A Review of Handling Practices for Mussels in the Wash Fishery with Comparison to Holland & New Zealand

MAFF Commission
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SEA FISH INDUSTRY AUTHORITY
Industrial Development Unit

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SUMMARY

The UK fishery for live mussels from natural beds (as distinct from cultivated mussel) is still a cottage industry by comparison with near Continental neighbours Eire and New Zealand. In trying to define good handling practice for the UK it is first necessary to agree with the Industry on the definition of a good mussel and there is a lot of subjective thinking on this relating to appearance rather than flavour or the purification procedure. The UK is at present therefore unable to produce mussels to a specification to the same extent as our Continental neighbours. The opportunities nonetheless are considerable as long as there is willingness by the Industry to grasp them.

It is shown that meat texture varies with season with the best months being August to December. Thus for the live food market the fishery should consider a closed season. A major problem on some natural beds is the risk of contamination and the need for purification

including removal of enteric pathogens. Part of the Wash production is not purified whilst part is and this leads to inconsistency in quality standards. The purification process whilst representing a step forward falls very short of ideal by comparison with other countries. Further difficulties occur in the post harvest phase where there is a need to reduce the time in transit and exposure to high temperatures the effects of wind and frost and further contamination for example from sea birds.

The Dutch practice is to control quality and production from seed collection and relaying to harvesting and production. All Dutch production is from relayed mussels. Mussels grown on sublittoral beds have better growth rates and yields and exhibit no barnacle growth. Beds are cleaned up prior to relaying and the water quality is monitored by Government laboratories for contamination from heavy metals and pathogens. In selection of lays the substrate, food content of the water, turbidity and current strength are important criteria since all affect the size and quality of the mussel. The most important process is re-watering or purification in which the harvested mussels are relayed on clean salt water beds for as much as 10 days before final harvesting followed by degritting ashore prior to marketing. From harvesting to marketing is a relatively short period during which time the live product is kept below $10^{o}C$ but above $0^{o}C$ and protected from airborne contamination. As such it does not suffer the same quality loss as the UK product. Although the bulk of the Dutch trade is in live mussels there is some cooking

and processing leading to a variety of products which are named in the report.

The New Zealand Code of Practice although for a different species of mussel gives further information about quality control. New Zealand sets a very high standard for an export product to the USA. There are many commonalities to the Dutch practices with the exception that in New Zealand the beard is never removed on the grounds it kills the mussel. The Dutch take a totally opposing view and have developed machinery to remove the beard.

Experimental data from Tasmania is included which shows the considerable extension of shelf life of live mussels by holding them in chill conditions.

The report lists machinery which is available in Holland for mussel processing all of which has been well tried in the Industry. Recommendations are made for further study but the overall observation is that whilst the UK could obtain a greater market share for live mussels there needs to be a cohesive plan for re-organisation of the industry and the promotion of a greater understanding of the spoilage process and what a quality mussel should be.

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1 INTRODUCTION

Documents received from various institutes, notably in Holland and New Zealand, indicate that the mussel industry is developing apace in those countries. With such development comes the requirement for some form of quality code for the industry in order that the producer may ensure that the customer obtains the best possible quality product.

Normally such a code may be given in the form of a 'code of practice' or a series of 'guidelines' which, when followed, result in consumer satisfaction and often an improvement in product quality.

As an initial step, it was decided to review the practices of handling mussels in the U.K.

The objectives of this review were as follows:-

1. To review the practices of handling mussels in the U.K. with particular emphasis on those factors which might affect product quality.

2. To identify those subject areas in which knowledge of the effects on quality is lacking.

3. To define a series of experiments/investigations to demonstrate the quality improvements which can be achieved by changes in practice and to fill the gaps in current knowledge.

The review was carried out under MAFF Commission QFA 16 by undertaking observations of the Wash fishery from harvesting to retailing, visiting the Dutch Research Institute (RIVO) at Yerseke and reviewing published data from Holland and New Zealand.

The work in the U.K. was limited to observations made on the Wash fishery, though many of the comments in this report will apply equally to other bottom culture fisheries around the coast. No account has been taken of the expanding mussel cultivation industry using rope culture on the N.W. Coast of Scotland. Many of the remarks relating to water contamination substrates and purification are obviously irrelevant in this case, but some of the post harvesting practices may well be applicable. The review is also limited in its identification of subject areas where further work is required, it does not attempt to state the answers to such problems, merely to suggest possible areas of investigation.

The review, whilst mainly concerned with the handling of live mussels does comment on the possibilities for cooked mussel production.

2 BACKGROUND

The edible mussel (Mytilus edulis) is a bivalve mollusc which occurs naturally around the coasts of Europe from intertidal level down to 20 metres below low water mark. For a variety of reasons, ranging from difficulty of harvesting to poor meat quality, the majority of natural beds are not suitable for exploitation. It is however possible to cultivate mussels in order to produce crops of the required shell size and meat content.

Methods of cultivation may be grouped into two main types:

(i) bottom cultivation
and
(ii) rope cultivation

In Spain, mussels are grown by raft cultivation which involves catching mussel spat on ropes and transferring, when large enough, to net "stockings" which are suspended from rafts. The rafts are usually moored in sheltered estuaries. Some 40 growers in N.W. Scotland now carry out a similar form of cultivation. The practices of these growers have not been studied in this review.

The French use Bouchot (pole) cultivation and staked rope cultivation in lagoons.

The remaining mussel fisheries of Western Europe are in Holland, Denmark, Germany (West), the United Kingdom and Ireland, where the mussels are from natural beds or bottom cultivation. It should be noted that virtually all the Dutch mussels products have been cultivated by re-laying from natural beds.

The production of mussels in the U.K. is small by comparison with the Spanish, Dutch or Danish fisheries.

The U.K. production is mainly for the home market but some is exported (live), mainly to France.

It was considered that the export of live mussels to France could be expanded with high quality cultivated mussels. However, new French import regulations which came into force 1985 coupled with problems in cultivation techniques and handling of the mussels means that such expansion has not yet been achieved.

The U.K. market requirement is satisfied by import of both meats, (frozen and acidified) from Holland, Denmark and Ireland, and live mussels from Holland, Spain and Ireland.

