keep in mind that lobster mortality may be attributed to a number of causes. In addition to toxic construction materials, heavy metals and chlorine, lobster are extremely susceptible to insecticides including "no-pest strips". These should not be used in the vicinity of holding tanks. Cleaning fluids, hand lotions, or any other foreign solutions should not come in contract with the water.

Although the potential lethality of toxic materials and abnormal system parameters has already been discussed, it is important to know that high temperature, low salinity, low dissolved oxygen, pollution, overcrowding, and aggression may be particularly detrimental during the molting period. The physiological changes which lobster undergo at this time make them particularly sensitive to stress and their vulnerability to physical abuse is much greater than hard-shelled lobster. The crowded conditions that potentially can occur in a holding tank will enhance stress by lowering the dissolved oxygen level,increasing waste production, and lowering pH. Low salinity, oxygen depletion, and gas disease appear to be more hazardous at high temperatures. Consequently, it is advisable to keep system parameters at the suggested ideal levels.

Lobster which are captured by trawler may be exposed to oxygen deficient mud which is also swept into the cod end of the trawl. This material may clog the gills and not only directly interfere with the normal flow of water over the gill surfaces but also compete for available oxygen. There is also the likelihood of physical damage to the fine gill filaments. Such stressed lobster are highly susceptible to mortality unless properly washed and stored at a low temperature (40° F). If uninjured, lobster can clean away most of the mud through the beating action of their gill bailers within a few hours. Nevertheless, if not properly cared for, trawl-caught lobster may be more likely to succumb to adverse holding conditions than trap-caught lobster.

Gaffkemia, a naturally occurring bacterial disease of the blood, has received the greatest notoriety as a potential lobster killer. American lobster ave very susceptible to it. Bacteria will enter the lobster through breaks in the shell, consequently, shell damage or broken claws caused by rough handling, puncture wounds from pegging claws (rather that banding), or lobster aggression under crowded conditions may result in losses if the bacteria are present. High temperatures and low salinity will shorten time to death to a few days; under ideal conditions the time to death may take one to two months. Since the disease is harmless to man, weakened lobster can be cooked without any problem.

However, given the ease at which the disease may infect other lobster some precautions should be taken. For insurance each new lobster shipment should be isolated in a separate tank. One can usually determine within 4-5 days if any diseased lobster are present. Infected lobster exhibit progressive weakness, sluggishness, and assume a spread eagle position just prior to death. They may also develop a pinkish to reddish coloration observable through the semi-transparent membranes on the underside of the tail. However, this condition can be caused by a number of other factors so the common name of "Red Tail" disease is a misnomer. If identified, diseased lobster should be quickly removed and the shipment quarantined until sold. The tanks should then be drained, thoroughly scrubbed and rinsed to remove as much organic material as possible (algae, etc.). Then rewash with a commercial chlorine bleach to kill bacteria, flush well and refill with dechlorinated water (1 grain of sodium thiosulfate per gallon of water). Dechlorination material is available from aquarium shops. Keep in mind that filters should be cleansed in the same fashion or reinfection may occur. Medicinally-treated foods have been developed to combat gaffkemia in lobster holding facilities. It should be noted that such antibiotics will also affect the flora in biological filters.

Another lobster ailment which also generally follows an initial external injury is shell disease. Invading chitin-consuming microorganisms cause a tunneling and pitting of the shell and eventually ulceration. Death will not usually ensue unless the chitinous covering of the gills is attacked, subsequently interfering with respiration. If ulceration of underlying tissue has not occurred then the symptoms will usually be eliminated when the shell is shed. Consequently, small lobster, which molt at a greater frequency than large lobster, are less likely to exhibit extensive symptoms.

Most parasitic infections are not believed to seriously impact lobster and may be responsible for only chronic low level mortality depending upon the species and anatomical site of attachment (digestive tract, gills, heart muscle). However, one species, a ciliated protozoan (Mugardia) has caused extensive mortality in some Maine impoundments in recent years. This pathogen is thought to enter the body through a wound or break in the shell. Mugardia has been found to actively devour lobster blood cells causing mortality within a few weeks through anemia and asphyxiation.

Troubleshooting system problems can be accomplished if the following symptoms and probable causes are recognized and corrective measures implemented:

Symptoms and Probable Causes of Death of Lobsters in Recirculated Holding Systems

(adapted from Goggins, 1960)

