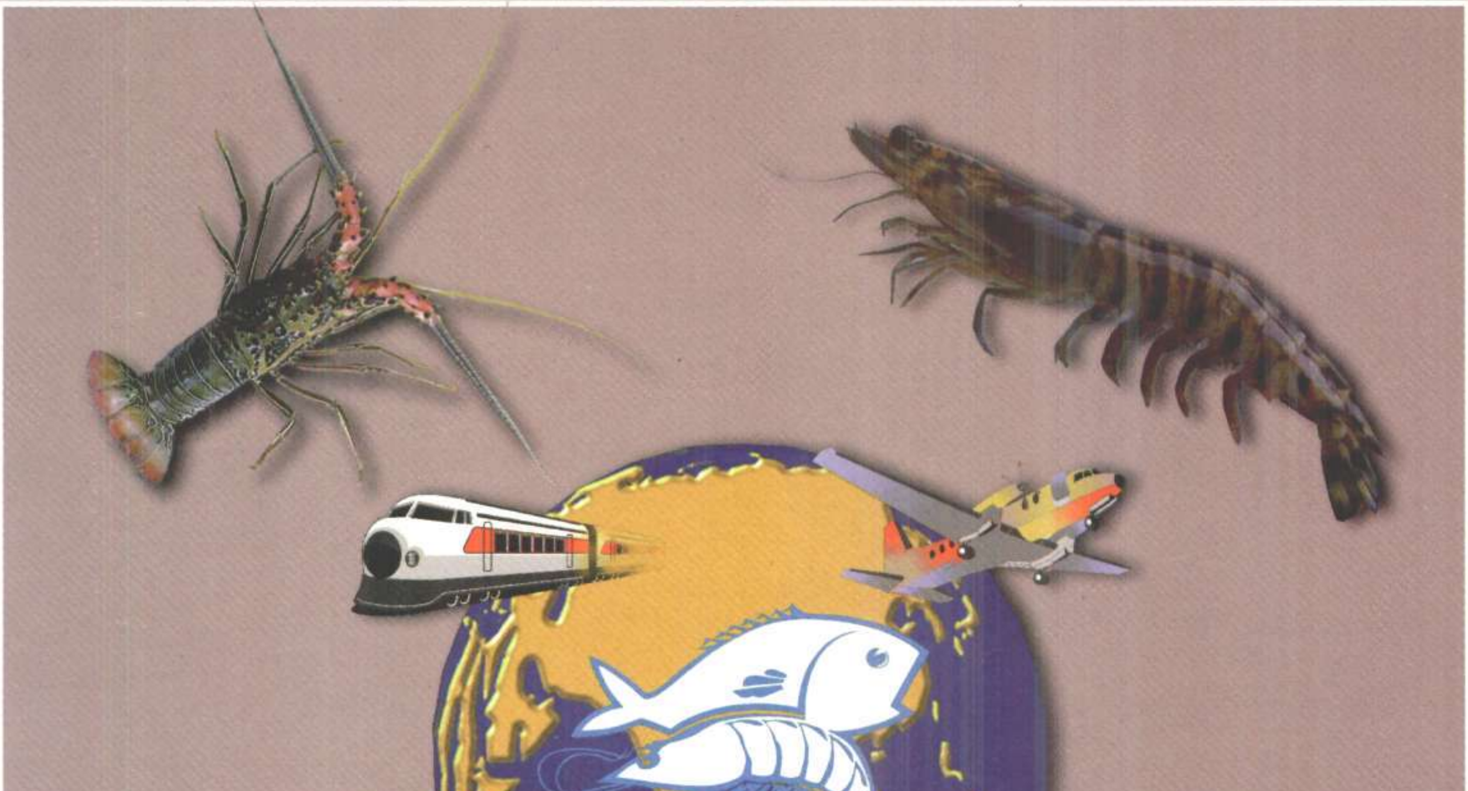
CMFRI SPECIAL PUBLICATION
Number 66

TRANSPORTATION OF LIVE FINFISHES AND SHELLFISHES



CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
INDIAN COUNCIL OF AGRICULTURE RESEARCH
Dr. Salim Ali Road, Post Bag No. 1603,
Tatapuram P.O., Cochin - 682 014, India.

CMFRI SPECIAL PUBLICATION
Number 66

TRANSPORTATION OF LIVE FINFISHES AND SHELLFISHES

M. Peer Mohamed
and
M. Devaraj

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Dr. Salim Ali Road, Post Bag No. 1603,
Tatapuram P.O., Cochin - 682014, India.

April 1997

TRANSPORTATION OF LIVE FINFISHES AND SHELLFISHES

Issued on the occasion of the Inauguration of the Golden Jubilee Celebration of the Central Marine Fisheries Research Institute on 25th April 1997, at Cochin.

Published by : **Dr. M. Devaraj**
Director
Central Marine Fisheries Research Institute
Cochin - 682 014

Edited by : **Dr. N. G. K. Pillai**
Head of Division
Central Marine Fisheries Research Institute
Cochin - 682 014

Citation : Peer Mohamed M. and M. Devaraj 1997
Transportation of live finfishes and shellfishes
CMFRI Spl. Publ., 66 : 1-43

Price : Rs. 90.00

Printed in India at Paico Printing Press, Cochin - 682 035.

CONTENTS

PREFACE

Livefish trade, especially the live ornamental fish and live seafood trade, is emerging as a major business venture in most of the tropical countries. Production of livefish through aquaculture has also undergone vast changes during the past 20 years. In aquaculture, transport of broodstock from the wild to the hatchery or seed from the hatchery to the growouts forms one of the basic requirements. The demand for live finfish and shellfish is rapidly increasing and in most of the developed countries, more and more livefish traders and restaurants are offering live fishery products to their customers. Air lifting of live seafood has also increased during the last few years. The major constraint to the development of live seafood export is the lack of information on handling the aquatic organisms after they are caught, right through the transport and sale to the customers. Necessary precautions have to be taken while catching, packing and transporting the aquatic organisms. Apart from careful handling, a thorough knowledge of the behaviour and physiology of the animal is necessary to minimise the stress during storage and transportation.

Mass production of the seed of cultivable marine finfishes and shellfishes and making them available in the required quantity for farming and ranching are among the priority areas of R&D in the CMFRI. Several techniques have been developed and perfected for the maintenance of livefish items in captivity, packing and transportation to distant places by road, sea and air. The information on these aspects is very much scattered and so far there has not been any major attempt to document systematically the information on captivity, packing and transportation of live finfishes and shellfishes from India. This special publication on the 'Transport of live finfishes and shellfishes' dealing with the methods of transport of live broodfish and fingerlings, shrimp, lobsters, crabs, oysters, mussels and clams, and the environmental and physiological factors affecting them in transit could be of great use as a practical guide to the fishfarmers, livefish traders, live seafood exporters, researchers and students. I appreciate the efforts of the authors and record my thanks to Dr. N.G.K. Pillai for editing this publication

Cochin-14 — *M. Devaraj*
April 1997 — *Director*

1. INTRODUCTION

In fish culture, transportation of livefish from the wild or hatchery to the growouts or the markets is of great economic importance. The main objective of this function is to transport as many fish as possible with minimal loss and at economic costs. This activity involves hauling large number of fish in small quantities of water, which can result in extensive deterioration of water quality. Due to hauling stresses, most of the time, fish arrive at the planting site or market in poor state of physiological conditions, resulting in heavy mortality at the time of planting or shortly thereafter.

Various government and private agencies undertake transport of livefish for artificial propagation of game and commercial fish or for the livefish markets. The transporters of live food fish, notably those who carry carps, probably are still second in the total weight of livefish including ornamental fish, moved. In terms of the range of species and distances shipped, tropical fishes stand first in livefish transport.

Air shipment of live aquatic products has increased rapidly during the last few years. There are many obvious advantages for fish traders to air-transport live selected high-value fishery products. The demand for live finfish and shellfish is rapidly increasing and in some industrially developed countries, more and more retail fish traders and restaurants are offering live fishery products to their high-income customers who can and do not object to paying considerably higher prices for live products than for fresh-iced products.

The major constraint to the development of live marketing of seafood is the lack of information on how to handle the products after they are caught right through the point of sale to direct customers.

Fresh and livefish are the main products being shipped, though live lobsters are perhaps the seafood with the longest history of shipment. Apart from careful handling, a thorough knowledge of the conditions that lobsters can tolerate in and out of water is necessary for profitable live storage and transportation.

There is an increase in the demand for crabs as a consumer's delight both in India and abroad. Several means and methods have been attempted and improved upon for the longevity of the captive crabs during transportation. If the required environmental factors could be provided, the crabs would reach their destination uninjured and without mortality.

An important molluscan product which is gaining ground as a delicacy is the edible oyster which can survive out of water for several days if carefully handled and kept moist and cool. If the oysters require to be kept in good condition, they should reach the customer's market within 3 days of their harvest. At the wholesaler's premises, these oysters can be kept alive for a few more days in small holding tanks with filtered natural seawater or artificial seawater and provided with adequate aeration.

2. METHODS OF TRANSPORT

Transport of live aquatic organisms which is more than a century old, perhaps started in the 1870's (Norris *et al*, 1960). When commercial farming of aquatic organisms developed, several methods of transport were also developed, particularly for fishes. The same methods could be applied to other aquatic organisms like prawns, lobsters, oysters and mussels. But, the traditional mode of transport was in open earthen pots and metal containers (Jhingran, 1975). There are three general methods of transporting live fish. First, they may be transported without any water at all under certain circumstances, except for being kept damped. The second method, which will be referred to as the "tank method" is to transport them in containers of various types open to the atmoshpere. The third method, which may be called the "plastic-bag method", is to transport fish in a closed bag partly filled with water, and with the air in the space over the water replaced by pure oxygen.

There is a definite time limit that fish can be transported out of water, but for very hardy species this can be a substantial period. On the west coast of North America, the long-jawed mudsucker, *Giffichthys mirabilis*, is flown in moist moss from the lagoons of Mexico to California. The mummichog, *Fundulus heteroclitus*, of the Atlantic coast is transported for bait in a similar fashion. It has also been demonstrated long ago (McDonald, 1984) that carp would survive long periods of time in limited amounts of water. In recent years, various salmonids (Cuerrier, 1952), northern pike and the yellow pike perch (Schultz, 1956) have been transported in crushed ice or moss with ice. These fishes were all relatively large from one to several kilos in weight. They were immobilized by tranquilizing substances like urethane or MS 222 and were packed much as fresh fish would be, although not closely together.

2.1 Tank method

Present day fish handling equipments used for the tank method are of many types, varying from simple metal cans to complex tank trucks holding as much as 10,000 litres of water. The larger tank units are usually equipped with circulation systems powered by small gasoline engines or electric motors. The circulated water is run through ventury aerators and then into the tank, or through spray nozzle system into the water surface (Horton, 1956). Turnover rates vary from once in 5 minutes to once in 15 to 30 minutes. In general, tanks with higher turnover rates haul the greatest weights of fish per unit volume. This is almost certainly related to the efficiency of gas exchange and distribution of aerated waters throughout the tank.

Several large tankers use diffuser aeration, employing carborandum airstones, or perforated loop aerators. In such units, compressed oxygen is released through regulating valves. Some tankers use electric stirrers which draw a vortex of air into the tank water or disperse air through perforations along the heels of the stirrer plates.

Water temperature in transport tanks is usually controlled with ice and tank insulation. Refrigeration units are bulky and are in use only on very large tankers.

Fish transport tanks are generally constructed of heavy planking, welded steel, aluminium or marine plywood coated with plastic resin. Fish holding equipment used in the marine bait industry or onboard tuna bait boats consists of large rectangular or oval wells with lighted hatches through which fresh seawater is continually pumped at rates varying from one turnover in 6 minutes to about one turnover in 12 minutes.

Transfer of fish into transportation equipment is accomplished by dipnet, bucket, and rubber conveyor belts. Planting trucks generally transfer fish from the truck to the planting waterbodies (e.g., growout farms) by means of large diameter hoses or portable metal pipings which discharge from the tank itself.

2.2 Plastic-bag method

Plastic-bag method of transport fish came into general use decades ago. The usual method of using plastic bag for transportation is as follows:

Two bags, one inside the other, are placed

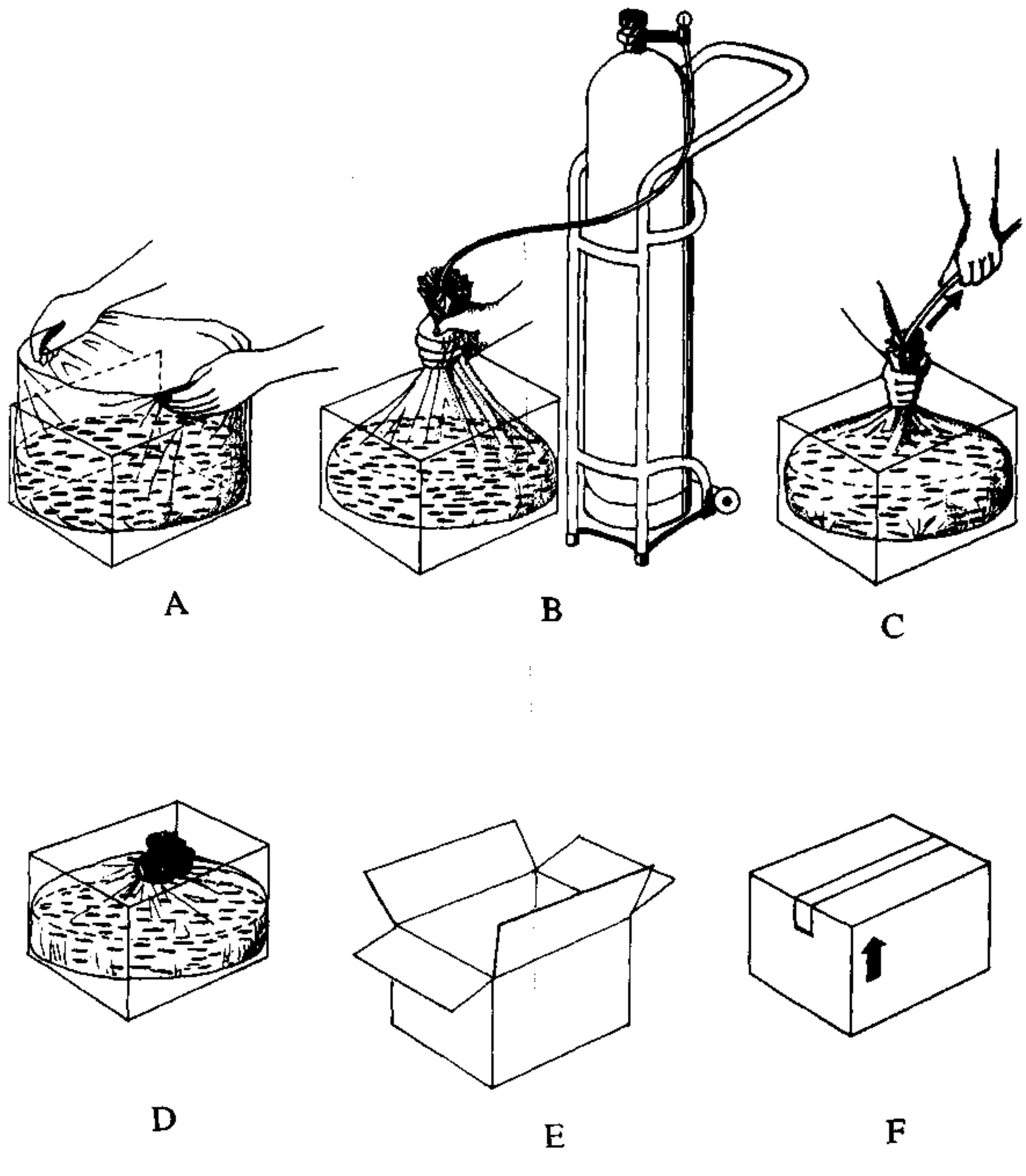


Fig. 1. Sequence of packing fish by plastic-bag method

in a cardboard box which is often insulated with slabs of glasswool or expanded cardboard. In India, the most commonly utilized containers are used-kerosene-cannisters. The plastic bags should be filled with 3 parts oxygen to 1 part of water. The fish are introduced and the upper part of the bag is compressed to drive out the air, and then inflated with pure oxygen. The top of the bag is then bent and tied with 2 or 3 rubber bands (Fig. 1). To keep the fish in darkness, transporting boxes, if white, are inlaid with black paper or foil. The cardboard boxes are then sealed and transported to their destination by different means of transport.