The mussel is a filter feeder. Food particles (mainly phytoplankton but some zooplankton and much organic detritus) are filtered from water down through the gills. The discharging of treated or untreated sewage into rivers and estuaries frequently leads to faecal contamination of mussel beds in estuaries or nearshore waters.

Because of their ability to filter out enteric pathogens the mussels are a known route for the transmission of enteric waterborne diseases.

This makes the handling of mussels an item of major concern if the quality of the product is to be improved and the risk of disease is to be reduced.

3 QUALITY OF THE MUSSEL

3.1 What is a Good Quality Mussel?

The answer to this question is difficult to identify clearly.

Comments such as:

'Should be of a good size'
'Full of meat'
'Clean mussels' etc.

are very subjective.

Factors such as purification procedures, and flavour changes during handling are rarely if ever commented upon.

It is important to remember that fresh mussels are sold live unlike (for example) cod or plaice which is sold after death.

The mussel is also cooked in the live state. Any dead mussels (gaping mussels which do not close their shells after being given a sharp tap) are discarded prior to cooking. Hence, any organoleptic changes due to spoilage after death are avoided.

However, research on the New Zealand green lipped mussel (Boyd & Wilson 1978) has indicated changes in the organoleptic characteristics prior to death due to storage conditions (Figure 1 overleaf). There would appear to be no published data on flavour changes due to other aspects of handling such as purification or impact during harvesting or processing.

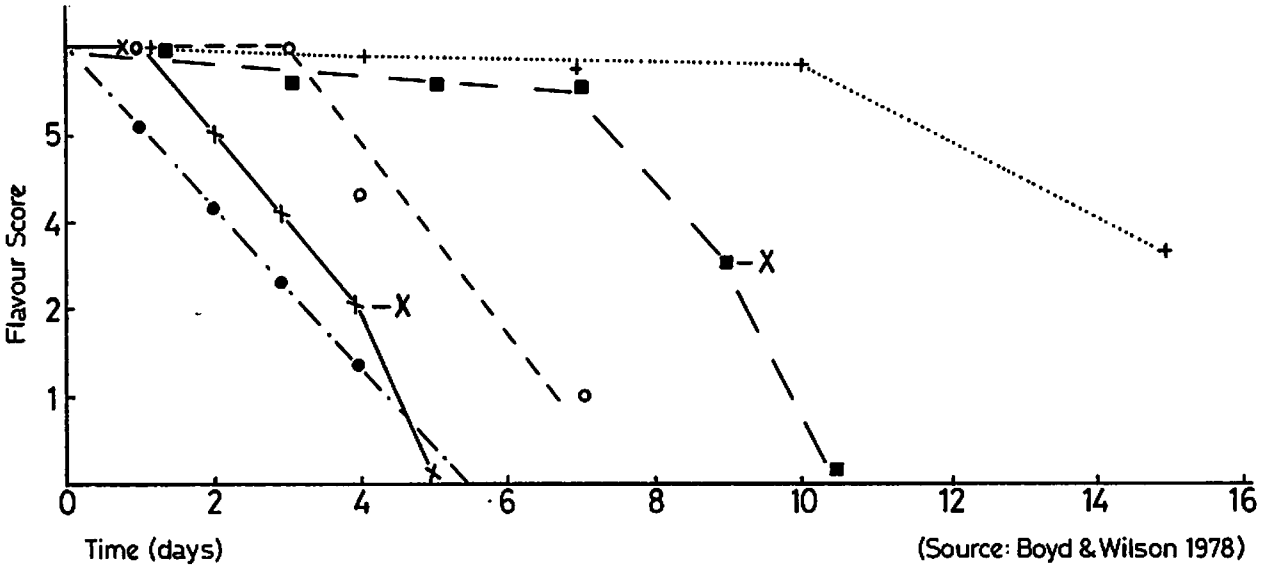

Figure 1. FLAVOUR CHANGES IN MUSSELS HELD UNDER STORAGE CONDITIONS.

Notwithstanding the lack of objective information, there can be little doubt that the shelf life of the live mollusc is affected by handling and from the research in New Zealand it is likely that the flavour is also affected.

The effect of shock, temperature and other physical agencies may adversely affect the flavour of the mussel. The problems of pollution due to mineral oil in the sea causing tainting will also affect the quality of the final product.

3.2 Size

The laws of supply and demand seem to determine the size of mussel (by which is meant shell length). Where larger mussels are required, customers buy Spanish or Irish mussels. The British mussels are supplied 'as fished'.

It would seem that any size grading will be dependant upon much improved management of the fishery to produce larger mussels in quantitites where grading becomes feasible.

3.3 Barnacles

There is little doubt that lack of barnacles on the shell is preferable. Such mussels are normally growing well down on the intertidal areas or are grown sub-littoral.

It is important that the situation of the growing mussel is condusive to growth. This results in larger mussels with rapid growth rather than stunted growth where shell is laid down as protection at the expense of increase in length. The former type are undoubtedly a more attractive and hence more saleable commodity.

3.4 Meat Content and Flavour

Meat content does not seem to be as important as flavour. There are comments indicating that "if the mussels have barnacles it means they will have a good flavour", but, as this comment came from a person selling such mussels, it is a statement shrouded in suspicion!

It is likely that the flavour of mussels does vary depending upon where the mussels are growing but no objective research seems to have been carried out in this area.

3.5 Meat Texture

Meat texture is probably just as important as flavour and this is known to change with the season. Spawning in the spring produces a very thin flesh which reduces the cooked meat yield and results in an unacceptable product on the British market.

The mussels build up reserves of carbohydrate (glycogen) during the summer, reaching a peak in September/October thereafter declining during the winter months. (The range is 35% to 40% of the dry weight of the meat).

Protein and lipid contents follow a similar pattern.

From the above, it is obvious that higher meat yields will be achievable when the mussels are fished in the season August - December.

3.6 Changes During Distribution

If a merchant is presented with a live mussel, then the shelf life with the merchant will depend upon what it has undergone previously.

The merchant himself may affect the subsequent shelf life of the mussel by poor handling techniques. "Live mussels warm up rapidly, and if left at ambient temperatures for long periods of time will suffer considerable quality losses in flavour and texture" (A Code of Practice for Mussel Processing; New Zealand Fishing Industry Board).

