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Inland storage of crawfish and lobsters

by

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Introduction

Numerous problems occur in the handling and transport of large live crustaceans. The experienced buyer will become familiar with these difficulties over a period of years and will know how best to surmount them in practice. Often, however, the precise cause of the problems is either not known or not appreciated. Satisfactory storage can be achieved by experience alone but a biological appreciation of the precise conditions required for storage of lobsters and crawfish will be most beneficial to the industry, and particularly to those persons entering it for the first time. With this in mind Fisheries Division has been carrying out investigations in this field, and work was advanced rapidly in 1973 by the availability of a research field station at Dunmore East, Co Waterford. A detailed biological study of the storage behaviourof crawfish based on experiments is being undertaken at this station. Meanwhile this Leaflet has been written to give some preliminary results of these investigations, and also to describe one practical commercial result based on early findings.

Gibson (1958) described the use of a high density lobster storage unit for the holding of lobsters in urban areas, using re-circulated sea water, and the system described in this Leaflet incorporates many advantages over this and other earlier types of recirculation.

In Ireland, most commercial live crustacean storage tanks have been installed on the sea shore and, with a few exceptions, have used water pumped directly from the sea. The exceptions are

located in Dublin where artificial or natural sea-water is recirculated. Storage systems in Europe, to which nearly all our lobsters and crawfish are exported, are not so completely dependent on proximity to the sea. Several inland tanks exist in France and Spain and these use artificial sea-water which is continuously recirculated within the tanks. Tanks installed inland permit animals to be stored close to centres of population, which reduces labour and transport problems. However, if artificial sea-water is required this will make the tanks more expensive to run and necessitate constant monitoring of the quality of the water itself. In Ireland where an adequate supply of clean sea-water has been available, there has been little incentive to develop inland storage sites.

In 1973 Fisheries Division was approached by Mr John J O'Dowd, Importer, Exporter, of Tralee, who, faced with the problem of having to relinquish existing shore facilities at the begining of the lobster season, had to make arrangements for alternative storage capacity. Tralee is on the end of an estuary, but for the purpose of this leaflet may be regarded as inland because the nearest clean sea-water source is ten miles away and the only suitable sites for building new tanks are some twenty miles away. Accordingly, the possibility of installing a closed circulation system in the town of Tralee was investigated. Experimental results obtained at the Dunmore East field station determined the various storage parameters and possible stocking densities. On the basis of these predictions it was decided to go ahead with the building of the tanks in the town of Tralee. As the success of this type of installation could be of very great benefit to the Irish export of crawfish and lobsters, Fisheries Division decided to follow the

results obtained with these tanks and to monitor the water quality at various times.

General requirements for crawfish/lobster storage.

Gibson (1972) described the general features required of storage pounds which are dependent on a constant supply of sea-water. The present leaflet is intended to meet the more demanding requirements of re-circulation storage.

As mentioned previously, there is no supply of clean sea water adjacent to Tralee. Therefore, storage water must either be brought by tanker lorry or manufactured from fresh water by the addition of suitable sea salts. The chemicals (various sea salts) needed for the manufacture of artificial sea water are very expensive, and therefore it was decided that storage water should be provided by tanker lorry. The tanks at Tralee, being of small dimensions (for detailed description see pp 9,10) their full water requirements could be met by one tanker lorry journey. However, if the convenience factor of inland storage is to be emphasised it is necessary to limit the frequency of water changing. Two months is regarded as the minimum period acceptable between water changes. Gibson (1972) states that provided lobsters are not held for too long a period, i.e., that there is a continuous input and output to and from the storage tanks, the sea-water supply can be used for long periods without being replaced.

The Tralee tanks are small and it was therefore necessary to design them for a high level of stocking, so as to permit the storage of the maximum number of crawfish and lobsters. High level stocking can be regarded as intrinsic to the design of this type of installation, because by its very nature it will be installed in

areas of population where shortage of space and site costs will be important, and as already stated high stocking rates reduce the difficulties involved in supply of water.

These two conflicting demands, of long water life and high stocking density, impose problems in controlling and maintaining adequate water quality in the system. The control of the tank environment needs to be much tighter than for a coastal installation where it is possible to flush out the tanks each day. In a closed circulation system not only must the crawfish and lobsters be kept healthy but also the water must be maintained clean so as to avoid the need for continual replenishing. Therefore careful attention must be given to the following:-

Oxygenation,
Circulation.
Filtration
Purification.
Temperature control.