SYMPTOMS	PROBABLE CAUSE	CORRECTION
Lobster becomes increasingly weak and sluggish; dies in spread-eagle position	1. Lack of oxygen 2. Copper poisoning 3. Poisoning due to breakdown of waste material	1. Remove some lobster from system or increase circulation 2. Remove copper from system. 3. Change water
Many dead upon arrival. Show above symptoms when placed in water. More active lobster, upon removal from water, die in from 15-20 minutes. If wounded, bleed to death quickly.	Bacterial disease, Gaffkemia Protozoan, Mugardia	1. Salvage weak lobsters. 2. Notify Mass. Division of Marine Fisheries.
Lobster become increasingly weak and sluggish. Die in spread-eagle position with bloating, while still alive, at junctions of carapace and tail, walking legs and body	1. Fresh water 2. Acute gas disease	1. Check salinity and correct. 2. Check vacuum side of pump for possible air leaks, and correct.
Lobster may show mild irritation (more activity than normal), walk on tips of walking legs with tail angled upward, then lose sense of balance, fall on side or back, unable to right itself. May not die for week or more.	1. Mild Gas Disease 2. Mild insecticide poisoning	1. Same as #2 above. 2. Drain tank thoroughly. Clean with strong alkali. Replace water.
Lobster hyperactive. May leap out of water. May die in from 2-4 hours.	Acute insecticide poisoning.	Same as #2, above.
Lobster hyperactive, at first. Will arch tail upward and forward as far as possible. Will back in almost perpendicular position against sides of tank, then relax and act normal. Then usually die in from 15-20 minutes.	High salinity. More than 40 parts per thousand.	Correct the formulation of water.
In winter, lobster sluggish when placed in water. Dies within 24 hours. When boiled, meat - usually tail section - mushy.	Freezing. Ice crystals formed in tissue cells.	Adequate protection in transit.
July to October, in new shell stock. Lobster weakens and dies.	Weak stock. Lobster more sensitive generally because of molting and adverse holding conditions, especially to abrupt changes in temperature. May be further weakened by poor handling.	Handle lobster as carefully as if they were eggs. Avoid abrupt changes in physical chemical environment.

SHIPPING

The general procedure for shipping live lobster involves removing them from their sea water medium and packing them in crates constructed of wood, insulated waterproof cardboard, styrofoam, or facsimile. The same precautions advised for storage tank operations are also recommended for shipping. However, the most important considerations for enhancing survival, particularly for long term shipments, are temperature, humidity, available oxygen, and use of hard-shelled, vigorous lobster, rather than recently molted lobster.

Lobster can live out of water for 4 to 5 days, however, their gills must remain moist in order to function. Their respiration in air is best when humidity approaches 100 percent.

Since oxygen consumption increases with the temperature and lobster are extremely sensitive to high temperature, refrigeration during shipping is necessary. Refrigerating lobster at a temperature between 32 F and 40 F will maximize survival. Lobster which are captured during warm weather should be stored in a holding tank at 45° F or lower in order to adjust them to a cool shipping temperature.

Shipping crates may contain or be covered with ice. However, lobster should not be allowed to directly contact the ice to avoid temperature shock nor should they be immersed in the fresh water from the melting ice as this can be lethal.

Shipping containers should not be completely air tight since this will cause the oxygen level to drop and carbon dioxide level to quickly rise to a lethal point. Under these conditions and a temperature of 50° F, 33 percent mortality was demonstrated within 36 hours. However, a colder shipping temperature may have solved this problem since it would have lowered the lobster's respiration rate. Nevertheless, dry ice (carbon dioxide in solid form) should not be used because as it warms it produces large amounts of carbon dioxide which can asphyxiate lobster. It is also too cold (-109° F) and will easily freeze nearby lobster. Shipping crates with 1/2" air vents on opposite sides will supply adequate ventilation if it is felt that containers are too well sealed and a low temperature cannot be maintained.

Since the oxygen consumption of feeding lobster doubles, lobster should be starved for at least three days before shipping. Small lobster will require more oxygen per pound than large lobster.

Lobster are generally shipped down form Canada and Maine in wooden lathe crates which hold approximately 100 lbs. of lobster. These crates are generally constructed of loosely spaced lathes which aid air circulation and contain several pounds of rockweed along with the stacked lobster to help maintain adequate humidity. Although the value of rockweed packing has been questioned, it is still widely used in long distance shipments which may last up to four days. Wet burlap may be an effective substitute. Crushed ice is packed on and between crates and then covered by a tarpaulin. Crates should have adequate drainage holes to dissipate fresh water from melting ice. Refrigerated trucks which can maintain a proper temperature and humidity are ideal for lobster shipping since icing of shipping containers will be unnecessary.

The major concern arises when lobster are shipped in open trucks in warm weather. Under such conditions the ice will melt rapidly and re-icing will be required to maintain a low crate temperature and maximize survival. The alternate layering of lobster, wet burlap, and crushed ice within crates may help to maintain proper shipping conditions in this case.

During winter, shipments may be made at very low air temperatures. At these times lobster must be protected from freezing. (Their body freezing point is 29° F). Under such extreme conditions enclosed trucks which are supplied with a heater may be necessary.