4 THE WASH FISHERIES

4.1 The Fisheries

The two main fisheries are based at Boston and Kings Lynn. A third fishery based at Brancaster is just outside The Wash but is useful to include for comparison.

All three fisheries are under the jurisdiction of the Eastern Sea Fisheries Joint Committee (E.S.F.J.C.).

However the Environmental Health Officers responsible for pollution controls are based at Boston (Lincolnshire) and Kings Lynn (Norfolk).

This causes some problems as fishermen from Kings Lynn fish areas of The Wash which come under the jurisdiction of the Boston port health authority. The political undertones that this engenders do nothing to improve the rivalry between the two groups of fishermen. Nor does it appear possible to police the fishery adequately.

The Brancaster fishery is a private fishery which is operated by re-laying of seed mussels which are grown on in Brancaster harbour to attain a minimum length of 50mm before being fished and sold to the inland markets.

4.2 Pollution

The sea water in The Wash is polluted due to the inflow of rivers whose origins are in the Industrial East Midlands and which flow through agricultural land which is farmed intensively. The possible problems of heavy metal contamination take second place to the very real threat of contamination by enteric pathogens.

The risk of such contamination is undoubtedly relatively high at the Western end of The Wash where most of the mussels are fished.

The Brancaster fishery is on the other hand in an area where the sea water is considered clean.

As such, the Brancaster mussels do not require any purification process.

Those fished in the area under the jurisdiction of the Boston port health authority must be purified before sale to the (U.K.)* public.

4.3 **Barnacles**

A major problem with The Wash mussels is the high proportion of mussels with barnacles on their shells. This is due to the intertidal nature of the lays.

Mussels grown on sub-littoral lays do not have the problem of barnacles attached to their shells.

The Brancaster mussels are, on the whole, barnacle free.

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* Mussels are fished and transported to France without purification, see Section 4.10.

4.3.1 Re-laying and growing

Wild mussels from natural beds are re-layed onto privately leased lays. Such lays are covered by a Several Order and leased to the fishermen by the E.S.F.J.C.

Once re-layed on such plots, the mussels become the property of the fisherman leasing the plot.

There is a major problem with this method of re-laying as carried out at present in that the mussels re-layed are of varying year classes.

This has a bearing on the quality of the product which is eventually sold to the customer. Older mussels tend to have thicker shells and more barnacles. Though some merchants will say that 'barnacles on the shell mean a better flavour', it is probable that this is a sales pitch rather than fact. Most fishmongers and consumers would appear to be demanding clean, black, barnacle free mussels. There is no doubt that such mussels do look very attractive.

4.3.2 By-laws

The E.S.F.J.C. by-laws require mussels of a size less than 1 3/4in to be returned to the sea. This should be done over the lays.

The wisdom of such a practice is questionable. (See Section 4.5).

4.4 Fishing

Mussels are dredged and the dredge emptied on the deck, a drop of about one metre. Work carried out at Conway on dropping mussels would indicate that shell fracture is a probability at this stage. Little can be done to

reduce the initial shock of falling from the dredge to the deck other than recommend that such a drop should be as short as possible. The maximum height is limited by the working height of the crew opening the dredge end.

Thereafter, the mussels which are clumped together by means of their byssus (threads) are roughly separated by the crew kicking and stamping on the clumps. Such treatment results in surprisingly few broken or smashed mussels reaching the shore. Possibly these are lost in the subsequent washing operation.

4.5 Washing/Sorting on Board

Some fishermen are known to leave the washing and sorting until after purification. Such practice will be beneficial in reducing handling of the mussels; but will increase the load on the purification plant.

The object of this 'washing' on board is to remove:-

1. Broken and half shells
2. Weed and silt
3. Undersize mussels.

This undersize material is returned to the 'lays'.

It is said that the shells encourage spat collection, this together with the fact that there is a minimum size grade allowed to be fished/landed are given as the reasons for washing through a 'grizzlie' or 'trommel' shown in Figure 2 overleaf.

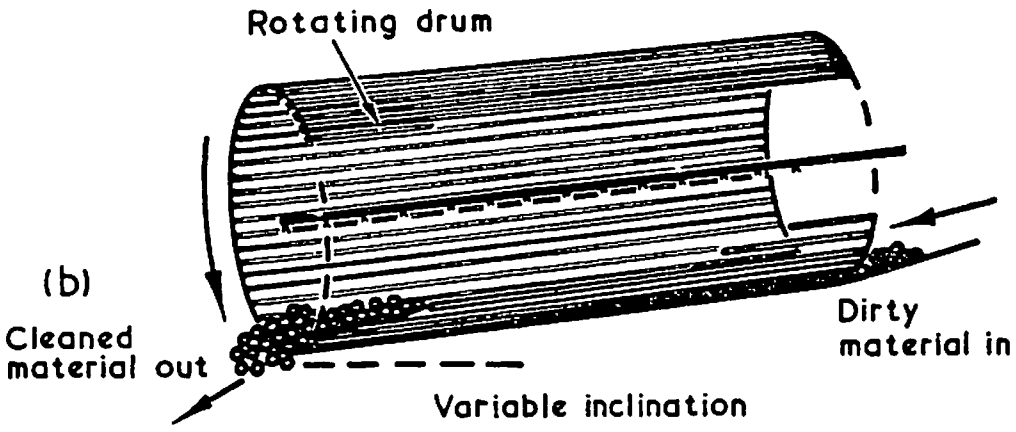


Figure 2 A "Grizzlie" or "Trommel"

Regardless of these comments, where this process is carried out it removes some mussels, which, though smaller than the locally enforced minimum size would probably be acceptable to the French market, "these are closer to the size of the French mussel".

A second point is that this probably causes a build up of broken and half shells on the lays, which may be detrimental to the quality of succeeding years 'harvests'.

The final point at this stage is to question the wisdom of returning a few small mussels to the lays. This will produce a range of year classes on the lays in a relatively short number of years.

The mussels are shovelled into the trommel which has wash water spraying through the mesh to remove debris.

Some trommels incorporate brushes which are for the removal of barnacles.