1. <u>Oxygenation</u>. Crawfish and lobsters 'breathe' oxygen by taking it out of solution from the surrounding water as it passes over their gills. The gills must be exposed to a very moist atmosphere, to obtain efficient respiration or breathing. Crustaceans survive in air for a short period because they can only absorb 3% of their oxygen requirements from a dry atmosphere. To survive satisfactorily in water they must have sufficient oxygen supply in the water. At the Dunmore East field station crawfish have been stored for a short time at very low oxygen levels (5% saturation), and have, when returned to normal saturation levels, appeared perfectly healthy. However, at low oxygen levels, stress symptoms have invariably been observed. Stress symptoms include such behaviour as standing on the tips of their legs, making paddling movements with their first pair

of legs, and curling the tail under the raised anterior part of the body. These symptoms sometimes occur in water with oxygenation saturation values as high as 40%, and therefore it was decided that the water saturation level should never be allowed fall below the 40% level.

Determinations of crawfish oxygen uptake made at the Dunmore East station vary widely with specimen size, water temperature, salinity etc.. A range of from 14.27 to 68.12 milligrams oxygen per hour per kilogram of body weight has been measured. A safe average based on the results of 65 experiments is 55 mg/hr/kg. Only a small percentage of the experimental results were above this figure, and it is unlikely that in a commercial tank, with a range of crawfish sizes, that this average would be exceeded. Larger specimens tend to use proportionately less oxygen than smaller ones. Lobsters being smaller than crawfish tend to use proportionately more oxygen. Only very little experimental data has, so far, been obtained for lobsters but this indicates a much higher consumption rate of oxygen in the region of 100 mg/hr/kg, or almost double that for crawfish.

2. Circulation. This was relied on to distribute the minimum level of oxygenation specified above throughout the storage tank. It is preferable to have both the function of water distribution and water aeration provided by the same pump. Permitting a minimum oxygen level of 40% makes it critical that good circulation is maintained, so as to ensure that no stagnant pockets develop in which the local oxygen level might fall much below 40%. Good circulation is also of prime importance in ensuring rapid filtration and purification of the tank water. For these reasons a pump of sufficient size to completely recirculate the water every 2 hours is necessary and because the success of storage tanks depends on continued movement of the water, a stand-by pump with automatic

cut-in, is also essential.

3. <u>Filtration</u>. With an expected tank water life of about 2 months, continuous and efficient filtration is essential, in order to remove any suspended particles circulating in the water. Most of this matter, being organic in origin, if left in the water would rapidly start to decay and give rise to serious deterioration of water quality. The main source of this material is the excrement from the stored crawfish and lobsters; as well as discarded eggs, food particles, blood and fragments of broken shell. Glass fibre attic insulation material one inch thick was used as a filter and all the water was forced to pass through this each time it circulated the tanks. This material has to be replaced at least every second day, but it is relatively cheap and is most effective in cleaning the water.

4. <u>Purification</u>. The main excretory product of lobsters and crawfish is ammonia which becomes highly toxic if it is allowed to build up in the water. There is little precise information on the level of ammonia toxicity but for crawfish it may be as low as 0.1 parts per million. Crawfish held in tanks with this level of ammonia have certainly shown signs of stress though to date no mortality figures have been recorded. This level, low as it may seem, is still vastly greater than levels normally occuring in the sea. Ammonia is soluble in water and consequently cannot be removed by mechanically filtering the water. However chemical filters are available (for example, charcoal) which greatly reduce the build up of ammonia. In the tanks in Tralee, oyster shells were used, because these are readily available in the area and have the added advantage of reducing the acidity of the water. Normal sea water is slightly alkaline having a pH (measure of acidity) of about 8.5,

but water in which heavy concentrations of crustaceans are stored will gradually become more acidic with a pH as low as 6.5. Oyster shells being composed mainly of lime tend to neutralise the acidyfying effect and also to help to reduce the toxicity of ammonia. The effectiveness of oyster shells in removing ammonia from water is due to bacteria which live on the shell. These bacteria are beneficial and require a few days in seawater to become effective in this process. Final results on the rate of excretion of ammonia by crawfish and lobsters are not yet available and until further experiments on this aspect are completed it will not be possible to describe all the factors required by a purification system for commercial tanks. In the tanks at Tralee a large amount of oyster shell was used and the build up of ammonia was monitored. Whilst this practice led to satisfactory results, further experiments are being undertaken, to determine the optimum purification system.

5. Temperature. This is a most important factor in any storage system but is of paramount importance in a closed circuit system. The main effects of a high temperature is to reduce the amount of oxygen which can be dissolved in the water and also to greatly increase the oxygen uptake by crustaceans. These two effects are shown in Table 1:

TABLE 1. Relationship between temperature, oxygen solubility, and crawfish oxygen uptake.