In case of transporting warmwater fish to cold places, several small bags filled with hot water and covered with paper are put into the

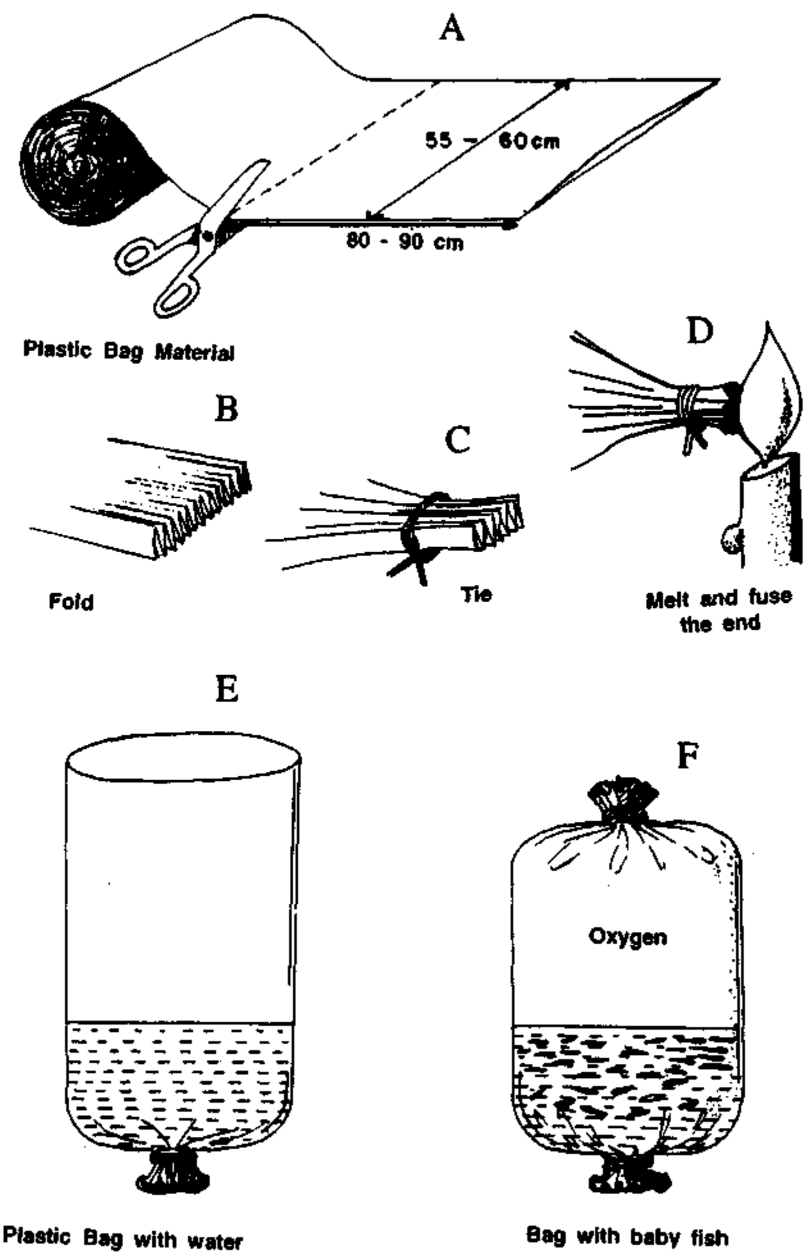


Fig. 2. Making plastic bags for fish seed transportation.

boxes. Conversely, for coldwater fish going to hot places, these bags are filled with ice. The plastic bags must be compactly packed to prevent them from rolling around.

If pure oxygen is not available, the plastic bags can be filled with compressed air and not inflated by mouth with carbondioxide. During such situations, fish density must be reduced by 50% and maximum duration of transport should not exceed 20 hours.

When ready-made bags are not available, we can make bags using plastic bag material. The method of making such bags is illustrated diagramatically (Fig. 2). Plastic bags of 33 litre capacity measuring 74 x 46 cm or bags of smaller volume (16 to 18 litre) made of 0.0625 cm gauge material are widely used for transporting youngones of fishes. But, for transporting broodfish, plastic bags are not suitable except in singles or pairs over very short distances.

3. ENVIRONMENTAL AND PHYSIOLOGICAL FACTORS

The problems which must be met in the successful transportation of livefish are many and diverse. The primary problem arises from the low capacity of water for oxygen together with its low capability to dissipate the end products of metabolism. The secondary problem is that of handling. Many fish are so stimulated by handling that they readily accumulate dangerous levels of lactic acid in their blood (Black, 1958; Karuppannan, 1972). Excessive changes in temperature are also deleterious, as is well known. The optimum number of fish to be transported in each tank is determined by the species (rate of respiration), fish size, general physiological and health conditions of the fish, water temperature and the duration of transport.

3 .1 Oxygen

The most important single factor in transporting fish is adequate levels of dissolved oxygen. The level of oxygen required is something more than the bare minimum that will prevent asphyxia in an undisturbed fish. Fish must at least perform compensatory movements throughout the journey. Furthermore, fish get easily stimulated resulting in an increase in their rate of oxygen consumption to near their maximum rates, but are slow to return to the resting level. Therefore, the excitement of capture and transfer to the transport tanks is likely to increase greatly the need for oxygen. Initial struggle may lessen the ability of the blood to transport oxygen for some time afterwards. A suitable physiological standard for the rate of oxygen consumption of fish in transport is half the rate of respiration a fish is capable of above the level required for maintenance in the resting state. To determine the rate required to meet the standard, two measurements of respiration must be made, one with the fish forced to be active, and the other with the fish quiescent. A general description of the methods of making these measurements, together with the other considerations on the respiration of fish, are given by Fry (1957). A modification of Fry's respirometer and fish activity counter (Kutty *et al,* 1971) and Blazka's respirometer (1958) are used for the simultaneous measurements of metabolic rates (oxygen consumption, carbon dioxide output and ammonia excretion), metabolic quotients (R.Q. and A. Q.) and swimming activity (random swimming and forced activity) under different experimental conditions.

3 . 2 Carbon dioxide

For every millilitre (ml) of oxygen that a fish consumes, it produces approximately 0.9 ml of carbon dioxide. The CO_2 thus released enters the equilibrium system of carbonates, bicarbonates and free carbon dioxide dissolved in the water. From the point of view of respiration, only the fraction that accumulates as free carbon dioxide needs to be considered. The effect of increase in carbon dioxide is to depress the ability of active fish to take up oxygen.

In addition to the direct effect on respiration, any excess of carbon dioxide (over the amount required for equilibrium with the bases available) will attack any unprotected metals. In particular, toxic quantity of zinc or copper may get dissolved from galvanized piping or containers or copper tubing. The toxic effects of such metals may be delayed, and the fish may complete the journey in apparent safety only to die a day or so afterwards. Therefore, zinc or copper should not be contained in the material out of which the transport tanks or any equipment in contact with water are manufactured.

Accumulation of free carbon dioxide upto 25 ppm can be tolerated by a sensitive species under adequate aeration, and upto 50 ppm by intensive aeration. It is also apparent that when the concentration of carbon dioxide considerably exceeds the limits mentioned above, the amount of oxygen is no longer important, since any reasonable increase will have no beneficial effect.

It can be concluded that the need for aeration during transport is to provide oxygen at a rate that will fill the half-scope needs and keep the concentration of carbon dioxide at a satisfactorily low level.

3 . 3 Ammonia

A large fraction (which for practical purposes here can be taken as half) of the nitrogenous excretion of fish is ammonia. All forms of ammonia ($NH_3 \cdot H_2O$, non-ionic free ammonia or undissociated ammonia, or undissociated ammonium hydroxide) are highly toxic substances (Doudoroff and Katz, 1950). The fraction of excreted ammonia which appears in the toxic form is markedly affected by the presence of acids in the water. The precise quantity of unionized ammonia associated with a given pH varies with temperature; it is higher at higher temperatures. There is little effect of temperature on the sensitivity of a given species to a given level of unionized ammonia (Woker, 1949).

The rate of excretion of nitrogen is related to the rate of metabolism. As with other products of metabolism, large fish of a particular species produce less nitrogen per unit weight than do small ones. In addition, they are somewhat more resistant to the toxicity of ammonia. Gerking (1955) found that at 25°C, bluegills of 25 g excreted nitrogen at a rate of approximately 500 mg / kg / day, whereas the rate for fish weighing 100 g was only 120 mg / kg / day. The exponent relating fish weight to nitrogen excretion in the case of the bluegill was slightly under 0.6, this value is exceptionally low compared to the general range of the exponents relating oxygen consumption to fish weight. The rate of nitrogen excretion could also be expected to be dependent on temperature and to vary with different species.

3 . 4 Effects of overexertion

Information on the effects of overexertion on fish has been summarized long ago (Black, 1958). Death occurs in certain circumstances following severe muscular activity, such as struggling in a livebox, vigorous avoidance of capture, and swimming against swift currents. The precise cause of death is not known. It is likely that the severe acid-base disturbance following the large accumulation of lactic acid may be the principal cause of death. Acid concentration is sufficient to reduce the acid-combining power of blood, and affect its oxygen-carrying capacity profoundly. There appears to be a marked reduction in the ability of the heart to pump blood following severe exercise. Severe muscular activity rapidly reduces the maximum swimming capacity of fish, and recovery is slow. This has been demonstrated in goldfish (*Carassius auratus*), rainbow trout (*Salmo trutta*) (Kutty, 1968) and the cichlid (*Tilapia mossambica*) (Karuppannan, 1972). Thus fish planted in a fatigue state may be at a disadvantage, apart from any death that may have resulted directly from overexertion. Hasler and Wisby (1958) reported that most of the sample of largemouth bass taken on hook and line and released over deep water failed to home, while the majority of trapnetted fish were successful. In the case of the mullet, *Rhinomugil corsula*, the survival rate was quite high in the trapnetted lots than in the castnetted ones (Peer Mohamed, 1974). The explanation is that the fatigued fish could not swim to keep above the oxygen-poor depths over which they were released. Even if there was enough oxygen in small tanks where the fish was released, the fish could not recover from the handling effect because of the physiological stress (Peer Mohamed, 1982).

3 . 5 Use of anesthetic drugs

Anesthetizing chemicals have been used for the transportation of livefish in recent times. A list of drugs used for anesthetizing carps (common, Chinese and Indian major carps) is given in Table 1. Sedation of fish brings about practical benefits such as:

1. reduction in overall stress on the fish
2. decrease in metabolic rates - oxygen consumption, carbon dioxide production and excretion of toxic wastes
3. control in excitability of the fish and thereby reduction in the metabolic rates, swimming activity and chances of physical injury
4. reduction in time required for handling them.

It is not essential that fingerlings should be anesthetized for transportation, but larger fish and broodfish should be anesthetized. The most inexpensive method of tranquilizing fish is the use of cold water (5 to 10°C water) as a transporting medium without any chemical tranquiliser. But this method is unpracticable in tropical and subtropical regions because of difficulty in getting and maintaining cold water during transport. If cold water as a transporting medium is not available, then chemical tranquilizers should be used before transporting larger fish and broodfish.

Of the stated drugs in Table 1, quinaldine and MS 222 are the most commonly used transquilisers nowadays. Phenoxyethanol is a recently introduced and much cheaper anesthetizing substance than the other two. Quinaldine is a toxic liquid which must be handled with care. Treatment with quinaldine is generally done when fish are held in a large volume of water such as large concrete tanks. The dilution rate of quinaldine to water is 1: 40,000. The precaution to follow with quinaldine treatment is that sometimes its use leads to irregular operculer movement in the fish. When such opercular activity happens, the fish should be immediately transferred to high-oxygenated water.

The procedure of tranquilizing larger fish and broodfish with MS 222 is as follows: The fish are kept in 1 : 20,000 dilution of MS 222 to water for 15 to 20 minutes. When the fish are fully tranquilized, the solution is diluted by adding water. The recommended dilution is 2 times, i.e., as 1 : 40,000 for hardy fish such as common carp and bighead; 2½ times i.e., 1: 50,000 for less hardy fish like grass carp; and 5 times, i.e., 1 : 1,00,000 for least hardy fish like silver carp. No dosages of dilution at the secondary stage are known for the Indian major carps.

For long and very long (distance-wise as well as duration-wise) transportation, the water in the container must be oxygenated. Care should be taken to see that the temperature of the medium does not rise higher than 28°C. The ideal water temperature for transporting livefish in tropics is 20 to 24°C. It is well known that during low temperature the dissolved oxygen content is more and the activity (random swimming and metabolic rates) of the fish comparatively less.

Table 1. Drug and dose for anesthetizing carps

Drug	Recommended dose
1. Novacaine	50 mg / kg of fish
2. Amobarbital sodium	85 mg / kg of fish
3. Barbital sodium	50 mg / kg of fish
4. Sodium amytal	52 - 172 mg / litre
5. Tertiary amyl alcohol	2 ml / 4.5 litre
6. Methyl paraphynol (Dormison)	1 - 2 ml / 4.5 litre
7. Chloral hydrate	3 - 3.5 g / 4.5 litre
8. Urethane	100 mg / litre
9. Thiouracil	10 mg / litre
10. Hydroxy quinaldine	1 mg / litre
11. Quinaldine	1 : 40,000 (water)
12. MS 222 (Tricane methane sulphonate)*	See text for dose rates
13. 2-phenoxy-ethanol	30 to 40 ml / 100 litre

*From Sandoz, Basel, Switzerland; also obtainable from Aquevet, 2242 Davis Court Hayward CA 94548, U.S.A. and Argent Chemical Laboratories, 14929 N.E. 40th St. Redmount, Washington 98052, U.S.A.

The anesthetic substance, 2-phenoxy-ethanol, is milder than MS 222 and the recommended dose is 30 to 40 ml / 100 litre of water.