The systems on board the boats are generally primitive and though effective to some extent, the shock to the mussel at this stage is questionable when considering the subsequent quality of the end product.

The use of a simple hopper for direct unloading of the dredge into a feed system to first a de-clumper and then the trommel would be a possible improvement. Handling would be reduced and such a system would probably be workable even on two-man boats. The problem of barnacles is particularly noticeable on intertidal mussels and is a special problem in The Wash fishery.

The 'washed' shells are packed into sacks which may be hessian or plastic net or discarded fertiliser sacks (made from polythene). Such sacks are readily available in an agricultural community and together with sacks used for lima beans from the large canneries in the area are an inexpensive form of packaging.

4.6 **Landing**

This is achieved by simple hoist onto the quay. The bags of mussels are stacked to about 5 feet high awaiting collection.

If their distribution is to the purification tanks then collection will be within 18 hours of landing. Where mussels are being fished for carriage overland to North Wales the sacks can be waiting for up to four days

before a load is uplifted. This means five days from fishing before they are being purified or otherwise disposed of.

The mussels fished for the French trade are despatched within 48 hours of catching. Longer periods of delay may result in loads being rejected by the French importer. (See Section 4.10).

It is worth observing at this point that the sacks of mussels are at the mercy of the elements whilst on the quayside. Whilst rain is probably no problem to the mussels, heat or cold are two problem areas.

During warmer periods such as the beginning of the season (September/October) it is likely that the mussels suffer loss of quality due to over-heating (see Section 3.6). This is borne out by tales of loads being rejected by the French importers at this time of year on the grounds of poor quality due to dead mussels.

Extremes of cold may have a similar detrimental effect on some mussels. Whilst piles of sacks full of mussels will have an insulating effect to some extent, the mussels on the outside may, over extended periods, freeze.

In such a situation spraying water over the sacks when frosts are forecast could reduce frost damage.

4.7 Purification

Boston has purification tanks run by a Fishermans Co-operative. It is situated about six miles from the landing quay, necessitating a journey, by road on a flat back truck.

All movement of sacks is manual.

Viz: 1) off quay onto truck
2) off truck onto wall of purification tank
3) off the wall into tank.

The mussels are placed in plastic trays in the tank. (Wooden potato-chitting trays are also used due to shortage of funds). The mussels are tipped out of the sacks and levelled off across the trays using a shovel.

The trays are useful in keeping various orders separate.

Purification is by re-circulated seawater using ultra-violet sterilisation tubes.

This method of sterilisation of sea water is well documented.

However a number of problems were observed. Firstly the water entering the tanks had a large proportion of suspended solids which would greatly reduce the efficiency of the U.V. light.

It would seem appropriate to consider the use of a clarification centrifuge in such a situation.

The second problem noted was lack of regular cleaning of the U.V. light tubes. The build up of algae was visible in the associated pipes and it was noted that the bacterial counts had been rising gradually over the previous three months.

The role of the local environmental health officers was to take samples for analysis and report the results to the Co-operative.

The third problem was attempting purification during conditions of extreme cold. Temperatures of the water in the tank were $0 \pm 2^{o}C$ and no evidence of mussels filtering could be seen.

Samples for analysis were still being taken and results were acceptable. This would indicate low levels of coliform organisms in the mussel before purification rather than effective purification.

4.8 **Sorting/Grading/Packaging**

After purification the mussels are removed from the tanks, passed over a riddle (vibrating screen) which incorporates water sprays, to remove weed, half shells and some barnacles. A visual inspection then removes broken mussels and extraneous matter.

The mussels are subsequently bagged, a card stating where and when purified inserted and the bag sealed.

This process subsequent to purification involves a number of places where the mussels are subjected to shock due to impact. This is an area where the stress caused by rough treatment does not show itself immediately but may result in a reduction of shelf life further along the distribution chain.

Some mussel fishermen carry out a subsequent process prior to sale. One fisherman passes the purified mussels through a machine which removes barnacles from the shell. Another does a similar job using a different method but the mussels are then packed (2 kg) into polythene bags for retail sale. (See Section 4.9).

4.9 Distribution

The bagged mussels are distributed to customers (wholesale and retail) for the following morning's market. Transport is non-refrigerated and may often be truck or trailer.

Some mussels are re-sorted and packed into perforated polythene bags 2 Kg., which are then packed into a polythene outer for transport to market. (There are no holes in the outers).

The re-sorting undoubtedly causes further stress which may be the cause of such mussels having a shelf life less than those in bulk sacks.

It is however possible that the packaging itself causes reduced shelf life. Possibly the increase in air temperature within the bags known as the 'greenhouse effect' due to radiant energy from light sources, is the reason for the problem.

The Dutch have been using polythene bag packing for some years with great success but it must be said that the Dutch mussels so packed are subject to much less handling before packing.

4.10 **Export to France**

Mussels exported to France are not purified and as such their value at first sale is very low at £2 per bag. Were they to be purified, then the value would be around £3 per bag. This export market would appear to be late in the season (January onwards) unless the French demand is such that earlier loads are required.