Temp.(^{o}C.)	O_2 solubility (mg/l)	O_2 uptake (mg/hr/kg)
9	9.62	16.78
12	8.99	24,67
15	8.42	30.28
18	7.92	41.99
21	7.46	52.06

Oxygen solubility varies with salinity; the figures given above are for water with a salinity typical for the Irish coast. The crawfish oxygen uptake figures are based on a series of twenty varying experiments with the same specimen (1.27 kg/weight). Table 1 clearly shows the two main disadvantageous effects of a high temperature. For example, at 18°C sea water contains 15% less oxygen that it does at 9°C, but at the same time a crawfish needs more than 3 times as much oxygen to survive at the higher temperature. Other effects such as an increase in metabolism with consequent increase in excretory products released into the tank will also be brought about by an increase in temperature. It is most desirable therefore that the temperature of closed circuit lobster storage tanks be kept low, and obviously the lower the better. However, because it is expensive to reduce water temperature by using cooling systems the temperature in the Tralee tanks was maintained as near as possible to 15°C. This temperature was chosen as the design maximum to keep the air in the tank room, by controlled ventilation, below this level for most of the time. The possibility of chilling the tank room was considered because there are great advantages to be gained by keeping the tank water as low as 9°C. However the expense involved in cooling a room sufficiently large to hold several storage tanks would probably outweigh the advantages obtained by increased stocking density. Cooling would probably be worth while in very high density units, i.e. units which would store crustaceans in shelves exposed to a continuous very fine mist or spray of sea water, as described by Gibson (1958).

TANK DESIGN AND INSTALLATION:

For reasons of space, at Tralee, three large pre-fabricated glass-reinforced plastic (GRP) tanks were installed. These tanks have many advantages, the main one from the biological point of view,

being the fact that they are completely inert, and do not rust or have any toxic components which might dissolve in sea water. To maximise this advantage all the fittings for the tanks were made of plastic (PVC) which is also non-toxic. The only metal component in the whole installation is the pump impeller which is made of stainless steel.

The space available permitted the installation of tanks measuring 12 feet by 6 feet by 2 feet, (366 X 183 X 61 centimeters), providing a volume of 144 cubic feet or 4,086 litres per tank, or a capacity of 12,260 litres for the whole system.

Working with a minimum permissable oxygen saturation level of 40%, and assuming total (100%) saturation of water entering the system this provides a usuable 60% range of saturation. Referring back to Table 1. it can be seen that at the maximum design temperature fully saturated sea-water holds 8.42 milligrams/litre (mg/litre) of oxygen and therefore 60% will hold 5.05 mg/litre. In other words there are 5.05 mg of oxygen available for every litre of water in the tanks, which provided a total oxygen supply amounting to 61,887 mg. Assuming that 55 mg/hr/kg body weight oxygen uptake to be a reasonable average consumption by crawfish, and dividing this into the figure obtained above, we find that there is sufficient oxygen in the system to supply 1,125 kg (i.e. just over 1 ton) of crawfish for one hour, or to supply 562 kg for two hours. If there is continuous circulation and re-oxygenation of the water with a complete recycling every two hours, then with a load of 562 kilograms (1,239 lb) the oxygen content should remain static at a high level. This explains how the suggested loading of 1,200 lb was estimated. It is a conservative estimate and it contains built-in safeguards, for example:-

(i) It assumes that the tanks will be run at 15°C. all the time. In practice they will often be cooler with a resultant saving in oxygen.

(ii) It assumes that there will be no oxygenation within the tanks and that the only reoxygenation would be when the saturation is returned to 100% on being pumped back into the tanks. In practice there is considerable aeration on the surface of the water and good mixing of air and water was achieved in passing from one tank to another.

(iii) The lower saturation level of 40% is in itself probably a conservative limit.

However these safeguards do provide an extra margin of safety in the event of such unpredictable occurrences as a power failure or a sudden need to overstock the tanks. They also to some extent allow for the fact that lobsters will probably consume significantly more oxygen per pound body weight than crawfish, and it thus allows for mixed crawfish/lobster storage.

The three tanks were placed in three tiers each two feet above the other, (Fig. 1). The water from the pump enters at one corner of the uppermost tank. It is drained from this tank by three 2" pipes suspended an inch below the surface of the water, and passes into the bottom of the next lower tank. Three more similar pipes bring water into the bottom tank. From this tank the water is again drained through pipes mounted near the top of the water and passes into the filtration system. (Fig.2.). This consists of a long trough containing about twenty cubic feet of oyster shells with a layer of glass-wool on top. The water level in this trough is just below the top of the shells so that they are immersed in water, but keeping the glass fibre out of the water. This ensures that the water passes through the filter rather than running along

its surface. The water is sprayed onto the top of the filter to ensure good aeration and filtration. From the filter unit the water passes into a 100 gallon reservoir and is then pumped back into the first tank.