3.6 Antiseptics and antibiotics

The possibility of induction of infectious diseases, parasites, predatory insects and aquatic weeds along with fish consignments calls for adoption of prophylactic and quarentine measures involving the use of antiseptics, antibiotics and germicidal chemicals. Prior to transportation, only short duration chemical baths to fish are desirable which will help in combing further transmission of infections in fish consignments. A few of more commonly used chemicals with their doses are given below:

Acriflavin	10.0 ppm
Copper sulphate	0.5 ppm
Methylene blue	2.0 ppm
Potassium permanganate	3.0 ppm
Chloromycetin	2.1 ppm
Sodium chloride	3%

3.7 Bacteriostatic chemicals

Bactericides can be used to prevent accumulation of bacteria in water during fish transportation. The most common bacrtericides are nitrofurazone or furacine (1 mg / l), acriflavin (1-2 mg / l), oxytetracycline (20 mg / l) and neomycin sulphate (20 mg / l).

3.8 Buffers

Rapid changes in pH stress fish, but buffers can be used to stabilize the pH of water during fish transportation. The organic buffer tris-hydroxy-ethyl-amino-methane is quite effective in freshwater and seawater. It is highly soluble, stable and easily applied. This buffer has already been used on 29 species of fish with no deleterious effects. For routine transportation of fish, 5 to 10 g / 5 l is the recommended dose. The least promising buffers for fish tankers have been inorganic compounds such as phosphates. Secondary sodium phosphate (Na_2HPO_4) may be added at 1.5 g / l may be added to transportation carrier for fingerlings to counteract the acidity of water medium.

3.9 Absorbents

A few absorbents like activated charcoal, amberlite, pulverised earth and permutit have been used for the rapid removal of carbondioxide and ammonia formed in transportation water. For transportation in polythene bags, the zeolite mineral clinoptiolite at a concentration of 14 g / l of water is suggested to keep ammonia level low during shipment.

Strong acid ion-exchangers loaded with sodium (Na^+) are able to reduce the concentration of poisonous ammonia. For example, 20 g / l of ion-exchanger filled in a paper tea bag and put into the plastic bag containing fish reduces ammonia concentration by 50 percent. If the ion-exchangers are used fish density can be raised by 20 percent. The cost of such a tea bag with 20 g ion-exchanger is less expensive and the suitable ion-exchangers available in most countries are amberlite IR 120 and dowex 50 x 8.

3.10 Antifoaming agents

Foam production is an inconvenient phenomenon experienced during the transportation of certain fish species such as the silver carp. The thick foam develops from mucous and organic matter affected by aeration. It can be very harmful since the foam covers the water surface, reducing the gas exchangers and resulting in the accumulation of carbondioxide acidification of water. The compound antifoam AF emulsion (DowCorning) could be used to eliminate foaming at a concentration of 0.05 ml / l.

3.11 Using salt

Common salt (NaCl) improves transporting conditions. The amount of salt added to water for transportation varies with the natural salinity tolerance of fish, ranging between 1 and 10 g / l. As salt reduces the efficiency of ion-exchangers, it should not be combined with the latter.

3.12 Preparation of fish for transport

A few days before transport, fish (specieswise and sizewise) should be kept in clean water in separate holding tanks. Weak, injured and diseased fishes have to be removed. The holding tanks are provided with continuous aeration through air-diffusers either by compressor or aerator to maintain the ambient oxygen concentration near air saturation; biological filters to fix ammonia; and dark-coloured cloth (preferably black) cover to avoid light and external stimuli. Under such conditions, the fish would recover quickly from the handling effects; their metabolic rates as well as random swimming activity would also be minimal. The fish should not be fed for some days, depending on their size. Before transportation, the last feed for small fish (larvae and fry) should be 12 to 24 hours; for youngones (upto 3 g body weight) 48 hrs; and for larger fish, 2 to 3 days. It has already been established that starvation does not affect the metabolic rates in fish for 7 days.

3.13 Organisation of transport

A practical schedule, right from packing until delivery at the destination, should be made. Sufficient plastic bags, insulated boxes, rubber bands and pure oxygen should be available for packing and transport of livefish.

3.14 Calculation of fish density

Fish density is the quantity of fish that can be packed in a litre of water.

This density depends on the average weight of the fish transported. If the duration of transport is for a maximum period of 48 hours, density may be calculated by the following equation.

$$\text{Fish density} = 38 \times \sqrt{W}\ g / l$$

where W is the mean weight of individual fish in gram.

The number of fish per litre may be calculated by the following equation.

$$\text{Number of fish} = 38 \div \sqrt{W}$$

The required water volume (Wv) in millilitre (ml) for individually packed fish can be calculated by the following equation.

$$Wv = 27 \times \sqrt{W}\ ml$$

For the safe transportation of fish in a distribution unit, the weight of fish depends on the efficiency of the aeration system, duration of the haul, water temperature, fish size and fish species.

If environmental conditions are constant, the carrying capacity of a distribution unit depends on fish size. Fewer kilos of small fish can be transported per gallon (4.546 litres) of water than of large fish. It has been observed that the maximum permissible weight of fish in a given distribution tank is directly proportional to their length. Thus, if a tank can safely hold 45 kg of small fish (2 inches), it could hold 90 kg of large (4 inch) and 135 kg of larger (6 inch) fish.

Fish loadings have been calculated by the water displacement method as explained (Table 2).

Table 2. Approximate amount of water displaced by a known weight of fish

Weight of fish (kg)	Water displaced (litres)	Weight of fish (kg)	Water displaced (litres)
60	60	1050	1263
100	120	1100	1323
150	180	1150	1383
200	241	1200	1443
250	301	1250	1504
300	361	1300	1564
350	421	1350	1624
400	481	1400	1684
450	541	1450	1744
500	601	1500	1804
550	662	1550	1865
600	722	1600	1925
650	782	1650	1985
700	842	1700	2045
750	902	1750	2105
800	962	1800	2165
850	1022	1850	2225
900	1083	1900	2286
950	1143	1950	2346
1000	1203	2000	2406

4. TRANSPORTATION OF BROODFISH AND FINGERLINGS

Broodfish need to be transported in larger containers which can also be used for fingerlings transportation. In India, two models of livefish carrier closed-system tanks have been designed. A modified model, originally designed by Mammen (1962) is of a petrol tank design having a capacity of 1500 litres termed as splashless livefish carrier. The carrier has an autoclave-type of lid and a built-in aeration system for supplying compressed air.

The aeration system works on a belt driven by the engine of the transporting vehicle, generally a jeep. An oxygen cylinder is kept on the carrier as a standby for emergency. The tank is lined inside with U-foam which provides cushioning effect to absorb shock and prevent physical injury to the fish during transportation. Nearly 250 kg of livefish can be transported at a time in the splashless tank. Adult catla of total weight of 60 kg or 99,000 carp fingerlings, in the fish-to-water-load ratio of 1 kg per 4.5 litres of water, have been successfully transported in such a splashless carrier. Another livefish carrier named as "double barrel" (Patro, 1968) is of a laboratory gas supply design and comprises of an outer chamber of 120 cm diameter open at the top and a slightly smaller inner one closed at the top. The top of the inner chamber is provided with an air vent and an oxygen valve. During transportation, the inner smaller chamber fits into the inside of the outer chamber which serves as a storage tank, and is filled with water along with the fish to be transported. The inner chamber which is slipped inside the outer chamber through the top open end, serves as an oxygen-holding chamber and is lined with U-foam to prevent injury to the fish during transportation. Once filled, the oxygen supply of the carrier lasts upto hours and thereafter refilling with oxygen is necessary. This "double barrel" carrier can transport a total weight of 100 kg of livefish at a time.

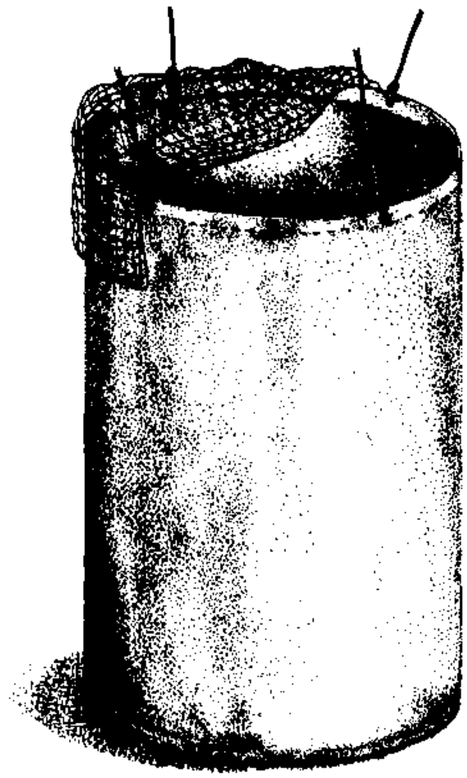


Fig. 3. An open canvas tank to transport broodfish and fingerlings; this is supported on strong metallic frames and mounted on motorised van. This can also be suspended in a water tank during transportation of broodfish. Note a net covering the top of the tank.

Special livefish transportation vehicles have proved to be very efficient in the West. These vehicles are furnished with pumping and cooling arrangements, circulation of cooled oxygenated water, and agitators for aerating water in fish holding containers which are lined with styrofoam for insulation. These systems are expensive and are not commonly used in developing countries due to the generally unsatisfactory conditions of roads in rural areas and the rather poor economic status of fish farmers.

The types of sophisticated livefish transportation units described above and other types should be either prefabricated or imported for use in hatcheries. If, however, such units are not available, circular, top-open canvas bag containers (Fig. 3) of 1000 l capacity, supported on sturdy metallic frames mounted on motorized delivery vans may be improvised. Portable battery operated aerators could be used for continuous aeration to maintain the ambient oxygen of the water near air saturation. Circular canvas container has the advantages that the fish would not injure themselves and the water would be cooler due to surface evaporation. Canvas container of 1 m diameter and 1.25 m depth is commonly used in India.

5. TRANSPORTATION OF LIVE SHRIMP

The ever increasing demand for prawn and shrimp, a major foreign exchange earner for the country, has resulted in their large scale culture. But, success of propagation and culture largely depends on a viable seed source either from the wild or from the hatchery. In both cases, suitable transportation methods which takes into account important environmental factors should be followed to transport the seed to the planting sites. Understanding the impairment of important environmental factors that contribute to the survival is a prerequisite to find out the optimum density of prawn seed that could be packed in a unit volume of water for different durations of transportation.

5 . 1 Packing of prawn seed in transportation bag or polythene bag

The transportation bags are much easier to pack and transport the prawn seed (postlarvae of different size groups) than the plastic bags for many reasons. The transportation bag is usually made of H / gauge, soft nontoxic, transparent PVC with a firm base and a double safety internal valve and caps provided with airtight washers. Because of its cylindrical shape, the packed bags can either be kept vertically or horizontally to give more space for the movement of the postlarvae (Fig. 4).

Packing density of postlarvae per litre of water is one of the factors to be looked into carefully during the transportation of seeds. When packing density is more, the rate of survival is less and vice versa. Therefore, to make the transportation economical and (indirectly the prawn farming) a profitable avocation, it is essential that maximum number of postlarvae be packed in minimum quantity of water, and at the same time obtain good survival. Krishna Kumar and Pillai (1984) had calculated, based on the seed transportation experiments, the number of postlarvae required for initial packing at different densities and the quantity of water required for packing them to get approximately one lakh of postlarvae after 24, 36, and 48 hrs under oxygen packing (Table 3).

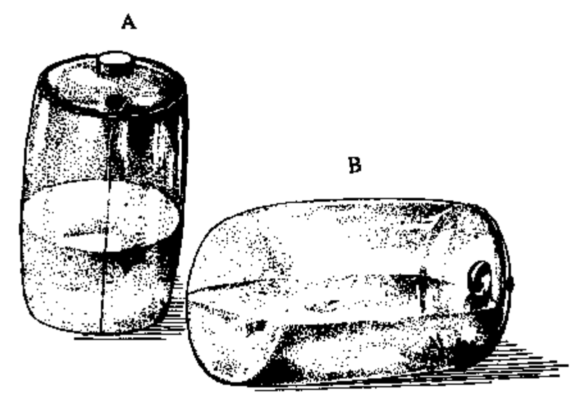
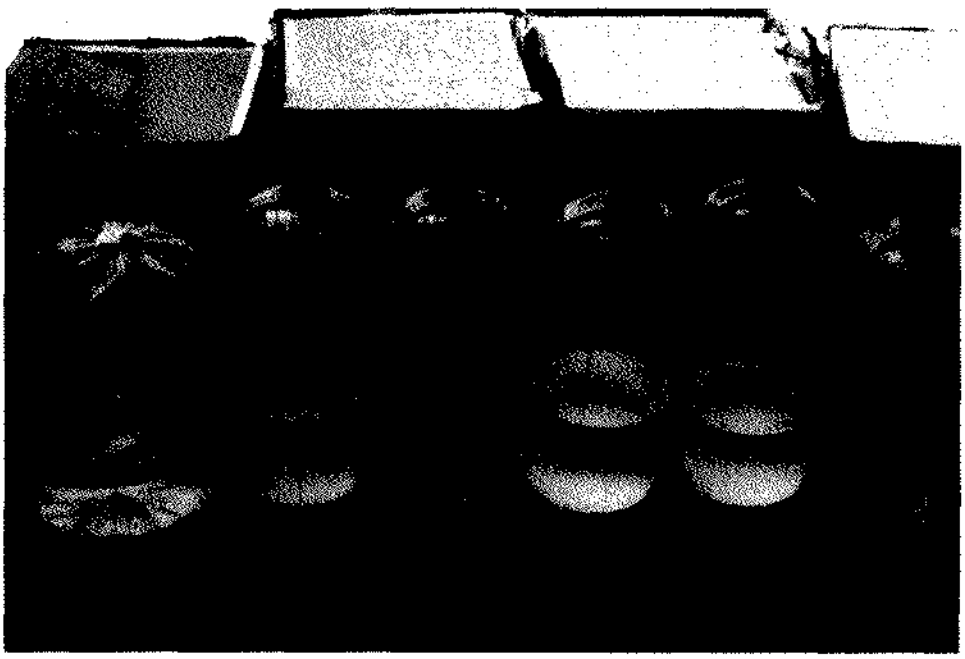


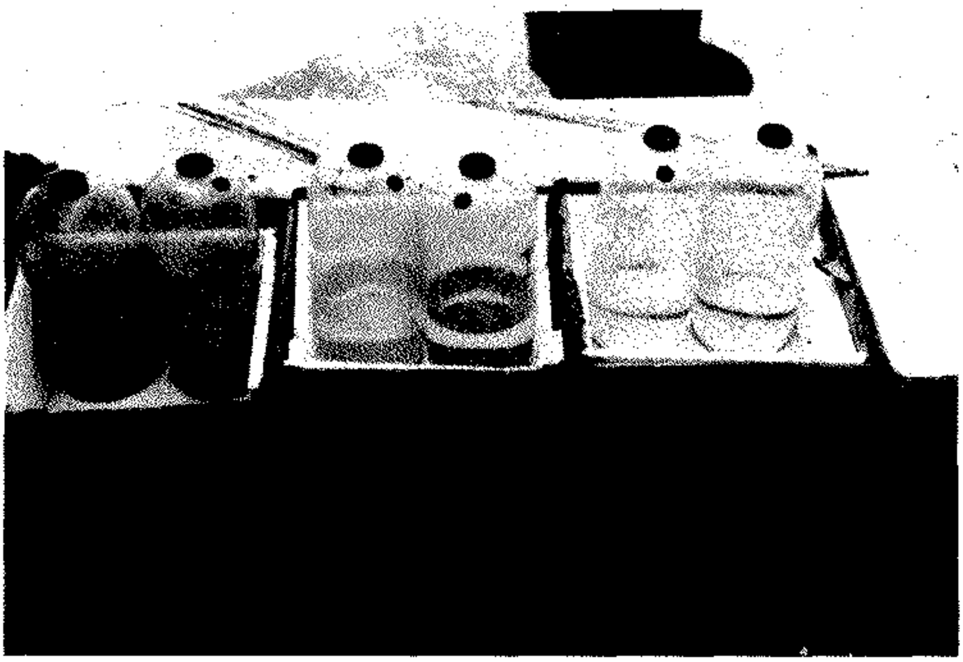
Fig. 4. Packed transportation bag can be kept in A. vertical position or B. horizontal position (pillow-type) in cardboard box for transportation.