5 THE DUTCH MUSSEL INDUSTRY

5.1 Introduction

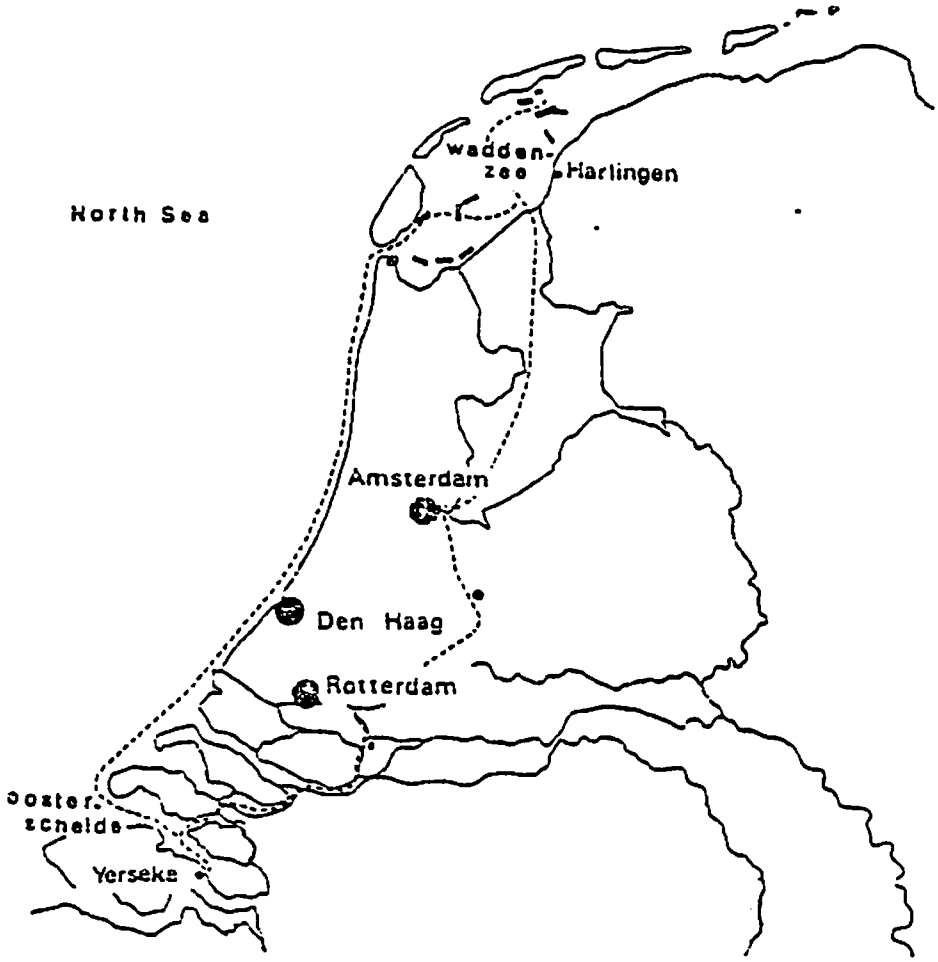
The Dutch mussel industry is a thriving and well organised concern, based at Yerseke, a fishing village on the Oosterscheld (see Figure 3 overleaf). The industry has developed in sophistication over the past thirty years with the assistance of the Netherlands Institute for Fishery Investigations.

The Waddenzee is now the major source of mussels in Holland but all mussels harvested in the Waddenzee must be re-laid on specified re-watering plots in the Oosterscheld before being processed and sold for human consumption.

In order to produce a good quality mussel for sale to the consumer, the Dutch control the processes involved from identifying the seed and deciding where to re-lay for optimum growth rates to fixing quality standards required before final processing.

The assistance given by the Institute started with an analysis of factors which control the growth and condition of mussels. This research produced recommendations of limits for those factors "wherein good growth and meat condition" can be achieved.

The parameters looked at were shell formation and meat condition.



Routes taken by the vessels carrying mussels from the Waddenzee farmingplots to Zeeland (Yerseke).

Fig. 3

Factors affecting these parameters seemed to be:-

(i) Bottom substrate, classed as sand, silt, clay, peat and gritty

(ii) Food availability - affected by tides and season

(iii) Current velocities

(iv) Salinity

(v) Temperature

(vi) Oxygen

(vii) Turbidity

It would appear that items (i), (ii), (iii) and (vii) are of major importance to the growth of the mussel.

The close cooperation of the Institute with the industry has lead to the transition of the industry from traditional fishing and processing methods, to high volume production techniques closely monitored by the Institute as well as the Industrial Board for Fisheries (Mussel Office).

All mussels are 'purified' by re-laying in clean seawater on what are known as 're-watering plots'.

The processing of mussels falls into two categories.

a) **For live sale**
Here the mussels are de-gritted, washed, sorted, de-byssed and then packed into bags 1 Kg - 50 Kg.

b) **For cooking**
Again the mussels are de-gritted, sorted, de-byssed and then shucked (cooked to release the meat from the shell). The meats are frozen, canned or marinated, though some are sold chilled for immediate consumption.

Sales of mussels are mainly to France and Belgium with the remainder going to Germany, Denmark, UK or the home (Dutch) market.

5.2 Mussel Farming in Holland

5.2.1 Re-laying

The farming of mussels involves the re-laying of seed mussels using bottom culture. Forms of rope culture are not practised in Holland (they leave that to the French and the Spaniards).

Seed mussels taken from inter tidal beds are often preferred as their black shells are thicker than the brown sub-littoral or yellow deep water seed. This gives them a greater protection from predators. (Shore crabs, starfish and sea birds).

The average yield is 2.5:1 (mature mussels:seed) though, theoretically, this can be improved.

An example would be to lay 2.25 kg seed (length 25mm, weight. 1.5g, i.e. 1500 mussels) per square metre which could, after 2 years become 45 kg if there were no mortality, a yield of 20:1!

Such a yield would be ideal but is obviously unatainable, however, Dutch research over the years has identified a number of factors which are important to the growth of the mussel.

5.2.2 Depth of Transplanting

The mussel, being a filter feeder will feed for a shorter period each day, the higher the mussel is up the shore. This affects growth, those exposed at low water will grow less quickly than deep water mussels. The other major difference here is that the shells of inter tidal mussels are thicker than sub-littoral mussels. This can affect the quality of the mussel in two ways.

Firstly, during the dredging and subsequent handling operations, the thicker shelled mussels can withstand more handling than the deep water mussels. Hair line fractures or worse are known to reduce the life of the mussel (Dare 1975).

Secondly, the mussels which are taken from inter tidal areas can withstand the rigours of being handled and transported better than others. (No recorded data has been found to date).

5.2.3 Seston Concentrations

The percentage of organic food particles in the seston (suspended particles) rapidly decreases as the number of inorganic silt particles increases, resulting in less efficient digestion with subsequent loss in meat condition.

Such a situation may occur during periods of storms.

Increase in meat weight is related to the assimilation rate of organic matter together with oxygen consumption. It has been found that low concentrations of moving particles stimulate the filtration rate more than the same concentrations in stagnant water.

Where seston concentrations increase, so the production of pseudo faeces increases up to a point at which the shells close due to irritation at the mantle edge.