The most interesting and important points of the design of these tanks are:

A <u>The interconnecting pipes</u>. As mentioned in the description above these take water from the top of one tank and pass it into the bottom of the next. By taking water from near the surface they create a vortex of air which is sucked down the pipe and issues at the other end as fine bubbles. This provides good aeration at no extra cost and it ensures that the oxygen level is as high in the lower tank as it is in the top tank. By passing water into the bottom of each tank it makes sure that the best water is available to the stored animals. The only disadvantage of this system is that it allows heavy material to be deposited at the bottom of the tanks. The current from the pipes is sufficiently strong to keep most light material, including most of the excrement, in suspension, and it is later removed by the filters. The heavy materials found on the bottom of the tanks consisted mainly of sand and pieces of broken shell. These are relatively inert and do not seriously effect the water quality, even if allowed to accumulate. Draining from the surface is of great practical benefit in that it permits easy regulation of the level of the water. The whole system is in fact automatic, so that if the power is switched off the water level in all the containers remains almost constant. It has been found useful to be able to turn off the pump when examining the tanks.

B The filter. The glass-wool materials used tend to hold on to pockets of air which cause the water to run along the surface of the filter. This feature may be counteracted if the air bubbles are pressed out after a new piece of filter material has been put in place, and also if the water is sprayed on to a wide area of the filter rather than all being poured on at one place. The filter can be seen to rapidly absorb particles of dirt and should be changed before it is so dirty that dirt starts to wash out of it. The oyster shells are never touched.

C The reservoir. This takes up any rise and fall in the water level and ensures that the pump never runs dry. If the pump is turned off in order to examine the tanks this reservoir will hold the inch or so of water that will drain off the tanks till they reach the level of the outlet pipes.

D The pump. In the design it was stated that the water should be recirculated completely every 2 hours. The whole system holds about 2,500 gallons, and thus to meet this requirement a pump of 1,250 gallons an hour capacity was needed. In actual fact a pump of 3,200 gallon/hr capacity was fitted, which with a head of twelve feet would give about twice the minimum required flow.

Results of test runs with the Tralee tanks

The tanks were first filled with water on the 24th May, 1973. The circulation of the tanks was more than adequate and no stagnant corners were located. The oxygenation obtained by the vortex effect in the water on passing from one tank to another was highly successful. The principle of oxygenation by vortex could be extended and a long series of tanks could be operated in this way, thus providing greatly increased storage space.

Crawfish and Lobsters were first stored in the ponds on the 1st June 1973. The stocking levels from then until the end of the season are listed below:

TABLE 2. Stocking levels in Experimental Tanks at Tralee.

Date.	Crawfish (lb) In	Crawfish (lb) Out	Lobsters (lb) In	Lobsters (lb) Out	Total Stock (lb) Crawfish	Total Stock (lb) Lobsters
Jun 1	1237		200		1237	200
3	260		10		1197	210
8	110		40		1607	250
9		450		50	1157	200
11		400		50	757	150
12		402			355	150
13					All dead.	
			Water left to purify.			
Jul 1	Tanks emptied and refilled with fresh sea-water.					
1			500		0	500
12				500	0	0
13	100		60		100	60
21	438				538	60
25		200			338	60
28	769				1107	60
30	231				1338	60
31	61				1399	68
Aug 1	30	996			433	68
2	318				751	68
3	89		12		840	80
4		491		18	349	62
8	400				749	62
11		242			507	62
16		55			452	62
17	265		16		717	78
18	78				795	78
23	166		29		961	107
24	128				1089	107
25		589		44	500	63
Sep 1		500			0	63

TABLE 2. (Contd.)

Date.	Crawfish (lb) In	Crawfish (lb) Out	Lobsters (lb) In	Lobsters (lb) Out	Total Stock (lb) Crawfish	Total Stock (lb) Lobsters
Sep 8	593		313		593	376
9	46		14		639	390
12				215	639	175
13	118		35		757	210
14	30		4		787	214
16	129		228		916	442
21	61		75		977	517
22				307	977	210
24	30		22		1007	232
25				150	1007	82
26		872			135	82
		82 (Dead)			53	82
27	167		62		220	144
Oct 1	630		50		850	194
6	120		28		970	222
10	50		10		1020	232
17		960			60	232
20	165		33		225	265
24		67		50	158	215
28		120		60	38	155
Nov 3		20		20	18	135
6		10		15	8	120
7		8		60	0	60
14				60	0	0

Within a fortnight of the start of operations heavy losses occurred in both crawfish and lobsters. This can be attributed to the very high stocking levels at this time causing the ammonia concentration to build up very rapidly. The tanks were heavily overstocked and this was particularly crucial at this early stage of their operation. An ammonia reading of 0.05 ppm. was obtained on the 6th June, before the mortalities occurred. This is still below the level at which crawfish show stress symptoms. However this reading was taken only 5 days after operations were started and the reading does show a

rapid build up on the level found in fresh sea-water. This build up must have continued and reached a lethal level on 12th of June. Unfortunately no readings for ammonia were obtained at the time of mortality, but it seems certain that high ammonia levels were the cause. Oxygen measurements made at this time were always very satisfactory. However the water did become brown and opaque and this can be taken as a visual warning of dangerous levels of ammonia in tanks.