Cannibalism during growth is a common and serious problem with the postlarvae. Dead ones would also be eaten away by others. So, during the transportation of early postlarvae to short distances and/or during short duration, the rate of survival would be high. When the transportation period increases, the rate of survival declines as observed by Krishna Kumar and Pillai (1984) when 8 day old postlarvae are transported for 24, 36 and 48 hours. The relatively poor survival encountered during the transportation of early postlarvae (till 8 days old) is due to the more frequent moulting and the cannibalistic behaviour of the early postlarval stages. Alikunhi (1980) could transport

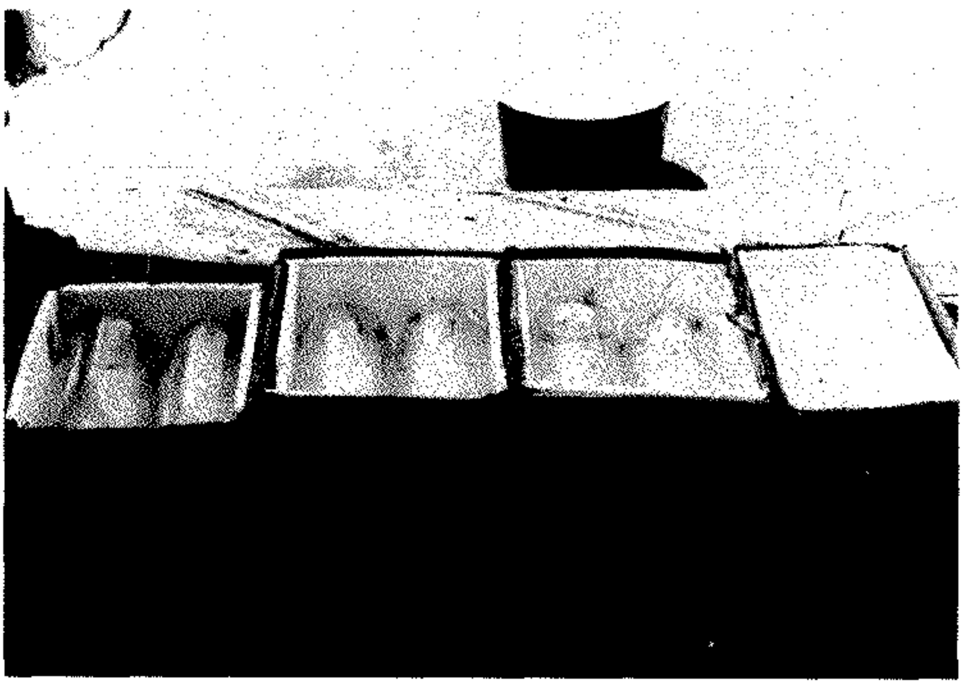
Plastic bags being made for easy, effective and economical transportation of fish seed.



Shrimp nauplii packed in polythene bag and transportation bags.



Transportation bags, packed with shrimp nauplii are kept in vertical position inside the wax-coated box for sealing before transportation.



Horizontal position of packed transportation bags.

Table 3 : Initial requirement of number of postlarvae (20 days old) to get approximately one lakh of postlarvae after 24, 36 and 48 hours at different packing densities computed from the survival rate recorded from the experiments and the quantity of water required to pack the given number of postlarvae.

Packing density Nos/l	No. of postlarvae required	Quantity of water (litres)	Survival recorded (%)	No. of postlarvae required	Quantity of water (litres)	Survival recorded (%)	No. of Postlarvae required	Quantity of water (litres)	Survival recorded (%)
25	1,03,413	4137	96.7	1,07,875	4315	92.7	1,14,548	4582	87.3
50	1,11,483	2230	89.7	1,31,062	2621	76.3	1,36,986	2740	73.0
100	1,17,925	1179	84.8	1,39,860	1399	71.5	1,42,248	1422	70.3
150	1,26,103	841	79.3	1,55,521	1037	64.3	1,62,602	1084	61.5
200	1,27,551	638	78.4	2,84,091	1420	35.2	—	—	—
250	1,37,174	549	72.9	—	—	—	—	—	—

1786 seeds / l by feeding with *Moina* sp. Freshly hatched nauplii can be added as feed to the seeds and this will help reduce the cannibalistic behaviour of the seeds. A few pieces of nylon net can also be put along with the seeds to guard the seeds from attacking each other.

It is well known that water temperature plays a major role in the metabolic rates (O_2 consumption, CO_2 production and NH_3 excretion) and the random swimming activity of the poikilotherms. When temperature increases, swimming activity of the animal increases which results in high metabolic rates. At the same time the dissolved oxygen decreases while water temperature increses. Under such conditions, the ambient oxygen in the water will be reduced to lethal level (0.2 ml O_2 / l) by the respiration of the seeds itself. To overcome such problems, water temperature should be lowered to 17 to 18°C which will reduce the metabolic rates, swimming actttivity and cannibalism. Alikunhi (1980) suggested that for short duration transportation of small seeds (less than 13 day old), feeding and low temperature may reduce cannibalism, thereby resulting in significant increase in the survival rate.

It is universally known that the pH of the water during transportation decreases concomitant with the accumulation of carbon dioxide, causing large scale mortality of prawn seeds (Armstrong *et al*, 1978; Krishna Kumar and Pillai, 1984). Even when the dissolved oxygen of the water is fairly high the accumulation of carbon dioxide brings in marked decline in pH causing mortality of the seeds. Table 4 shows that the rate of survival of seeds is indirectly proportional to pH. To maintain pH within the permissible limit (7.5) during transportation, care should be taken to prepare the seeds to maintain a steady standard (basal) metabolic rate before and during transportation. It is well known that the excitability caused by handling, low ambient oxygen (hypoxic level and below), warm water temperature (30°C and above) increase the metabolic rates (rate of O_2 consumption, CO_2 output and NH_3 excretion) in aquatic animals including fishes (Peer Mohamed, 1974).

Table 4. Survival rate of *Penaeus indicus* seeds (16 days old) at different packing densities and the final pH valves (all values are the average of three determinations)

Packing density No./l	Survival (%)	pH
25	93.3	7.58
50	81.0	7.53
100	75.8	7.45
150	72.1	7.43
200	60.5	7.36
250	39.3	7.16
300	31.9	7.06

5.2 Salient features of a successful transportation

Nonavailability of required number of seeds at farm sites necessitates seed transportation from hatcheries and / or collection sites. A transportation is acknowledged to be successful when the survival after stocking is more than 90%. Methodical acclimation ensures high rate of survival in growout, nursery and during transportation.

Healthy, disease-free and uniform sized seed should be selected and reared in filtered seawater with continuous aeration.

Seed should be stress-checked for assessing their overall quality and visually checked for their erratic behaviour, loss of legs, entrapment of exuviae etc.

Sampling and counting of seed should be accurate to avoid overcrowding or underutilizing the transportation facility.

Short duration transportation even in very high concentration is more successful than long duration transhipment. Transportation can be done by land, sea and air, but duration is the telling factor.

The seed has to acclimatise to many physical and chemical parameters. Temperature, dissolved oxygen and salinity should be taken special care of. Temperature reduction decreases the metabolic rates of seeds, which result in high D.O. and pH, and low CO_2. Lower temperature also reduces cannibalism.

Fasting before and during transportation reduces NH_3 excretion, but it enhances cannibalism. For long-duration transportation it is suggested that 5 artemia per ml of water enhances survival. Addition of phytoplankters like *Chaetoceros* sp. reduces NH_3 and toxicity, but light is required for photosynthesis and in the absence of light the phytoplankters compete with the PL for oxygen for respiration. Addition of substratum containing denitrifying bacteria brings down the ammonia level considerably.

Disssolved oxygen is the most important factor in transportation and the ratio of water and oxygen by volume can be 1:1 or more, since more oxygen produces no adverse effect. Water at lower temperature and lower salinity can hold more dissolved oxygen. Water temperature can be between 18°C and 22°C for long duration and 22°C and 24°C for short duration transportation. For long duration transportation above 24 hr, temperature could be brought to below 18°C upto 15°C. The low critical level of temperature for *Penaeus monodon* is 13.5°C, which varies from species to species among the penaeids.

Acclimation to temperature should be done at the rate of 1°C per 15 minutes and to salinity the rate is 1 ‰ per 15 minutes.

Transportation water should be free from pathogenic bacteria, virus, suspended solids, metals and dissolved organic matters. Filtered seawater is always better for transportation. Dissolved organic matter can be reduced by adding activated charcoal (in a meshed bag) at the rate of 1 g / l of transportation water. Metals can be chelated by adding EDTA upto 10 ppm for long duration transportation.

Use of anesthetics for shrimp seed transportation is not recommended.

Use of antibiotics during transportation may be avoided since many precautions would be required to be taken.

Packing density can be arrived at by anticipating the transportation-duration, size of the seed, anticipated temperature change during transportation etc. For short duration upto 3 hr the density (PL 20) can go upto 1500 / l and for longer duration upto 24 hr, 250 / l.

5 . 2 . 1 Packing

Insulated big tanks of 2 to 3 ton capacity, which could be totally drained by gravity, can be mounted on trucks and the PL transported upto the pond-dikes and drained into the ponds fully. The interior of the insulated tanks should have baffles to break the swells and aeration grids to pass compressed air. This is used for short duration transportation.

For long duration transportation PL have to be packed in polythene bags. The size of the bag can range between 10 and 30 l capacity. The length of the bag should not exceed more than 150% of the breadth. Such a ratio increases the bottom area for PL to settle and increase the interface between pure oxygen and water in the bag. For longer duration transportation, larger bags are preferred as higher water volume can stabilize water temperature better than smaller volume. Bags should be washed thoroughly when toxicity is suspected. Sharp corners in the bags should be made round-shaped by rubber-bands to avoid PL entrapment - unrounded corners are subjected to greater pressure and subsequent breakage. Seed transportation should be made always in double walled bags i.e., by keeping one bag inside the other.

When planned for transporting in chilled water, PL should be chilled before packing, in the harvesting chamber of the hatchery itself.

By adding freshwater ice at 1:100 ratio, the temperature is reduced by 1°C and salinity by 1 ‰ approximately. When temperature alone has to be reduced in the water, freshwater ice can be packed in small polythene bags and dropped in water.

When the PL are transferred into the seed bag, the air over the water column in the bag should be removed by pressing the bag and allowing pure O_2 through a tube to bubble in the medium with the PL for 5 minutes. After attaining the required inflation, the bag should be sealed air-tight by rubber-bands.

The sealed bags are kept in wax-coated cardboard boxes with styrofoam insulation. Small pieces of ice packed in polythene bags are kept inside the cardboard box around the seed bag above the water-level, touching only the O_2 portion of the seed bag. When the ice packs are kept against the water column, it brings down the temperature of the already chilled water drastically.

5 . 2 . 2 Modes of transportation

It is done by road, rail or air. Air transportation is quicker than road and rail, covering long distances in a short time but, road and rail transportation allow sufficient mixing of oxygen in the water. During long distance transportation by road, an oxygen cylinder should be kept for reoxygenation.

5 . 2 . 3 Acclimation

Shrimp seed from the sea and hatcheries come from a stable environment unlike those from estuaries which have rather a fluctuating environment. When seed from any one of these sources are stocked in growout ponds or nurseries which have an entirely different ecological condition due to its smallness, less water replenishment and other physicochemical parameters, the stress on PL is rather high, and felt when not acclimated.

Since salinity tolerance is found upto PL 20 for *Penaeus monodon* and it varies between different species of penaeids, it is advisable to stock between PL 15 to PL 20.

Acclimation can be done at hatchery or pond site; in the former case, it should be from PL 1 onwards and in the latter by floating the seed bag in the pond water till temperature equilises. On finding the salinity difference to be more than 5‰ salinity should be equalised by adding pondwater at the rate of 1‰ every 30 minutes. PL older than 20 days should be given more time for acclimation.

5 . 2 . 4 Stocking

Temperature of pond water can be 26°C during the time of stocking which could be evening, night or morning. When stocked without nursery phase it is advised to keep them in hapas in the same pond with feed and aeration for 24 hours. Then the seed could be released in the pond after counting. This is very essential to have good management of stock, environment and predictions.

5 . 3 Transportation of spawners

In India, *Penaeus monodon* is found more along the east coast than on the west coast. Therefore, spawner transportation is inevitable. It is undertaken by air and sometimes by road which exceeds 36 hr duration.

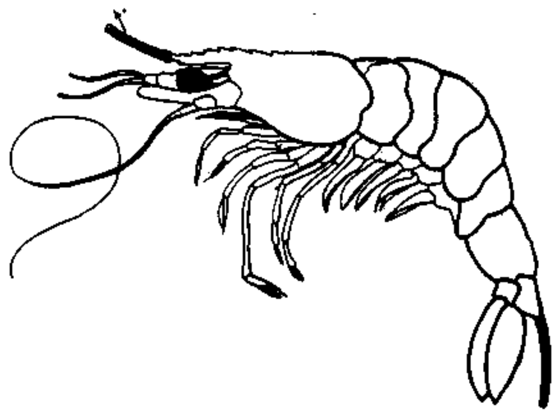


Fig. 5. The pointed rostum and telson of the shrimp spawner are covered with rubber caps before transportation by plastic-bag method.

Large, healthy and injury-free spawners are selected from the catches of bottom trawls, bottom set gillnets and trammelnets. When the spawners are taken from the fishing ground aboard, they are kept in open containers and aerated. To avoid water pollution, the spawners are not fed. On reaching the fishing harbour or landing centre, they are quickly transferred to big containers.

When the hatchery or spawning facility is near and reachable, stage IV spawners can easily be transported. When it involves overnight transportation, spawners having ripe ovary may spawn in transit and spoil the limited water, thereby killing the mother and the other co-spawners also. The eggs thus spawned, mostly do not hatch.