The rate of filtration and its stimulation by seston concentrations is apparently dependant upon mussel size. Young mussels produce pseudo faeces faster than adult mussels in a given low seston concentration. It is considered that this would agree with the practice of placing seed in areas where low current speeds are evident and moving them when half-grown to areas of higher current speeds.

The Dutch scientists are quite certain in their opinion that the current velocities and seston concentrations are of major importance in the growth rate and quality of the mussel meat.

It must be said that some of the mussel farmers argue that deeper waters are less susceptible to storm damage and re-lay seed mussels in deep water. Growth in such situations can be rapid and the quality very good.

5.2.4 Current Velocity

The maximum current velocity of the ebb and flood tides should not exceed 1.5 knots. This avoids problems of silting up resulting in suffocation.

5.2.5 Nature of Sea Bed

"Stable, smooth and gentle substrates are preferred" by the Dutch farmers, especially where the flood tide scours the plot to bring fresh organic matter and remove waste products. The best parts of plots are considered to be on the lower slopes of channels.

In the Wadden Sea (Figure 4 overleaf), many plots are situated across secondary channels reaching up on the tidal flats, but only the deeper parts are used. In such channels a food supply gradient is possible increasing in upstream direction during the flood tide. "Nobody likes a plot situated at the end of such a channel unless there is an overflow from another inlet, in which case the middle part (of the channel) may be less optimal".

Where a channel ends in a blind flat, a steep increase in the ammoniacle by-products concentration has been observed - coming from mussels on plots lower down the channel. This results in stunted growth and a low cultivation rate.

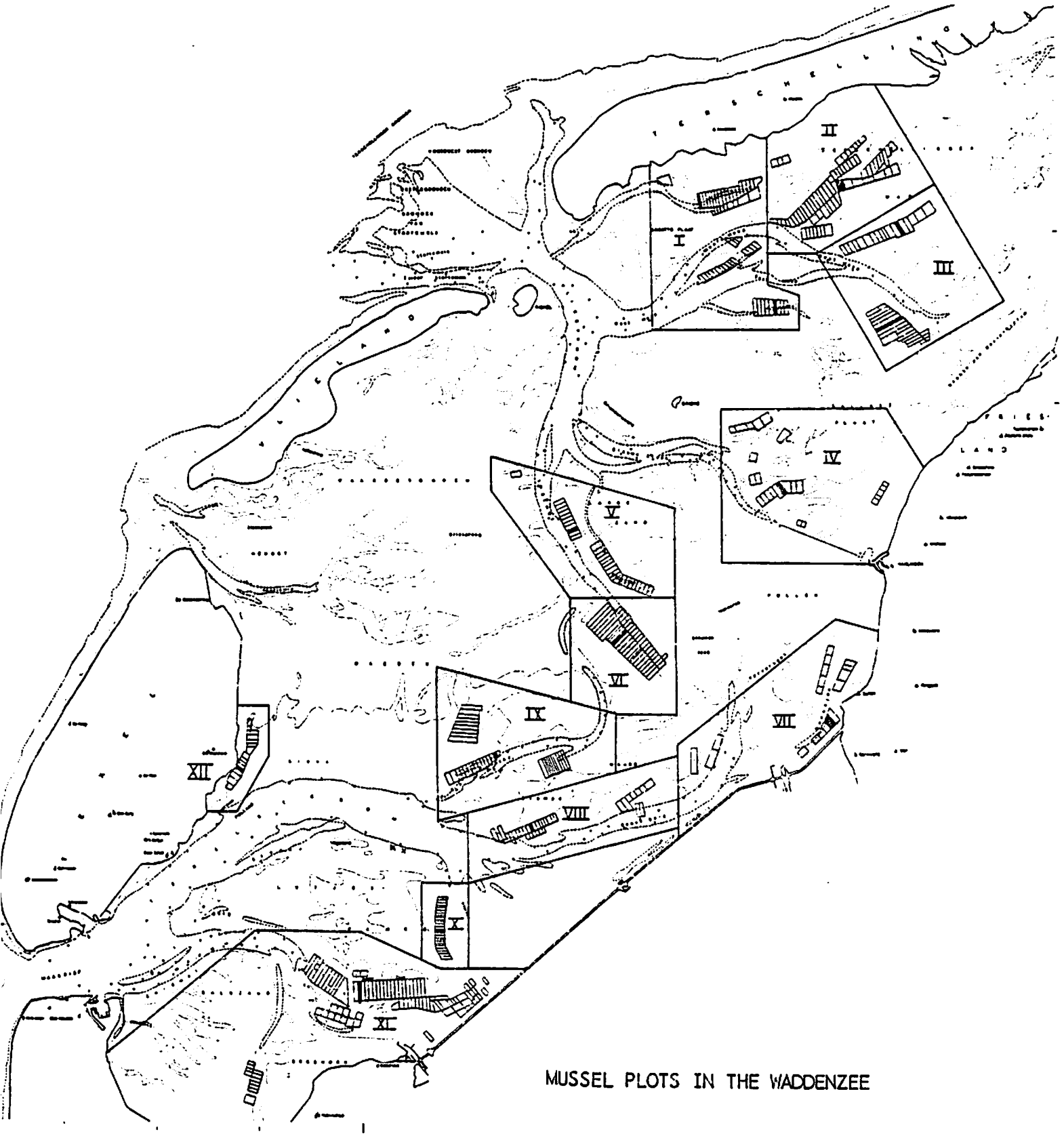
Before re-laying it is necessary to clean up the plots before the next growing cycle. This removes left over mussels (c.f. Wash fishery where this is not the case) and the use of old bagless dredges and chain harrows produces a smooth bottom which is desirable for re-laying.

Mussel silt has been found to stabilise a loose sandy bottom.

The situation of a plot obviously (from conversations) affects the quality of the mussel being marketed.

To allow for this, mussel farmers are allocated plots in a number of different areas.