The average weight stored in the tanks over this period was 1,282 lb crawfish and 200 lb lobsters. Even after long usage the design capacity of this type of installation should never be exceeded (except for a very short period), as doing so may quickly destroy the quality of the water. A continuous overload of almost 300 lbs for twelve days, including a period of six days with a 500 lb. overload, must be regarded as excessive.

In addition to the crawfish and lobsters stored the tanks were used for storing 5,000Oysters and 2,000 Escallops during the period from the 1st October to the 7th November. No losses occurred.

After the initial failure, the tanks were operated satisfactorily for the rest of the year with somewhat lover levels of stock. This included some short periods when the 1,200 lb limit was slightly exceeded without harmful consequences.

To estimate the success of the tanks from the beginning of July to the end of October (practically the end of the season) one can consider the average daily combined weight of crawfish and lobsters held. This figure will give no indication of short term abnormally high or low stocking levels but it gives an indication of the overall through-put on an assumed daily basis. The value

of this is that it gives an indication of the ability of the system to remove harmful substances assuming these were being produced at a constant level. The assumption would not be valid if there were periodic gross overloadings of the tank as these might necessitate either a change of water or a long period of recuperation without stock. In the period under discussion no such severe overstocking occurred and we may assume that the average daily load derived from analysis of Table 2 represents a level of stocking well within the tolerances of the tanks and filtration system. The load held in the tanks was obviously restricted by the commercial availability of crawfish and lobsters and consequently this average level determined cannot by any means be regarded as being a maximum level allowable to keep the ammonia in the water down to desirable limits.

The daily average weight of stock held during the months of July to October inclusive was 680 lbs.. This minimum figure could well be exceeded if it were possible to continually maintain stock at a high level. However the figure is still regarded as being very satisfactory. It must be remembered that the estimate of the possible stocking levels of these tanks given in the design aims was based on the need to supply sufficient oxygen. It was not known, and still is not certain, how much ammonia may be excreted per animal per day, or how much filtration might be needed to counteract this. However it is perfectly clear that the stocking density of 680 lb was a safe and sustainable level in tanks of the type and size of those installed in Tralee. As it is thought that this level might be greatly increased, the figures for the July-October period have been worked out in terms of a daily average of half-monthly periods. These results are given below:

TABLE 3. Stocking densities in terms of daily averages.

Period	Combined daily average weight(lb) (crawfish & lobsters)
Jul - Oct.	680
1st half July.	427
2nd half July.	599
1st half August.	611
2nd half August.	740
1st half September.	558
2nd half September.	972
1st half October.	1167
2nd half October	397

These figures show averages significantly higher than the overall average for three of the eight fortnightly periods. Two of these periods (September and October) are consecutive, indicating that prolonged storage is possible at these levels without causing mortality from ammonia build-up or any other factors. Ammonia toxicity is regarded as being the main problem hindering the improvement of this type of installation. It has been shown (results given below) that maintaining adequate oxygenation of the water even at high stocking levels is not a problem with such a closed-circuit storage system. It will be noted that the weight of stock held in the first half of October equates closely with that used in the design aims regarding oxygen supply.

Monitoring of conditions in the tanks.

In operating any crawfish or lobster storage system, especially at high densities, it is well worth while carrying out periodic checks on the water quality. This can be dispensed with in tanks

where water is brought in from the sea each day unless the quality of the sea-water is suspect. However in tanks such as the ones under discussion it is of the utmost importance that the quality of the water be regularly monitored. The tanks at Tralee were checked periodically but not nearly as frequently as would have been desirable. The monitoring work was done by Fisheries Division but if these tanks, or similar ones, were envisaged as a long term commercial operation then it would be highly desirable that the pond owners should equip themselves with the basic instruments for continually checking the water. The qualities of the water which should be checked can be listed in order of priority:

1. Oxygen level.
2. Ammonia level.
3. Temperature.
4. Salinity.

All these factors with the exception of the ammonia level can readily be measured by any person with the aid of a few scientific instruments. The money spent on the basic instruments, oxygen meter, thermometer, and hydrometer, can be very quickly recovered because a good knowledge of water conditions will prevent or greatly reduce mortality. This is particularly true in the present case where adverse stocking levels or weather conditions could very quickly upset the delicate equilibrium of the system.