The spawners thus collected are kept in water chilled to 25°C. The pointed rostrum and telson of the spawner are suitably covered with rubber caps (Fig. 5), and either transported in large containers (when the duration is less) or kept in double-walled plastic bags (10 - 20 l capacity), half filled with filtered seawater of 25°C and rest with pure oxygen. Although the cold temperature would reduce the metabolic rates and swimming activity of the animal, the handling effect caused by the process of packing may excite the animal which becomes active in the confined space in the polythene / transportation bag. This spurt in activity causes the pointed rostrum and telson to puncture the sealed bag. No feed is given to the spawner and the bags are kept in insulated cartons for transportation. During a long distance / duration transportation, water may be changed and repacking done on the way.

Sometimes spawners are kept straight in 1.5" or 2" diameter slotted PVC pipes with both the ends covered with nylon mesh (Fig. 6). The pipe with the animal is kept reverted so that the animal's head is kept down to prevent movement and struggle. Then the perforated pipe with the animal is put in the transportation bag containing filtered seawater of 25°C and packed with oxygen for early transportation. Two or three animals could be packed in one transportation bag of 10 to 15 l capacity. This method has the advantage over the previous one in that one animal cannot see the other hence there is minimal / no excitement in the animal. During long distance / duration transportation also, changing of water and repacking could easily be done without disturbing the animal.

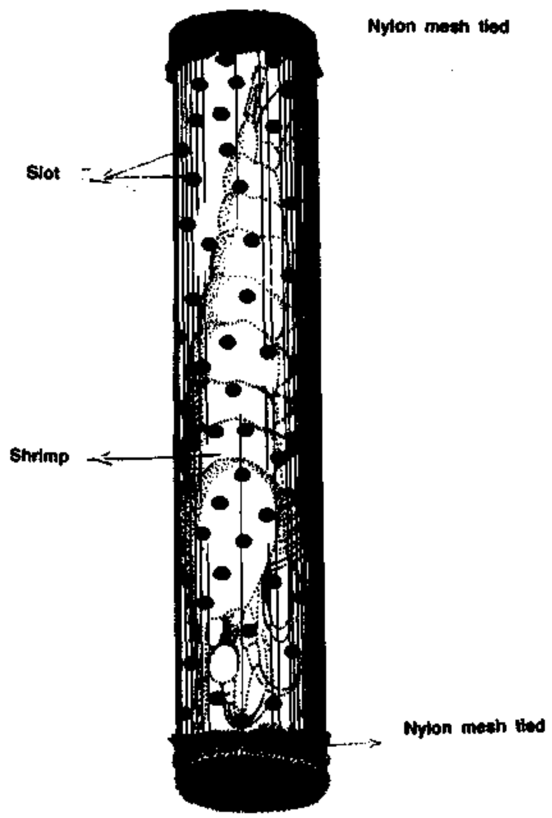


Fig. 6. Shrimp spawner is kept straight in a slotted PVC pipe. Note the pipe is reverted and the spawner is kept head down for transportation.

6. TRANSPORTATION OF LIVE LOBSTERS

There is an increasing demand for live fish and shellfish all over the world, particularly in the industrially advanced developed countries. In the developed countries retail fish traders and restaurants are offering live fishery products, such as lobsters, crabs, shrimps, bivalves, groupers and various other items to their high income customers who can afford to pay considerably higher prices for live than for fresh, iced - products. This situation necessitates transportation of live lobsters and other commodities by air. In order to store and transport lobsters, it is vital to have a thorough knowledge of the conditions that lobsters can tolerate in and out of water. Some of the critical factors to be noted in the transport of live lobsters are:

1. prevention of injury
2. maintenance of a high relative humidity above 70%
3. maintenance of low storage temperatures
4. condition of the lobsters prior to shipment.

6.1 Transportation of lobsters by sea

Healthy, vigorous and uninjured lobsters should be selected for shipping. Low temperatures should be maintained since it renders the lobsters dormant leading to a lower rate of metabolism. This in turn leads to a reduced need for oxygen. The recommended range of shipping temperatures are between 1 and 7°C without which the lobsters may quickly die.

Control of relative humidity is also an important factor in the packaging of lobsters. A humidity of 70 to 100% is ideal to prevent dehydration of lobsters, and thus to reduce the mortality rate during transportation. If the lobsters are exposed to temperatures higher than 7°C and relative humidity lower than 70%, they would not survive for more than 24 hours.

6.2 Handling of lobsters

Another major reason for mortality during shipment of live lobsters is body injuries, arising from rough handling and improper packaging.

Careful handling of lobsters for live shipment begins on the fishing vessel itself. The catch is carefully removed from the fishing gear. The injured and weak lobsters are separated from the non-injured and strong ones simultaneously. The animals are then placed in a container well supplied with a good constant flow of fresh unpolluted seawater.

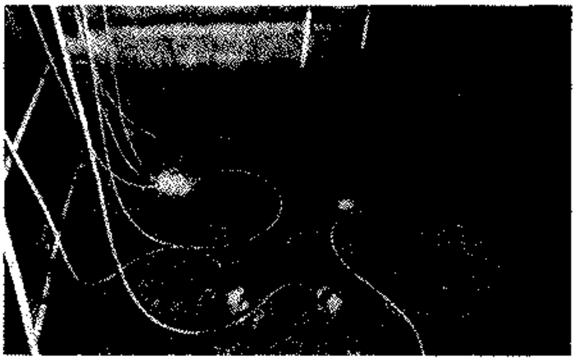
Once ashore, the selected non - injured lobsters are immediately transferred to a tank with fresh, unpolluted flowing seawater. It is preferable to keep the lobsters in a holding tank for a minimum period of 24 hrs to facilitate identification and isolation of weak animals when selecting for transportation, especially by air.

Some shippers of live lobsters some times hold them out of water for a while before transportation. This practice is detrimental to the health of the animals, allowing for dehydration and eventual death. It is important, therefore, that live lobsters should not be held out of water for any length of time prior to shipment.

Lobsters do not absorb oxygen from air in the same way as we do. They require moisture in which oxygen is dissolved. If the air in their immediate vicinity has a relative humidity of less than 70%, then the oxygen in such "dry" air is useless for lobsters. Refrigerating the water in the tanks to about 7°C is another factor that facilitates proper handling of lobsters ashore because it greatly reduces the activity of the animals, thus making it easier to handle them.

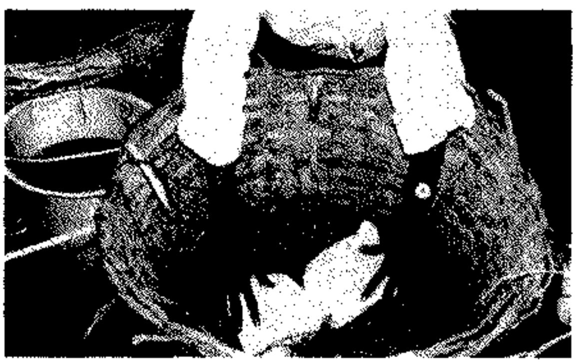
Just as it is very important to pay careful attention to proper handling of live lobsters prior

Lobster holding tank, provided with continuous seawater supply and aeration.



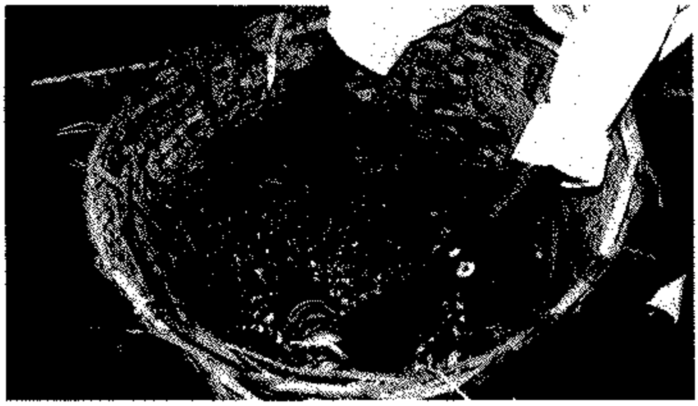
A view of the holding tank with ice-blocks packed in polythene bags and floated to reduce the water temperature.

Straw soaked in seawater and spread in wicker basket to pack live lobsters for transportation.

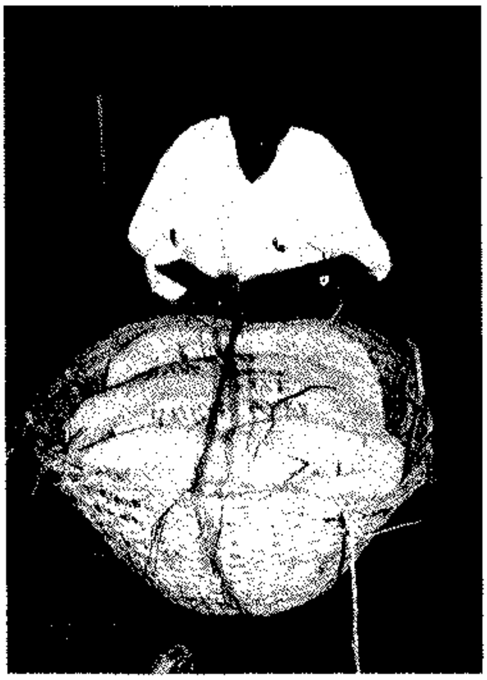


Ice-blocks packed in polythene bags are placed over the straw.

A second layer of soaked straw is spread over the ice-blocks.



Live lobsters being packed over the straw.



Final packing - a layer of soaked straw is spread over the lobsters and covered well by a gunny bag. Coir ropes are used to tie basket. This method is suitable for inland transportation by road and rail.

to transportation, it is equally important to adhere to good packaging practices and an adequate choice of packaging material.

6 . 3 Transportation of lobsters by air

Selection of a container suitable for shipping live lobsters by air is of primary importance. The container must be insulated, leakproof, light weight, easy to handle and strong enough to withstand external pressure. This container must be insulated against both heat and cold; it must maintain its shape and structural integrity to protect the product from physical damage; it must meet airline requirements for size and weight and in particular it must not leak. Such containers are now available in the market. These containers are made either in plastic form, polythene, wax impregnated fibre-board or corrugated cardboard.

Some airplanes have "structural containers" which are made of metal fitting with the contours of the aircraft cargo bay. But it should be noted that these containers are not water - tight, so lobsters should be first packed in the afore mentioned leakproof containers before planting them in the "structural containers". One of the main advantages of using "structural containers" is that the smaller container to be placed in the "structural containers", could be constructed less strong, since they would not be exposed to much external damage during loading and shipment.

6 . 3 . 1 Packing

In transportation, packaging materials too play an important role as they help to prevent injury to live lobsters during shipment. A variety of materials including burlap newspaper and woodshavings are being used by transporters.

One of the most effective packaging materials for lobsters is a crepe cellulose fibre blanket which not only cushion the packed test animals, but also (when lightly moistened), help to maintain the humidity in the container. An additional benefit in this material is its ability to absorb water, which is often a problem when shipping seafood by air.

When transporting live lobsters without too high a mortality rate, a suitable cooling agent is necessary. The most efficient type of refrigerant is ordinary ice. However, when ice melts, it produces water which must be prevented from leaking out of containers during transportation. Since this is very difficult to achieve, an alternative to ordinary ice is gel-ice (chemical or reusable ice). Gel-ice is a chemical solution enclosed in plastic bags, or occasionally in metal containers. When kept in a freezer, the gel-ice solidifies at a temperature below 0°C. Once at ambient temperature (above freezing point), it absorbs heat from the surroundings and becomes liquid again. However, while the interior is kept cool, the liquified gel-ice within the plastic bags is not released to the surrounding and consequently no leakage from the shipping container ensues. After each time the gel-ice is used, it should be re-frozen prior to the next use.

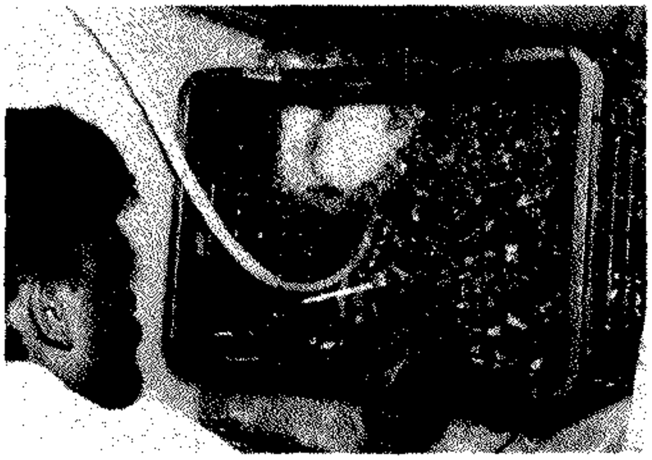
Refrigerating live lobster packages with gel-ice for air-transportation involves selecting a suitable insulated leakproof container with a capacity to hold about 100 kg of lobster. About 20 to 40 kg of pre-frozen gel-ice is then placed at the bottom of the containers. The gel-ice can be placed either on top or in the middle of the load, whichever is more convenient. It should not however be placed in such a way as to injure or freeze the animals. Over the gel-ice, a single layer of moist packing material (such as wooden shavings) should be laid. The container is then placed in a cold store for at least an hour. The prechilled container is now ready for loading the dormant live lobsters. Once all the layers of lobsters are in place, they should be covered with another layer of prechilled packing material, covered with insulation and the container sealed and secured, preferably with double strapping.

It is important that the containers are loaded preferably only just before transportation itself because the mortality rate of lobsters outside seawater is considerably higher than when they are kept in seawater holding tanks. It is generally understood that outside the water, and under good handling, packing and air-shipping practices, lobsters will survive one to three days, depending on the ambient temperature and the level of adherence to the suggested practices for handling the lobsters from the point of catch. In warm climatic zones packaging operations should be done in refrigerated premises and the packed live lobsters later transported to the airport in refrigerated trucks. If there is no chill room available at the airport, it is better to leave the packed lobsters in the refrigerated truck as long as possible before loading into the aircraft. The holding temperature in all these cases must never be at, or below freezing point.

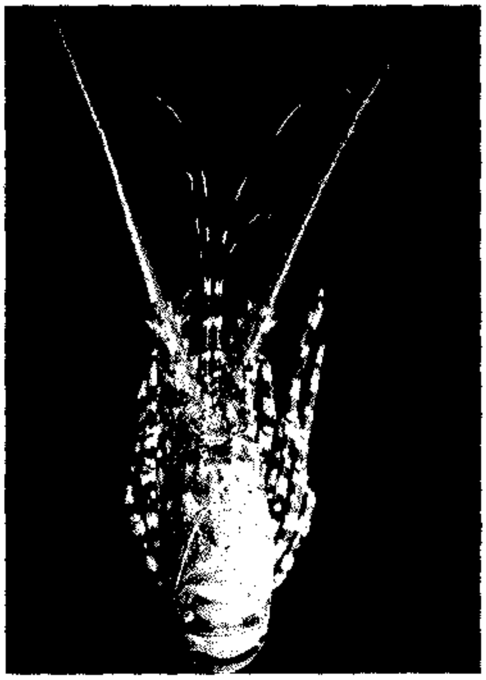
The reliability of the airlines chosen to take proper care of the live lobster transportation is of paramount importance. Therefore, particular attention should be paid to the choice of and the arrangements with the airlines in order to ensure that the shipment is appropriately handled.