FIGURE 4



MUSSEL PLOTS IN THE WADDENZEE

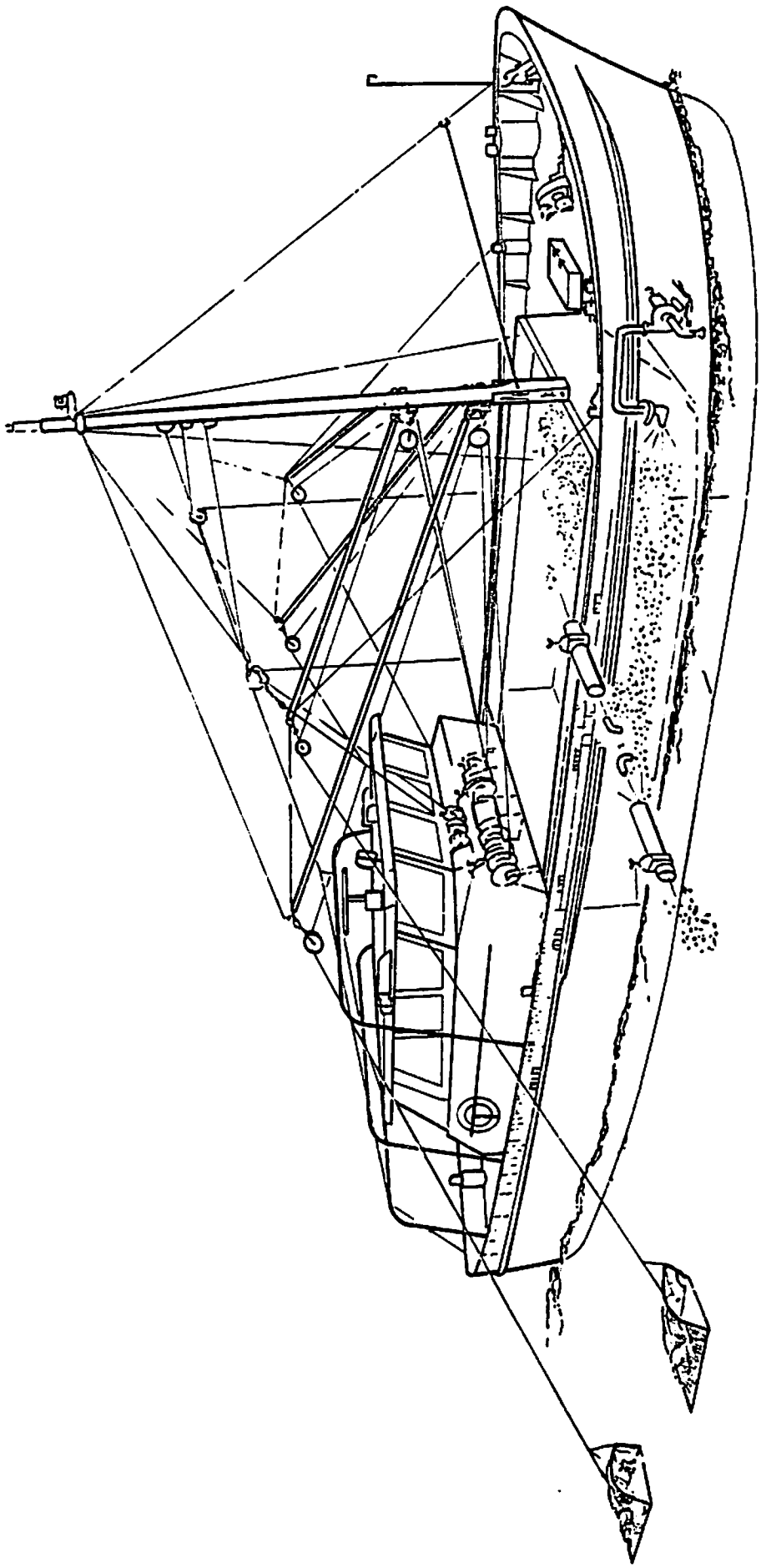
In the Wadden Sea the Crown Lands have leased 6,000 hectares (15,000 acres) to mussel farmers of which about 50% is regarded as good ground. The Oosterscheldt in the south has about 1,500 hectares of good ground. The farmers may be allocated about half a dozen plots of 15-20 acres. It is worth noting that all the beds in the Wadden Sea are sub-littoral. The natural beds on higher ground are opened up for dredging (controlled) of seed mussels for relaying in May and October onto the growing plots.

5.2.6 Mussel Dredgers

Whilst the original dredgers were converted sailing ships and later converted barges, the modern mussel dredger is a purpose built vessel capable of fishing with four dredges simultaneously allowing it to fish around 20 tons per hour (see Figure 5 overleaf). The holds have a capacity of up to 120 tons.

When the dredge is lifted from the sea bed, it is dipped in and out of the water two or three times to remove a good deal of mud from between the mussels. This washing is known to affect the physiological condition of the mussel (cf washing on board in Wash).

The dredging operation results in clouds of silt being stirred up and it is considered that several grammes of very fine silt enter the mussel shell cavities, during this time. This produces a mussel which is unacceptable to the consumer as far as direct sale for consumption or shucking for subsequent canning/bottling operations are concerned.



A Dutch mussel vessel, loading capacity 120 tons, and equiped with four dredges, each 1·9 m across.

Fig. 5

The holds of the mussel dredgers are three to four metres deep and some are capable of being filled with sea water which is re-circulated through the bed of mussel cargo by means of a perforated base to the hold leading to a pump and subsequently feeding sparge pipes along either side of the hold above the surface. (This positioning of the sparge pipes obviously helps oxygenation of the re-cycled water).

Other boats are equipped with purpose built skips into which the mussels are deposited. These can be removed from the vessel when full and replaced with fresh empty skips when the vessel brings a load ashore to the processor. Such systems using skips are ideal as handling is greatly reduced, the skips being off loaded by means of a crane.

5.3 Purification and Cleaning

Purification as we understand it is only necessary for mussels from the Wadden Sea. This is achieved by the process known as re-watering, that is re-laying in the re-watering plots off Yerseke. Here the sea water is sampled on a regular weekly basis by RIVO and sent to T.N.O. (Ijmuiden) for analysis for coliform organisms.

Using E.E.C. directives as a basis, water used for storage of shellfish must meet the requirement of less than 300 faecal coli/litre. A maximum of 4 faecal coli/g are allowed in the meats. The shellfish should also be free of any toxins and plankton. Heavy metal pollution is insignificant.