The oxygen level was checked at the very beginning of the season and then on a number of other occassions during the Summer. Using an oxygen probe it was possible to check the level in different parts of the tanks to ensure that no "flat" spots existed. All readings obtained were between 95% and 100% saturation. (100% saturation is the maximum amount of oxygen that can be disolved in water that is thoroughly mixed with <u>air</u> at any given temperature.)

These readings are clearly very satisfactory and indeed were higher than anticipated. Readings taken at all levels of stocking, including the beginning of June when the tanks held 1,500 lb, were in the range mentioned above. However this should not be interpreted as implying that much higher levels could be stored, because this would lead to troubles with ammonia build up. If even better purification could be arranged, the 1,200 lb limit would still have to be adhered to, because the ponds are entirely dependent on continuous running of the pumps and it is important to allow a margin for safety in the event of their failure. Maintaining the level high, under normal conditions, allows much greater safety in the event of pump failure. In designing the tanks it was thought that in the event of a breakdown with a full (1,200 lb) stock of fish it would take 2 hours for the water to drop to the 40% saturation level. On the 5th of June the tanks contained 1497 lb, of crawfish and 210 lb of lobsters and the oxygenation level was at 96%. The pump was then shut off for an hour. At the end of this time the oxygen level varied slightly from tank to tank but all were in the range 70 - 75%. With a drop of 23% in the first hour and assuming a drop of 30% (which is probably a gross exaggeration) in the second hour, then at that time there would be 43% saturation in the tank water. Bearing in mind that the tanks were overloaded this is a very satisfactory level. The crawfish and lobsters would have come under stress during the next hour but it is probable that no long-term damage would have been caused for at least another three hours. Conclusions from the oxygen measurements made in these tanks are that while the pumps are running the level will be maintained extremely satisfactorily, and that in the event of pump failure the stock is absolutely safe for three hours and almost certainly for five hours.

Ammonia levels are more difficult to determine and measurements were made by transferring tank water samples to the Dunmore East station. Consequently it is not know whether the level was constant within the tanks or whether it would have fluctuated locally. As ammonia is soluble it seems certain that it would have been evenly distributed throughout the system. The state in which ammonia exists in water depends on the acidity (pH) of the water. In alkaline conditions it occurs in the form of free ammonia (NH_3) in which form it is volatile and gives off the strong acrid fumes which one associates with ammonia. In neutral or acid conditions it is present as ammonium ion (NH_4^+). As sea-water is almost neutral, ammonia tends to be present as the ion in which form, not being volatile, it does not have a strong smell, nor does it tend to come out of solution.

Ammonia measurements made of the Tralee tank water showed gradually increasing levels during the season and by the end of the season had greatly exceeded the "stress level" for crawfish. Water entering the tanks at the beginning of the season was checked and found to contain less than 0.01 ppm of ammonia. A sample taken on the 6th of June was slightly higher. From then until the 1st August no samples were taken. In early August a reading of 0.8 ppm. was obtained, which is above the "stress" level and the final reading taken in November had risen to 2.5 ppm. These ammonia results are shown in Table IV. The last crawfish stored in the tanks were on the 6th November, when the ammonia level was much above the level at which signs of stress had been observed. These crawfish survived well enough but showed signs of loss of balance and dizziness.

TABLE IV. Ammonia levels in storage tanks at Tralee

Date.	Ammonia (ppm.)
Jun 1	0.01
Jun 6	0.05
Aug 1	0.8
Nov 21	2.5

This continued build-up of ammonia raises the question as to how long the tanks could have continued to operate satisfactorily if the season had not come to a close. The oyster shells seem to have worked satisfactorily to keep the level even as low as they did, and it is possible that an increased amount of shell might achieve the desirable result of keeping the ammonia level below the stress level for crawfish. No signs of discomfort were seen in lobsters stored even at the highest levels of ammonia, and it appears that they are much more tolerant of this substance than are crawfish. Further development of the purification system is needed and it is proposed to carry out investigations in this regard at Dunmore East, during 1974.

The effect of temperature and the value of keeping it down have been discussed earlier. During the 4 months of the tanks operation the highest temperature reached was 18°C. (66°F.), for one day, otherwise they never went above 16.5°C. (62°F.), and generally remained below 15°C..

Salinity measurements tended to rise during the season due to evaporation. Water lost from the tanks by evaporation and by being carried out when fish were removed was topped up with sea-water. The high salinity was never a cause for worry and, indeed, may have been beneficial, especially for the crawfish.