Upon arrival at the final destination point, live lobsters should be examined immediately. Weak or dead animals should be removed and the weak ones should either be cooked or frozen. The lobsters which arrive in good condition should be immediately packed in tanks with circulating refrigerated seawater. If natural seawater is not available synthetic seawater can be used.

Lobsters being graded before packing for transportation.



Lobsters in the basket being dipped in chilled seawater (15^{0}C - note the temperature being recorded) before packing.

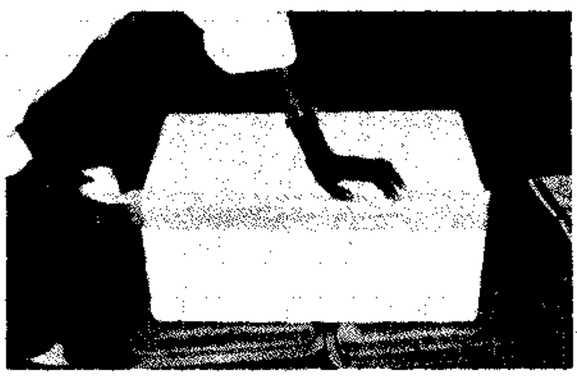


A tied lobster - rubber bands are used to restrict the movements of the lobster by tying it to the spines at carapace and abdomen.

Packing of lobsters - they are first wrapped in newspaper and then put into the thermocol box.

Two layers of lobsters packed - frozen water (in bottle) placed in the middle. A few lobsters are exposed for view.

A completely packed box of lobsters ready for transportation by air.



The lid is being sealed by plastic adhesive tape.

A consignment of packed live lobsters ready for transportation by air.

7. TRANSPORTATION OF LIVE CRAB

In India, the consumption of live crab is more or less confined to places near the fishing centres. However, if the crab could be transported alive to the interior places (far away from the fishing centres), there would be more demand for this crustacean delicacy than what is existing at present. A considerable proportion of crab is caught by commercial fishermen in Northern Australia in remote locations in the Northern Territory and the Gulf of Carpentaria, and transported alive from these production areas, which are thousands of kilometers away from the markets in Southern Australia. This crustacean is an important fishery in the Philippines and among the two varieties available - 'red claw' and 'green claw' - the 'red claw' is preferred by pond operators because it exhibits faster growth rate and is stress-tolerant.

Mud crab gathering, culture and fattening provide income and livelihood to many in developing countries. The development of mud crab fishery has, however, been quite slow, compared with other exportable commodities like tuna and shrimp. Mud crab being a supplementary crop from milkfish and shrimp ponds, it has virtually been overlooked as a potential species for culture. Some pond operators even consider mud crab a nuisance because of their burrowing habits which cause extensive damage to pond dikes. But with the increase in prices and demand from domestic and foreign markets, the attitude towards mud crab has been changing. Therefore, the development of transportation techniques has become critically important, and attempts were made in the mid-fifties (Roach, 1956) to store live crabs in large tanks onboard fishing vessels, with continuous aeration, water circulation and temperature regulation of seawater. In some cases, refrigerated seawater was used to lower the rate of oxygen consumption of the crab.

7.1 Handling after capture

Of all the commercial species of crab, *Scylla serrata* (Forskal), is the most common and is caught in fairly large quantities all along the coast of India. Large sized live crab (500 g and above) are transported to foreign countries and small ones are transported to places where they are reared for fattening before export. Immediately after capture, the crab should be handled minimally and bound with coarse twine to render their claws immobile. They should not be handled by their claws, as they readily shed them. Commercial fishermen either pack their catch immediately or, in remote locations, store them under water until enough have accumulated for a full consignment (upto 200 crab), either by road or by air. The holding structures are either net-pens or floating steel cages. Some fishermen attempt to hold the crab out of water, keeping them moist by covering them with damp bags or mangrove leaves. For easy handling, the chelae and the legs of the crab are tied with synthetic or coarse thread prior to packing for transportation. Tying of crab is clearly illustrated in Fig. 7.

7.2 Longevity of crab outside seawater

Crab can live out of water in the normal circumstances for some time only. But if the environmental factors such as temperature and humidity are adjusted to the optimum level, they can live for longer duration outside seawater. Observation period show that crab can live out of water for 24 to 210 hours, depending upon the humidity percentage in the atmosphere (Table 5).

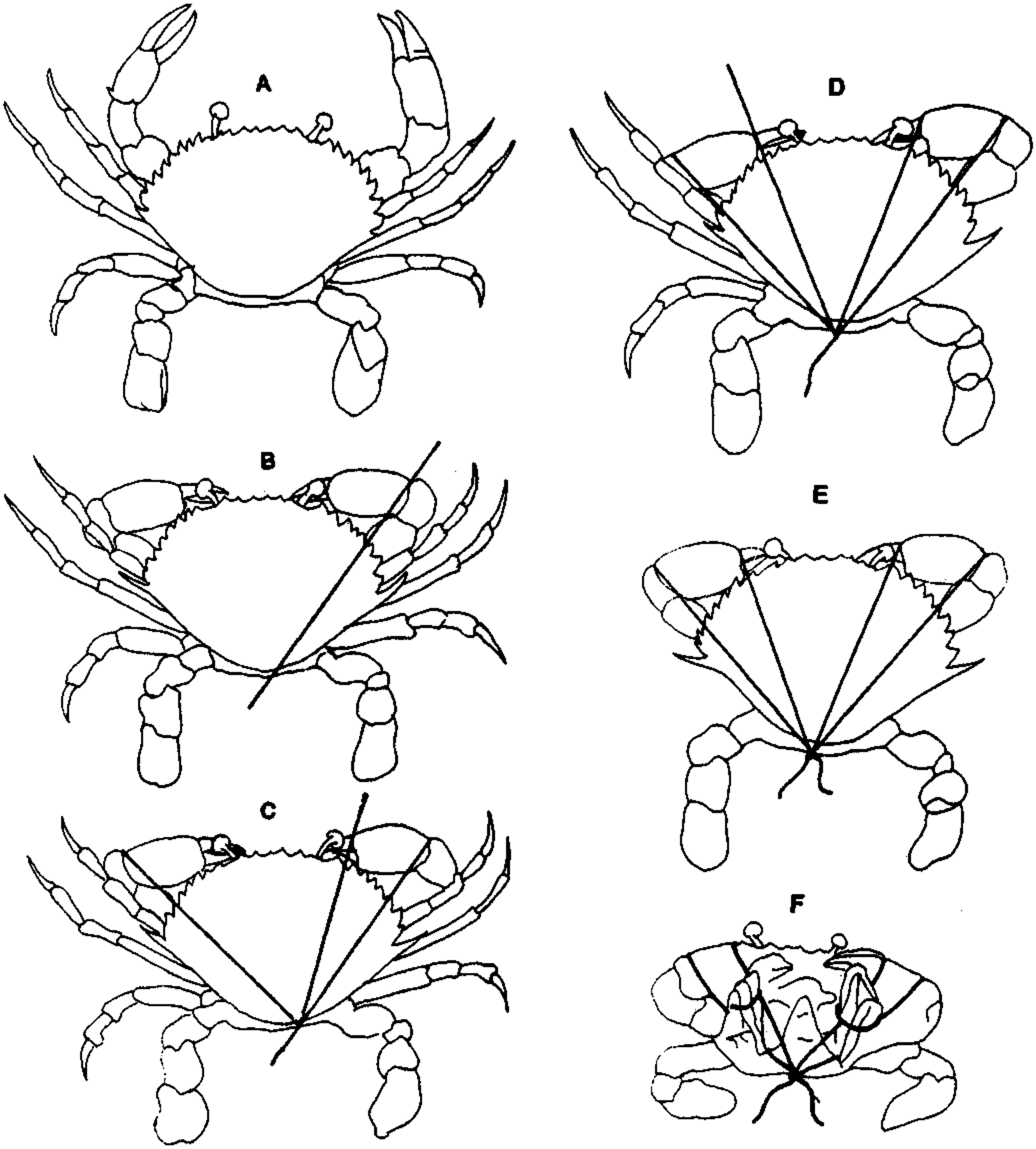


Fig. 7. Tying crab with plastic thread.

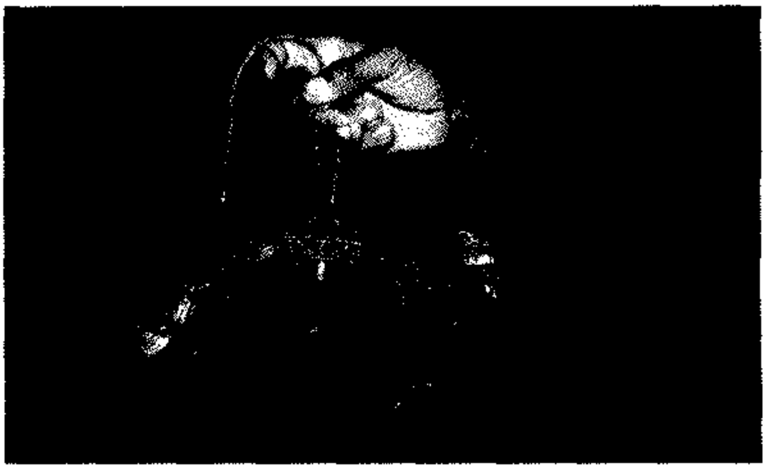
A - crab before tying *B, C & D - process of tying*
E - dorsal view of the tied crab *F - ventral view of the tied crab.*

Pen for holding crab for fattening before transportation.

Tying of crab
(a) Front view

(b) Rear view

Tying crab near completion.



A tied crab - note that the chelae and the other legs are tied to immobilise the animal.

Crabs tied and ready for packing.

Table 5. Survival period of the crab, *Scylla serrata*, outside seawater.

S.No.	Carapace		Sex	Survival period	Average	
	Length (mm)	Breadth (mm)		(hr)	temp. °C	humidity (%)
1.	42	63	F	24	31.3	64.5
2.	53	79	M	48	31.3	66.0
3.	40	60	M	196	27.3	90.0
4.	55	82	M	210	26.0	91.1
5.	44	57	M	175	28.0	86.3

Source: Vasudeo and Kewalramani (1960)

It is clear that relative humidity has a major impact on survival time. Weight loss in less than a saturated atmosphere was quite rapid and crab became moribund and died after losing about 10% of their body weight (Gillespie and Burke, 1991).

Temperature below 20°C enhances survival time. Crab stored at 12, 16 and 20°C survived for about 10 days, whereas crab survived for only 6-7 days at higher temperature of 24, 28 and 32°C. At 12°C and 32°C survival was affected by temperature stress as well as dehydration. At 12°C the crab were almost totally immobile and died due to dehydration. Crab stored at 32°C also died earlier, due to dehydration. Many exhibited a tendency to regurgitate a black fluid, indicating that the animals were stressed (Gillespie and Burke, 1991). It is apparent that optimum conditions for maintaining crab alive in air include saturated humidity, temperature between 16°C and 20°C, and 95% relative humidity.

As dehydration has such a significant effect on survival, handling conditions after collection/ harvest should be such that the crab are not subjected to drying winds. Exposure to direct sunlight for long periods also has a negative effect on survival.

7.3 Packing of crab in algae

Algae as packing material for retention of moisture in live crab, is commonly used in India and abroad. In India, in most of the collection centres, crab are placed in baskets with algae and brought alive to the markets and disposed off the same day. However, this method involves the risk of algae getting decomposed especially during long transits when the baskets are stacked one upon the other. To avoid damage due to stacking, containers (tins) can be used for short distance / duration transportation in a few hours. It was reported that the crab packed with seaweeds in tins were found dead and the seaweeds decomposed after 24 hours (Vasudeo and Kewalramani, 1960).

7.4 Packing of crab juveniles

Mud crab juveniles of assorted sizes are placed in bamboo wicker baskets of 40 x 50 cm diameter. Nearly 300 to 500 juveniles of 2.5 cm CL with pincers tied are placed in each basket. The baskets are lined with mangrove leaves to ensure favourable temperature and to minimize fighting among the crab. Some fishermen cut the tips of the pincers to prevent fighting. Often the baskets are packed in larger containers made of 'pandan' leaves, or wooden boxes. These larger containers are lined with mangrove leaves and regularly sprinkled with seawater to keep the crab moist and cool.

7.5 Packing of crab in wet cotton

The failure of algae as packing material necessitated selecting some other material which would not be perishable, but would have moisture-retaining quality. So, cotton soaked in seawater was used for live transport of crab. Crab under this condition were found to live as long as 17 to 18 days, with average atmospheric humidity of 83.5% and atmospheric temperature of 27.9°C. Trials of small commercial packing (7 crab of 50 mm breadth in 10" x 9" x 8" wooden box) resulted in 100% survival after 72 hours. Although packing of crab in wet cotton was quite successful, it would be rather expensive if used for packing crab on commercial scale. Besides, cotton after soaking with seawater becomes compact and obstructs the movement of crab.

7.6 Packing of crab in woodshavings

To comply with the two basic requirements of moisture retention and nonperishable loose material, woodshavings soaked in seawater were used as packing material. Under such packing condition the crab (packed in wooden box of 18" x 12" x 6") could live for 7 days (average temperature, 26.1°C; humidity 91.1% - Vasudeo and Kewalramani, 1960). Therefore, it would be safe to transport live crab packed in soaked woodshavings to any place comprising journey/ shipment under 7 days.

7.7 Packing of adult crab for export

Although crab are in great demand in foreign markets, they must arrive at their destination alive, clean and healthy. FAO law 162 prohibits the export of live crab measuring less than 10 cm CW and weighing less than 200 g. Crab for export are classified into four different groups, based on weight as follows:

Small	: 250	-	300	g
Medium	: 300	-	500	g
Large	: 500	-	850	g
Extra large:	850	-	1000	g and above

Over the past two decades, live crab have almost always been packed in waxed cardboard cartons. Crab that have been individually trussed as described earlier are packed tightly into the carton in a vertical position, with their claws uppermost. Heavy-duty plastic liners are used for air transportation, as leakage of blood or regurgitated digestive juices can damage aircraft. The liner is inserted in the carton first and several layers of coarse paper or newspaper are placed in the bottom to absorb the fluid lost by the crab. 10 to 12 kg of crab are packed to ensure availability of sufficient oxygen. Crab transported in this way are exposed to variable temperature conditions and the mortality is commonly less than 10% .

In some countries such as Philippines, the crab (after tying individually) are placed in cartons lined with plastic sheets. The cartons and plastic sheets have ventilation holes. Crab are also packed in polystyrene boxes with holes. Sometimes, outer cartons are required for air transport. If polystyrene boxes are used, each is packed with 20 to 30 medium / large crab weighing 10 kg. Three such packed boxes containing 30 kg of crab are kept in a cardboard carton and transported by air (Ladra and Lin, 1991). Mortality during flight is usually 5 to 10%, whereas during sea voyages it reaches 40%.