Long distance shipments requiring a lengthy period of time by truck or train may be handled by air freight. For air freight or any short trips lasting up to 24 hours, styrofoam insulated cartons holding up to 50 lbs. of lobster are generally used. The convenience of commercial reusable freeze packs (gel-paks) has eliminated the need for crushed ice and its associated drainage problems in these instances. Care should be taken to properly gauge the duration of the frozen reusable ice packs and judge shipping time accordingly. Provisions should be made for the cold storage of shipped lobster as soon as possible after arrival at their destination.

Commercially produced corrugated shipping cartons with molded styrofoam internal containers which are specifically designed for shipping live lobster are widely used and available in several sizes (Appendix A).

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Appendix A

STORAGE SYSTEM COMPONENTS AND SHIPPING CRATE MANUFACTURERS

The following list of manufacturers of lobster storage system components and shipping crates is intended as an aid to prospective dealers in finding needed equipment. The list includes only known manufacturers taken from newspaper, magazine, and "yellow pages" advertisements. It is in all probability not a complete list and does not represent an endorsement by the Division of Marine Fisheries.

Manufacturer or Distributor	Complete storage systems	Tanks	Filters	Pumps	Refrigeration units	Synthetic sea salts	Water analysis test kits	Shipping crates
Aquaria, Inc. 2290 Agate Court Simi Valley, CA 93065 Tel. (805) 584-9400	X					X		
Aquarium Systems 8141 Tyler Blvd Mentor, OH 44060 Tel. (216) 255-1997						X		
Atlantic Lobster Systems 735 E. Indust. Park Dr. Manchester, NH 03103 Tel. (603) 669-2728	X					X		
Charles English, Inc. 6140 St. James St. West Montreal, Quebec CANADA H4A 264 Tel. (514) 481-2065	X		X			X	X	
Dayno Lobster Tank Co. 165 Commercial St. Lynn, MA 01905 Tel. (617) 598-5566	X		X			X	X	

Manufacturer or Distributor	Complete storage system	Tanks	Filters	Pumps	Refrigeration units	Synthetic sea salts	Water analysis test kits	Shipping crates
FDC Packaging 113 Adams Street Medfield, MA 02052 Tel. (617) 359-8566								X
Frigid Units, Inc. 3214 Sylvania Ave. Toledo, Ohio 43613 Tel. (419) 474-6971	X	X	X		X			
HACH PO Box 389 Loveland, CO 80537 Tel. (800) 525-5940							X	
Marine Biotech, Inc. 117 Elliot St. Beverly, MA 01915 Tel. (508) 927-8720	X				X		X	
Packaging Products Corp. 198 Herman Melville Blvd. New Bedford, MA 02742 Tel. (508) 997-5150								X
Sea Plantations, Inc. 29 Congress Street Salem, MA 01970 Tel. (508) 745-4560	X	X	X	X		X	X	
Tech Pak, Inc. 2 Fifth St. Peobody, MA 01960 Tel. (508) 532-3500						X		X
Wolf Marine Systems 709 Hart Street Brooklyn, NY 11221 Tel. (718) 443-1567	X	X	X	X	X	X	X	
Any refrigeration specialist					X			
Any aquarium dealer							X	

Appendix B

REQUIRED MASSACHUSETTS PERMITS AND INSPECTIONS

All persons engaged in the wholesale or retail trade of raw fish, shellfish and lobster, including bait, whether frozen or unfrozen, must have a Dealer Permit from the Massachusetts of Marine Fisheries (DMF), and is subject to inspection by the Department of Public Health, Division of Food and Drug. A "request for Public Health Certificate" form must be completed and sent to the Food and Drug office in Jamaica Plain. Questions about permit applications should be directed to the DMF at (617) 727-3193, Boston office; (617) 745-3113, Salem office: or (617) 888-1155, East Sandwich office. Questions about inspection should be directed to the Food and Drug office at (617) 727-2670, Jamaica Plain.

WHOLESALE DEALER PERMIT is required from the DMF to acquire, handle, store, distribute, process, fillet, ship, or sell raw fish, whether frozen or unfrozen, in bulk or for resale. The wholesale dealer may also retail fish at on location. The WHOLESALE DEALER PERMIT may also be issued for broker activities only. A "broker only" form must be filled out in lieu of the Public Health Inspection.

RETAIL DEALER PERMIT is required from DMF to sell raw fish, whether frozen or unfrozen, at retail.

RETAIL TRUCK OPERATION PERMIT is the same as the RETAIL DEALER PERMIT except that a town or county Board of Health inspection report, rather than a state inspection is required. (Refer to the Food and Drug Regulation on Mobile Retail Fish Vehicles for inspection criteria). A separate permit is required for each vehicle. A Hawkers and Peddlers permit may also be required. The Massachusetts Division of Standards may require possession of a State Peddlers License. Call (617) 727-3480 for more information.

NO DEALER PERMIT SHALL BE ISSUED UNLESS ACCOMPANIED BY A COMPLETED DEALER STATISTICAL QUESTIONNAIRE FORM, ALSO AVAILABLE FROM THE DMF.