General observations on the tanks (mainly provided by Mr. J O'Dowd) relate to the colour of the water and the symptoms of dizziness among the crawfish. The water tended to take on a brown opaque appearance if high levels of stock were held. This colour was produced by material dissolved in the water which could not be filtered out. If stocks were reduced, the colour dissapeared after a few days. The cause is not known but it seemed to be of no great harm, except in that it indicated possible overloading of the tanks.

Stress symptoms similar to those described were observed at the beginning of August when the ammonia level was already quite high. This forms a very valuable biological indicator especially as crawfish show these signs well before the ammonia appears to be toxic to them.

General Comments and Conclusions

The tanks have been a success in that large numbers of crawfish and lobsters were stored during the season without excessive mortality (apart from the initial mortality caused by overstocking) and without having to change the water. There appears to be no outstanding problems in the storage of lobsters and it seems that the 1,200 lb limit which was based on crawfish research can equally well be applied to lobsters despite their proportionatly greater oxygen requirement. The outstanding difficulty with crawfish lies in their sensitivity to ammonia. It is hoped that it will be possible to greatly improve the purification system, to control the ammonia level below that which causes stress in crawfish. However even now it has proved possible to handle at least 670 lb, mainly of crawfish, over a 4 month period without appreciable mortality and without having to change tank water. This and the convenience of the tanks are the main achievements of the experiment.

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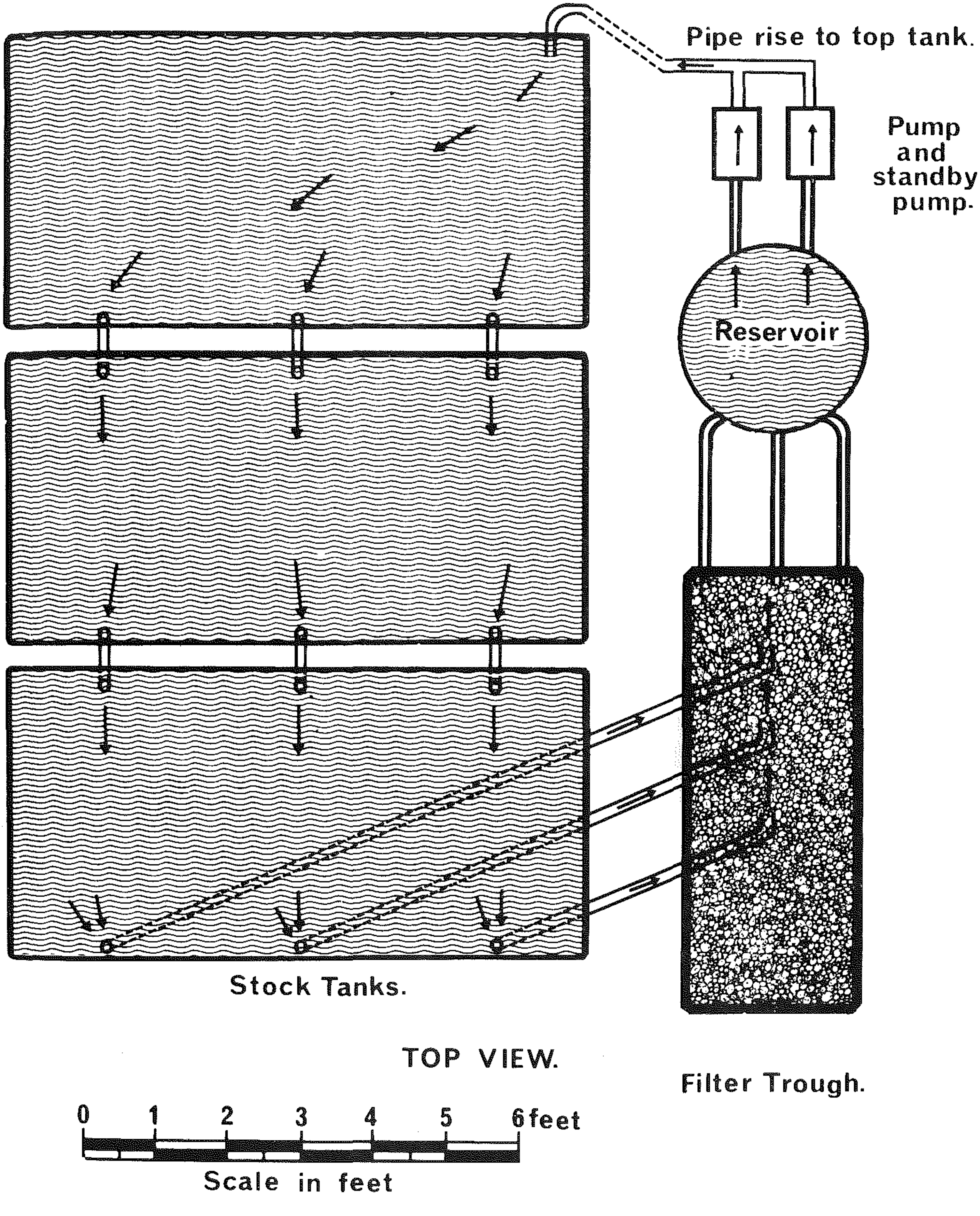
Pipe rise to top tank.
Pump
and
standby
pump.
Reservoir
Stock Tanks.
TOP VIEW.
Filter Trough.
0 1 2 3 4 5 6 feet
Scale in feet

Fig. 1.