One of the ways to prolong the shelf life of crab is to pack them in polystyrene boxes with ice placed at the bottom of the box and chicken-wire mesh used to separate the crab from the ice. Crab kept in this manner have a 60% survival rate compared to those packed in 'pandan' bags or baskets. For large shipments, it is best to put the packed crab in a cool area which has a temperature of 18 to 22°C.

8. TRANSPORTATION OF LIVE OYSTER, MUSSEL AND CLAM

Mass production of seed of cultivable marine shellfishes and to make available the required quantity to the farmers and for ranching is one of the priority areas under the R & D efforts of the Central Marine Fisheries Research Institute, Cochin. The shellfish hatchery at the Tuticorin Research Centre of CMFRI undertakes mass production of spat of pearl oyster (*Pinctada fucata*), edible oyster (*Crassostrea madrasensis*) and clam (*Paphia malabarica*). Trials were carried out during the past decade to evolve safe methods of seed transportation. The outcome of such trials has paved the way for evolving effective methods of handling the seed before, during and after subjecting them to long distance transportation by road, sea or air.

8.1 Transportation of seed of pearl oyster

The pearl oyster spat are known to be highly susceptible to fluctuations in dissolved oxygen concentration, temperature and salinity. Owing to the special characters of spat in their natural environment, the following criteria should be adopted in their transportation from the wild:

1. selection of spat of same batch
2. conditioning of spat for 24 hrs in filtered seawater before packing
3. refreshing spat with fresh seawater in one, two or more stages at intervals of 4 hrs during transport and on reaching destination
4. devising easy methods of packing the spat.

8. 1. 1 Transportation in cages / bags

The spat should be uniformly spread in closely knit nylon meshed cages or bags and arranged under shade on the deck of the mechanised boat. Care should be taken to keep the spat always wet by sprinkling seawater during transit. By following this cage method spat could easily be transported to long distances either by sea, 80 to 100 nautical miles in 10 to 12 hrs or by road 600 to 700 kilometers in 10 to 12 hrs.

Pearl oyster spat of size 8.3 cm (35,000) and 24 mm (15,000) were transported successfully in cages by sea as explained above, from Tuticorin to Krusadai. The distance covered was 80 nautical miles in 9 hrs. The survival rate was hundred percent (Chellam *et al*, 1988).

8. 1. 2 Transportation of spat with and without oxygen

The spat could also be transported in polythene bags (12 l capacity), each bag containing 1 part water (3 l) and 3 parts oxygen to pack 700 to 800 spat (average size, 10 mm) to cover the distance of 400 to 500 km in 10 to 12 hrs by road.

Without oxygen spat can be kept in plastic troughs with fresh seawater and adequate aeration. This method is best suited for transportation by sea.

By following the two methods (with and without oxygen) mentioned above, 10,000 spat of 3.7 mm size (2,000) and 13.7 mm (7,500) were sent to Agatti in Lakshadweep. The distance covered was 400 km by road and 250 nautical miles by sea. The spat (750) were packed in polythene bags containing 3 litres of filtered seawater and filled with oxygen. The bags were encased in containers. After 12 hours from Tuticorin by road, the spat were transferred to plastic troughs with fresh seawater and adequate aeration and transported by sea from Cochin with constant changes of seawater. During the transportation there was no mortality in spat.

Chellam *et al* (1988) transported 5,800 spat of size 10 mm (5,500) and 23 mm (300) from Tuticorin (Tamil Nadu) to Sikka (Gujarat) by road (180 km) and by air (1,700 km) in 33 hrs.

The spat were transported by road in wet condition. Before boarding the plane, the spat were kept in trough containing fresh seawater and aerated overnight. The spat were then put in heavy duty polythene transport bags, each containing 4 litres of filtered seawater and each bag contained 500 spat. The bags were filled to capacity with oxygen and were tightly closed. Wet cotton wool was used to wrap the bags which were then put into retrievable polythene bags. These bags were put in tin containers with lids and whose sides were lined with thermacol. Since the transportation was undertaken during the peak summer when atmospheric temperature was beyond 30°C and water temperature 33°C, these measures had to be adopted. In spite of such precautionary measures, there was a mortality of 14.5% when the spat reached Sikka (Gujarat).

8 . 2 Transportation of seed of edible oyster

The seed of edible oyster (*Crassostrea madrasensis*) are known to be more hardy and if subjected to 'hardening' *prior* to transport, they are known to survive the transit impact very well. When the process of hardening was not adhered to, the percentage of spat mortality was found to be fairly high during and after transits.

'Hardening' is a simple process of wet packing of oyster seed, kept without water and disturbance for nearly 24 hrs. Then the seed are kept in clean, filtered and aerated seawater for nearly 24 hrs. Repeated exposure to different environment (with and without water) results in hardening. Such hardened seed withstand the transport stress well, and the mortality is very meagre.

8 . 2 . 1 Wet packing of edible oyster

Prior to packing, the process of hardening should be followed for some days. Then the oysters are wrapped in gunny sheet soaked in seawater and put in a box type nylon mesh cage (40 x 40 x 10 cm). Packed in this way the oyster seed can be kept alive for nearly 90 hrs.

Following the above mentioned wet packing method Chellam *et al* (1988) transported edible oyster seed from Tuticorin successfully. About 250 oyster seed of 30 to 40 mm in size were transported from Tuticorin to Madras by road. A distance of 650 km was covered in 17 hrs and the consignment reached Madras with only 0.4 percentage mortality.

In another instance, 2,000 spat of 15 to 20 mm size were transported from Tuticorin to Narakkal (Kerala) by road,covering a distance of 470 km in 15 hrs. In this case, no mortality occurred during transportation.

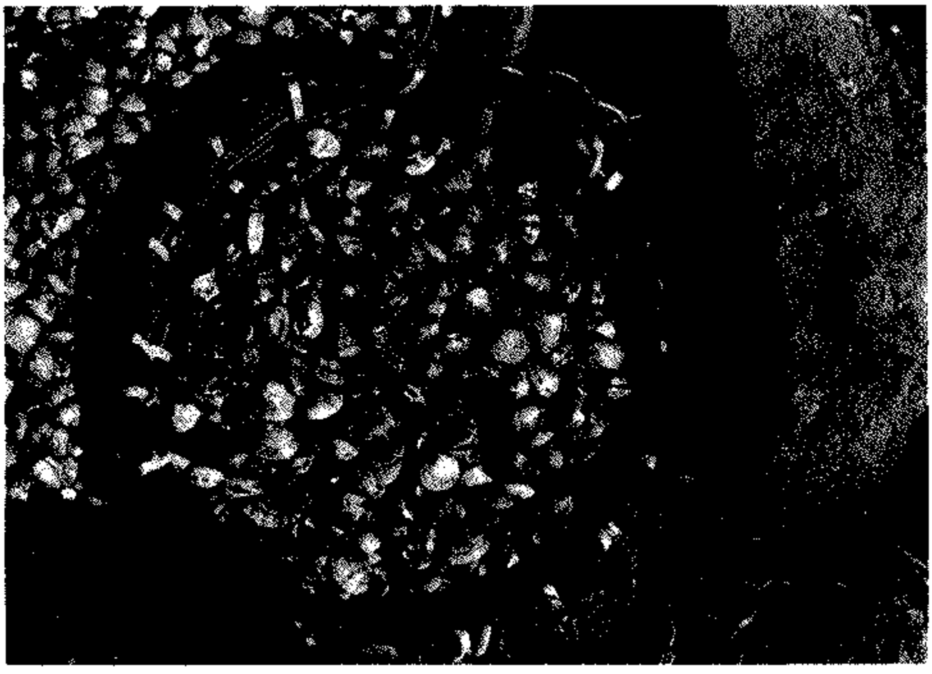
This method had been adopted in the transportation of 5,800 spat of 10 to 20 mm in size from Tuticorin to Sikka in Gujarat. In this case the transportation involved both road and air. From Tuticorin the spat were brought to Trivandrum by road covering a period of 6 hrs. They were then air lifted to Jamnagar via Bombay involving a duration of 33 hrs.

Gunny sheets soaked in seawater were used to wrap the oyster seed. They were kept in tin containers to facilitate easy handling at the time of loading in the plane. When the spat reached Trivandrum, the seed were emptied into plastic troughs which contained fresh seawater. They were then repacked as before. This procedure was followed to enable the seed to remain fresh during the aerial transit. It was observed that there was very little mortality during the transportation.

Spat of pearl oyster spread uniformly in nylon meshed cage for transportation (without water).

Harvested edible oyster, by long-line culture at Andhakaranazhi near Cochin by CMFRI, being transported by sea.

Harvested green mussel before transportation.



Clam spat spread on wet gunny sheet and put in a shallow bamboo basket for short duration / distance transportation.

8.3 Transportation of seed of mussel

Unlike the oyster, the mussels are not so hardy to withstand long distance or long duration transportation without water. There are two methods of transporting the mussel. The first one is to keep the mussel in tanks with filtered seawater and aerated or oxygenated at regular intervals. If the transit period is more than 24 hrs the water should be changed at an interval of 12 hrs. This method is suitable for transportation by road or sea.

Seeds are packed in polythene bags which are filled with one part water and three parts oxygen. For easy handling, the polythene bags are put in tins or cardboard boxes. This method is more essential and suitable for transportation by land, sea or air.

In this method, the density of the mussel (av. size 25 mm in length, 13 mm in width and 5 g in weight) could be 25 / l unlike the first method where only 3 / l could be packed.

By following the two methods described above, Trivedi *et al* (1986) transported 9,000 seed (av. length 24.4 mm, wet weight 4.6 g, width 12.8 mm and breadth 7.7 mm) of green mussel (*Perna viridis*) from Calicut (Kerala) to Port Okha (Gujarat) covering a distance of 2,300 km in 5 days by a closed body insulated 10 tonner truck.

8.4. Transportation of seed of clam

Among bivalves, clams are the most abundant, widely distributed and commercially exploited resource in several countries. In India, clams form subsistence fisheries all along the coast. In recent years, clams have emerged as a delicacy and luxury food item in most developed countries. Clam culture is practised in several countries but it is not as popular as oysters or mussels. In clam culture, the seed is generally collected from natural grounds and relayed in areas with a suitable substratum having congenial environmental condition. Due to adverse impact of the viral diseases in shrimp culture, threre is growing interest in India to utilize the clams as an alternative species in shrimp farms. Clams also act as a bio-filter in upgrading the quality of water used in shrimp farms.

The increasing demand for clam, both for edible purpose and for various industrial uses, has resulted in indiscriminate exploitation of adult and juvenile clams.

Hatchery production of clam seed technology has been developed at the Tuticorin Research Centre of C M F R I and seed produced in the hatchery are searanched.

The clam spat are highly susceptible to the tide level, substratum and salinity. Owing to such characteristics of spat in their natural habitat, the following criteria should be followed in their transportation from the wild / hatchery:

1. selection of spat of the same size / batch
2. refreshing spat with fresh seawater at intervals of 4 to 5 hrs. during transportation
3. following easy methods of packing the spat.

8.4.1 Transportation of spat with and without oxygen

The spat could also be transported in polythene bags (12 l capacity), each bag containing 1 part water (3 l) and 3 parts oxygen to pack 800 to 1000 spat (av. size, 10 mm) to cover a distance of 400 to 500 km in 10 to 12 hrs by road. The number of spat can be doubled (2000) and the oxyen-packed polythene bag should be kept horizontally (pillow - like) as shown in Fig. 4.

The spat can also be transported without oxygen by keeping them in plastic troughs with fresh seawater and adequate aeration. If continuous aeration is not possible, it can be given at random or water can be replenished. Care should be taken in spreading the spat evenly for three layers only and not in a heap. By following this method, 64,000 seed of *Paphia malabarica* (av. length, 12.4 mm) were transported from Tuticorin to Ashtamudi near Dalavapuram and 8,500 seed to Munambam during 1993 (Narasimham, 1993).

8.4.2 Wet packing of clam spat

The clam spat are wrapped in gunny sheet soaked in seawater and put in a plastic trough. For long distance / duration transportation, the gunny bag containing the clam should be dipped in well - aerated seawater for 5 to 10 minutes once an hour. Packed in this way the clam spat can be kept alive for nearly 6 hours and the mortality rate will be 10 to 15%.

9. REFERENCES

Alikunhi, K. H. 1980. Observation on mass rearing of penaeid and *Macrobrachium* larvae at the regional shrimp hatchery, Azhikode, during 1979-1980. *Bull. Dep. Fish.,* Kerala. **11** (1) : 20-24.

Armstrong, A. D., Chipendall, D., Knight, A. W. and Colt, J. E. 1978. Interaction of ionised and unionised ammonia on short term survival and growth of prawn larvae, *Macrobrachium rosenbergii. Biol. Bull.* (Woods Hole). **154** : 15-21.

Black, E. C.1958. Hyperactivity as a lethal factor in fish. *J. Fish. Res. Bd. Can.* **15**: 573-586.

Blazka, P. 1958. Anaerobic metabolism in fish. *Physiol. Zool.* **31** : 117-128.

Chellam, A., Dharmaraj, S., Velayudhan, T. S. and Muthiah, P. 1988. Experimental molluscan seed transport. *Mar. Fish. Infor. Serv., T&E Ser.* **79** : 26-28.

Cuerrier, J. P. 1952. Transfer of anesthetized adult lake trout by means of aircraft. *Can. Fish. Culturist.* **13** : 1 - 4.

Daisy, F. Ladra and Jeff C Lin. 1991. *Trade and marketing practices of mud crab in the Philippines.* BOBP/REP/**51** : 211-221.

Doudoroff, P. and Katz, M. 1950. Critical review of literature on the toxicity of industrial wastes and their components to fish. I. Alkalies, acids and inorganic gases. *Sewage and Ind. Wastes.* **22** (11) : 1432-1458.

Fry, F. E. J. 1957. *The aquatic respiration of fish. In*: The Physiology of Fishes (Brown, M. E., Editor), Vol. **1** : 1-63 Academic Press, New York.

Gerking, S. D. 1955. Endogenous nitrogen excretion of bluegill sunfish. *Physiol. Zool.* **28** : 283 - 289.

Gillespie, N. C. and Burke, J. B. 1991. *Report on the seminar on the mud crab culture and trade.* BOBP/REP/**51** : 207 - 209.

Hasler, A. D. and Wisby, W. J. 1958. The return of displaced largemouth bass and green sunfish to a "home" area. *Ecology.* **39** : 289 - 293.

Horton, H. F. 1956. An evaluation of some physical and mechanical factors important in reducing delayed mortality of hatchery - reared rainbow trout. *Progressive Fish Culturist.* **18** : 3 - 14.

Jhingran, V. G. 1975. Fish and Fisheries of India. Hindustan Publishing Corporation (India), New Delhi.

Karuppannan, N. V. 1972. Studies on the locomotory metabolism of *Tilapia mossambica* (Peters). Ph. D. Thesis, Madurai Kamaraj University, Madurai, India.

Krishna Kumar, K. and Pillai, N. N. 1984. Studies on survival of postlarvae of *Penaeus indicus* H. Milne Edwards under oxygen packing. *J. mar. biol. Ass. India.* **26** : (1&2) 145-153.