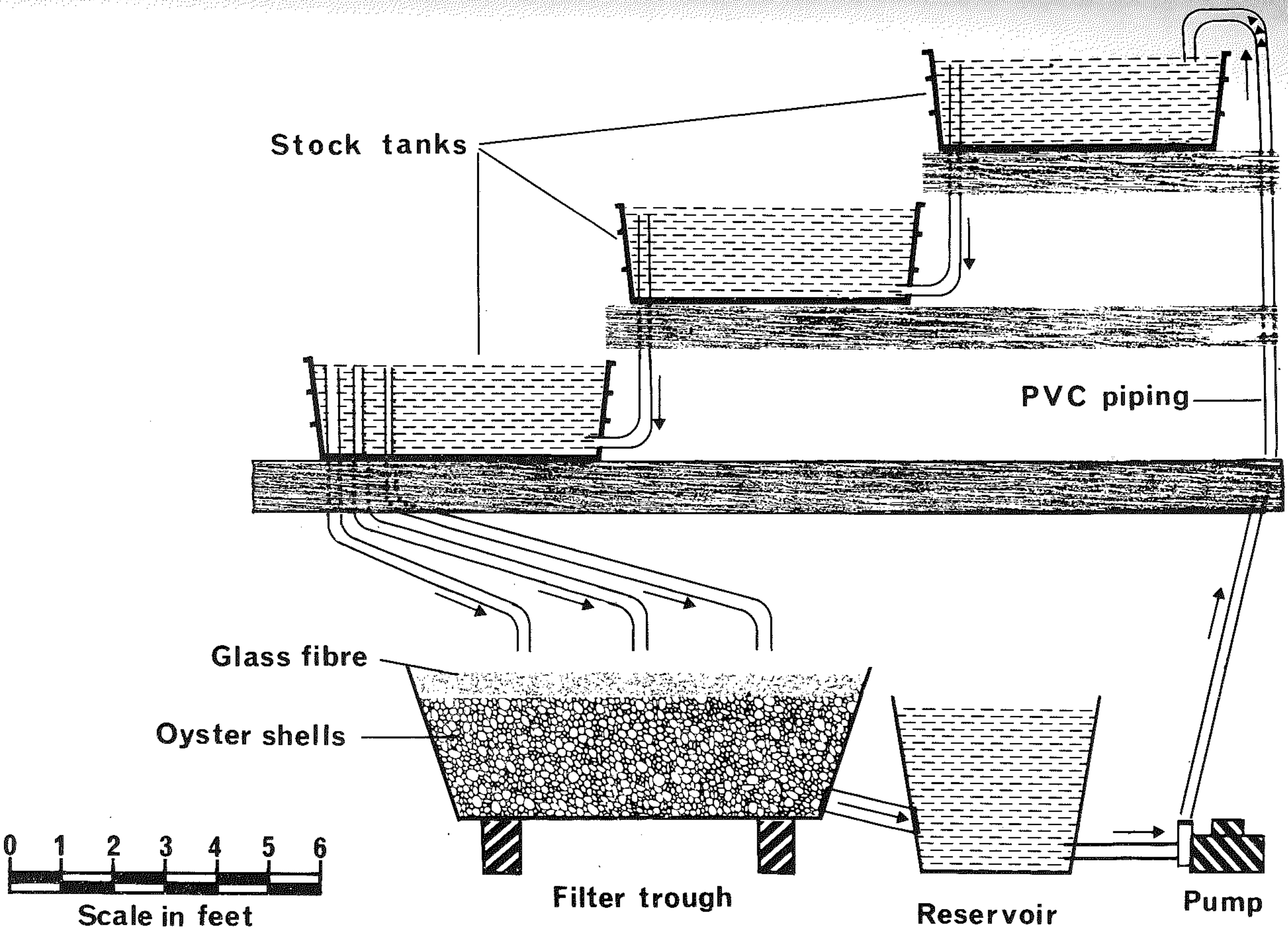

Fig.2. Transverse diagram of Tralee Tanks.