Kutty, M. N. 1968. Respiratory quotient in goldfish and rainbow trout. *J. Fish. Res. Bd. Can.* **25** : 1689-1728.

Kutty, M. N., Peer Mohamed, M., Thiagarajan, K. and Leonard, A. 1971. Modification of Fry's fish activity counter and respirometer. *Indian J. Exp. Biol.* **9** : 218-222.

Mammen, T. A. 1962. Live fish transport using modified splashless carrier with compressed in aeration. *In: Training Course on Live Fish Transport,* November 19-21, Hyderabad, Fisheries Extension Unit, Government of India. 5p.

McDonald, M. 1984. Report on the distribution of carp during the season of 1882. *U.S. Comm. Fish. and Fisheries; Commissioners Rept.*, 1982 (38): 915-942.

Narasimhan, K.A. 1993. Ranching of clams in the Ashtamudi lake. *Mar. Fish. Infor. Serv., T & E Ser.* **124** : 14-15.

Norris, K.S., Brocato, F., Calandrino, F. and McFarland, W.N. 1960. A survey of fish transportation methods and equipment. *Calif. Fish Game.* **46** : 5 - 33.

Patro, J. C. 1968. A note on a new fish carrier, double-barrel type (mimeo.) 6p.

Peer Mohamed, M. 1974. Influence of hypoxia on fish metabolism and activity. Ph. D. Thesis, Madurai Kamaraj University, Madurai, India.

Peer Mohamed, M. 1982. Effects of handling on oxygen consumption and random activity in the freshwater mullet, *Rhinomugil corsula* (Hamilton). *Proc. Indian Acad. Sci. (Anim. Sci.).* **91** : 469 - 472.

Roach, S. W. 1956. Storage of live crab in refrigerated seawater. *Progress Reports of 1956 of the Pacific Coast Stations.* No.**106** : 6-7.

Schultz, F. H. 1956. Transfer of anesthethized pike and yellow walleye. *Can. Fish. Culturist.* **18** : 1-5.

Trivedi, C. R. Bhaskaran, M., Wadher, D.J. and Khhayya, F. D. 1986. Successful long distance road transport of green mussel from Calicut to Port Okha. *Mar. Fish. Infor. Serv., T & E Ser.* **70** : 24.

Vasudeo, R. B. and Kewalramani, H. G. 1960. Transport of the common crab (*Scylla serrata*) in living condition. *Indian J. Fish.* **7**(1) : 169-173.

Woker, H. 1949. Die Temperaturabhangikeit der Giftwirkung von Ammoniak auf Fische. *Proc. Intern. Assoc. Theoretical and Appl. Limnol.* **10** : 573 - 579.

CMFRI SPECIAL PUBLICATIONS AND BULLETINS

I SPECIAL PUBLICATIONS

Spl. Pub. No.	Title	Year	Price Indian Rs.	US $
1	2	3	4	5
1	Pearl culture training : Long-term and short-term course. 39 Pp.	1977	5	2
2*	Mariculture research and development activities. 26 Pp.	1978	26	10
3	Summer Institute in breeding and rearing of marine prawns. 129 Pp.	1978	20	5
4	Economics of the indigenous fishing units at Cochin : A case study. 24 Pp.	1978	5	2
5	Seminar on the role of small-scale fisheries and coastal aquaculture in integrated rural developmment. Madras, 6-9 December 1978. Abstracts 44 Pp.	1978	10	5
6	Proceedings of the First Workshop on Technology Transfer in coastal aquaculture held at Cochin, 23 & 24 July, and Mandapam, 27 & 28 July 1979. 96 Pp.	1979	15	5
7*	Manual of research methods for crustacean. biochemistry and physiology. 70 Pp.	1981	70	25
8*	Manual of research methods for finfish and shellfish nutrition. 131 Pp.	1982	131	45
9	Manual of research methods for marine invertebrate reproduction 214 Pp.	1982	40	15
10	Analysis of marine fish landings in India : A new approach. 42 Pp.	1982	10	5
11*	Approaches to finfish and shellfish pathology investigations. 54 Pp.	1983	54	20
12*	A code list of common marine living resources of the Indian seas. 80 Pp.	1983	80	25
13*	Application of genetics in aquaculture. 50 Pp.	1983	50	15
14*	Manual of research methods for invertebrate endocrinology. 63 Pp.	1983	63	20
15*	Production and use of *Artemia* in aquaculture 42 Pp.	1984	42	15
16*	Manual on marine toxins in bivalve molluses and general consideration of shellfish sanitation. 53 Pp.	1984	53	20
17*	Handbook on diagnosis and control of bacteiral diseases in finish and shellfish culture. 32 Pp.	1984	32	10
18	Proceedings of the workshop on sea-turtle conservation. 90 Pp.	1984	25	10
19*	Mariculture research under the Centre of Advanced Studies in Mariculture. 58 Pp.	1984	58	20
20*	Manual on pearl culture techniques. 30 Pp.	1984	30	10
21*	A guide to prawn farming in Kerala. 52 Pp.	1985	52	15
22*	Water quality management in aquaculture. 53 Pp.	1985	53	15
23*	Hatchery production of panaeid prawn seed : *Penaeus indicus*. 35 Pp.	1985	35	10
24	The present status of ribbonfish fishery in India. 49 Pp.	1986	15	5

1	2	3	4	5
25	A practical manual for studies of environmental physiologgy and biochemistry of culturable marine organisms. 45 Pp.	1986	10	5
26	Theorems in environmental adaptation. 50 Pp.	1986	15	5
27	Bibliography of the publications by the staff of CMFRI 1948-'85 168 Pp.	1986	40	15
28	The present status of our knowledge on the lesser sardines of Indian waters. 43 Pp.	1986	10	5
29	Exploitation of marine fishery resources and its contribution to Indian economy 32 Pp.	1986	10	5
30	Seminar on potential marine fishery resources. April 23, 1986. 32 Pp.	1987	30	10
31	An appraisal of the marine fisheries of West Bengal 32 Pp.	1987	10	5
32	An appraisal of the marine fisheries of Orissa 36 Pp.	1987	10	5
33	An appraisal of the marine fisheries of Andhra Pradesh 52 Pp.	1987	15	5
34	An appraisal of the marine fisheries of Tamil Nadu and Pondicherry 63 Pp.	1987	15	5
35	An appraisal of the marine fisheries of Kerala 42 Pp.	1987	10	5
36	An appraisal of the marine fisheries of Karnataka and goa 104 Pp.	1987	25	10
37	An appraisal of the marine fisheries of Maharastra. 46 Pp.	1987	15	5
38	An appraisal of the marine fisheries of Gujarat. 51 Pp.	1987	15	5
39	An appraisal of the marine fisheries of Lakshadweep and Andaman & Nicobar Islands. 18 Pp.	1987	5	2
40*	National symposiumm on research and development in marine fisheries. Mandapam Camp, 16-18 September 1987 (Abstracts). 133 Pp.	1987	113	40
41	A manual for hormone isolation and assay. 46 Pp.	1987	10	5
42	Manual of techniques for estimating bacterial growth rates, productivity and numbers in aquaculture pnds. 28 Pp.	1987	5	2
43	Nutritional quality of live food organismms and their enrichment 28 Pp.	1987	5	2
44	An evaluation of fishermen economy in Maharashtra and Gujarat - A case study 80 Pp.	1988	20	5
45	Motorization of country crafts in Kerala - An impact study 74 Pp.	1989	20	5
46	Atlas of clam resources of Karnataka. 56 Pp.	1989	15	5
47	Annotated bibliograpby of commercialy important prawns and prawn fisheries of India. 326 Pp.	1989	90	30
48	The Indian oil-sardine *Sardinella longiceps* Valenciennes - An annotated bibliography. 80 Pp.	1990	25	10
49	Hatchery production of pearl oyster spat : *Pinctada fucata*. 36 Pp.	1991	10	5
50	Annotated bibliography of the silverbellies (Pisces: Family leiognathidae). 220 Pp.	1992	70	25

1	2	3	4	5
51	Bibliography (Part 2) The publications by the staff of CMFRI 1986-1990. 112 Pp.	1992	40	15
52	The Indian mackeel *Rastrelliger kanagurta* (Cuvier) - An annotated bibliography. 126 Pp.	1992	45	1 5
53	Mariculture Research under the Postgraduate Programme in Mariculture. Part 2. 176 Pp.	1993	40	15
54	-do- Part 3. 155 Pp.	1993	35	10
55	-do- Part 4. 134 Pp.	1993	30	10
56	-do- Part 5. 154 Pp.	1993	35	10
57	Hatchery techniques and culture of sea-cucumber *Holothuria scabra* 40 Pp.	1994	40	15
58	An annotated bibliography on sea-cucumbers. 92 Pp.	1994	30	10
59	Hand-book on Indian sea-cucumbers 47 Pp.	1994	40	10
60	Shrimp feed formulation and management 22 Pp.	1994	15	5
61	Mariculture research under the Postgraduate Programme in mariculture Part 6 123 Pp.	1995	35	10
62	Economically important Seaweeds. 36 Pp.	1995	70	25
63	Manual on pearl oyster seed production, farming and peral culture 53 Pp.	1995	50	15
64	A Maual on bioassays in the laboratory and their techniques 75 Pp.	1995	40	15
65	Report of the speical scientific team to Andaman & Nicobar Islands to give research support to thrust areas in fisheries	1996	35	10

II CMFRI BULLETINS

1*	Bibliography of marine fisheries and oceanography of the Indian Ocean, 1962-1967. 218 Pp.	1968	218	75
2*	Catalogue of serials and expedition reports in the Library of the CMFRI 55 Pp.	1968	55	20
3*	An annotated bibliography on the breeding habits and development of fishes of the Indian region. 158 Pp.	1968	158	55
4*	Bibliography of the Indian Ocean 1900-1930 - A supplement to the 'Partial Bibliography' 121 Pp.	1968	121	40
5*	Bibliography of the Indian Ocean, 1968 (with a supplement for 1962-1967). 152 Pp.	1968	152	50
6*	Distribution pattern of the major exploited marine fishery resources of India 84 Pp.	1969	84	30
7*	Catalogue of sponges, corals, polychaetes, crabs and echinoderms in the reference collection of the CMFRI. 66 Pp.	1969	66	20

1	2	3	4	5
8*	Catalogue of fishes from the Laccadive Archi - pelago in the reference collection of the CMFRI. 35 Pp.	1969	35	10
9*	Catalogue of molluscs, prawns, stomatopods and marine algae in the reference collection of the CMFRI 52 Pp.	1969	52	15
10*	Catalogue of fishes (excluding from the Laccadives) in the reference collection of the CMFRI. 38 Pp.	1969	38	15
11*	Bibliography of the Indian Ocean 1931-1961 : A supplement to the 'Partial Bibliography' 171 Pp.	1969	171	55
12*	Exploratory fishing by R.V. *Varuna* 125 Pp.	1969	125	40
13*	Marine fish production in India, 1950-1968. 150 Pp.	1969	150	50
14*	Prawn fisheries of India 360 Pp.	1969	360	120
15*	Bibliography of the echinodermms of the Indian Ocean. 45 Pp.	1969	45	15
16*	The Indian oil-sardine. 142 Pp.	1969	142	45
17*	Mackerel and oil-sardine tagging programme (1966-'67 to 1968-69). 41 Pp.	1970	41	15
18*	The polynemid fishes of India. 79 Pp.	1970	79	25
19*	Bibliography of contributions from CMFRI. 75 Pp.	1970	75	25
20*	The economic seaweeds of India. 82 Pp.	1970	82	25
21*	The Bombay-duck *Harpodon nehereus* (Hamilton). 75 Pp.	1970	75	25
22*	Primary productivity in the Indian seas. 63 Pp.	1970	63	20
23*	The tunas and tuna-like fishes of India. 110 Pp.	1970	110	35
24*	The Indian mackerel. 112 Pp.	1970	112	35
25*	The commercial molluscs of India 173 Pp.	1974	173	60
26*	The dugong *Dugong dugon* 49 Pp.	1975	49	15
27*	Exploited marine fishery resources of India : A synoptic survey, with comments on potential resources. 36 Pp.	1976	36	10
28	Coastal aquaculture : Marine prawn culture Part I : Larval developmment of Indian penaeid prawns. 90 Pp.	1979	15	5
29	Coastal aquaculture : Mussel farming - Progress and Prospects. 56 Pp.	1980	10	5
30A	Proceedings of the Seminar on the role of small-scale fisheries and coastal aquaculture in integrated rural development 6-7 December 1978, Madras. 203 Pp.	1981	35	10
30B	Present status of small-scale fisheries in India and a few neighbouring countries. 89 Pp.	1981	15	5
31	Coastal zone manaement : Mudbanks of Kerala Coast 74 Pp.	1984	15	5
32	Resources of tunas and related species and their fisheries in the Indian Ocean. 174 Pp.	1982	35	10
33	Fishery resources of the Exclusive Economic Zone of the northwest coast of India. 86 Pp.	1982	15	5
34	Mariculture potential of Andamman and Nicobar Islands: An indicative survey. 108 Pp.	1983	25	10
35	Sea-turtle research and conservation. 82 Pp.	1984	20	5

1	2	3	4	5
36	Tuna fishery of the Exclusive Economic Zone of India 216 Pp.	1985	50	15
37	Cephalopod bionomics, fisheries and reources of the Exclusive Economic Zone of India. 195 Pp.	1986	50	15
38	Oyster culture - Status and Prospects. 78 Pp.	1987	20	5
39	Pearl culture. 136 Pp.	1987	35	10
40	Marine catfish resources of India : Exploitation and Prospects. 94 Pp.	1987	25	10
41	Seaweed research and utilization in India. 116 Pp.	1987	25	10
42	National Seminar on shellfish resources and farming. Tuticorin, 19-21 January 1987.			
	Session-I Part I. 238 Pp.	1988	60	20
	-Do- Session II-VI Part II. 212 Pp.	1988	60	20
43	Marine living resources of the Union Territory of Lakshadweep - An indicative survey with suggestions for development 256 Pp.	1989	70	25
44	Proceedings of the National Symposium on Research and Development in Marine Fisheries. Mandapam Camp, 16-18 September, 1987			
	Session I & II Part I. 296 Pp.	1989	80	25
	-do- Sessions III & IV Part II. 183 Pp.	1990	50	15
	-do- Sessions V, VI, & VII Part III. 193 Pp.	1991	60	20
45	Monsoon fisheries of the west coast of India : Prospects, Problems and Management. 259 Pp.	1992	95	30
46	Proceedings of the National Workshop on *Beche-de-mer.* 113 Pp.	1994	70	25
47	Perch fisheries in India. 137 Pp.	1994	75	25
48	Artificial reefs and seafarming technologies. 126 Pp.	1996	160	55

Please make your order to

The Director,
Central Marine Fisheries Research Institute,
Dr. Salim Ali Road, P.B. No. 1603,
Tatapuram - P.O., Ernakulam
Cochin - 682 014, INDIA.

Payment may be made in advance by Demand Draft in favour of "ICAR UNIT-CMFRI" payable at State Bank of India, Ernakulam.

Bank Commission and Postage will be charged extra.