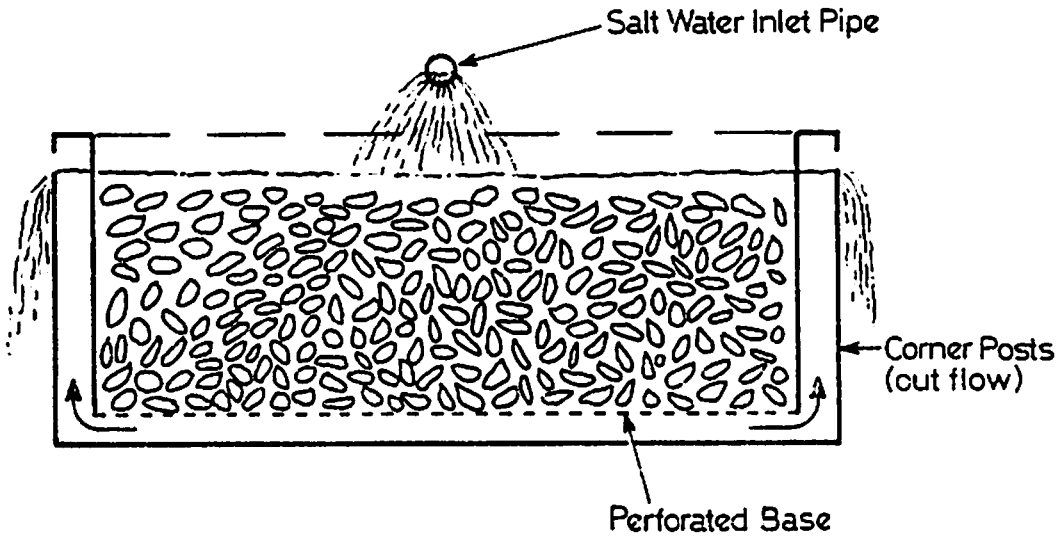
The re-watering plots also serve to allow the mussel to re-gain shell water lost during its 18-24 hour journey from North Holland.

The re-watering plots also remove the silt acquired in the original dredging operation, the reason being that the lays are on a hard bottom. It does seem likely however that mussels re-layed in densities ranging from 10 - 25 kilos per square metre will themselves produce silt which is in turn dredged into "clouds of fine grit".

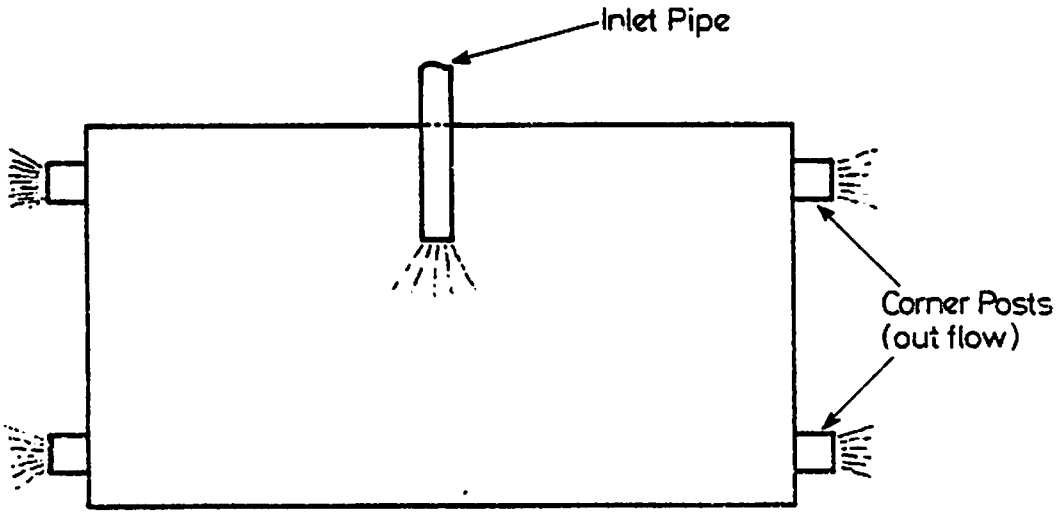
To some extent, this suspicion is confirmed in that the mussels from the re-watering plots are de-gritted once ashore. The mussels are de-gritted in large skips specially designed to allow water to pass from the top of the container through the bed of mussels, through a grid in the base into a false bottom the outlet from which is provided via passage up the corner posts and out just below the top of these hollow supports (see Figure 6 overleaf).

The depth of mussels in these tanks is between 1 and 1.5 metres. When questioned regarding the validity of this system the Dutch are positive that the mussels at the bottom of the skips are opening, filtering and removing sand. The volume of sea water being pumped through the mussels is considerable.

It would seem plausible to suggest that the water produced a certain amount of bouyancy and the velocity over the shells stimulated their opening and filtering.



SIDE ELEVATION



PLAN

Schematic Diagram of De-gritting Skips Used by the Dutch Industry Fig.6

Certainly the passage of water over the mussels is much greater than any purification system that I have seen in the United Kingdom.

If the mussels are filtering, then it would seem plausible to suggest a purification system based on this principle is worth experimenting with.

The major difference between this system and the U.K. system is that in the Dutch system the water must pass through the bed of shellfish. With U.K. systems it is all too easy for the water to meander over or under the shellfish mass (similar to smoke in a traditional smoking kiln).

It should be noted that 10 days is the minimum time allowed on the re-watering plots.

These plots also act as a working stock-in-hand for the processors as they can be fished in all but the most severe weather.

5.4 Pollution Control

In order to meet the purity standards regarding coliform organisms, the fishermen and processors have gone to great length to protect the mussels from the droppings of sea birds. e.g.

(i) wire hoops or bollards on the quay to prevent birds landing on them

(ii) Roofs over hoppers

or even

(iii) a complete building to cover skips containing mussels which are being de-gritted.

It is the pollution by the sea gulls which is blamed for increasing coliform counts. If this is so, then it must be happening during the de-gritting process as it would seem unlikely to effect the situation on the sea bed. Such a hypothesis would indicate filtering by the mussels during de-gritting but how far down the bed? This is certainly an area of interest for possible research work.

One of the mussel dredgers was equipped to de-grit in the hold and also cook on board. This vessel was, at the time of the visit, providing live, de-gritted mussels to one of the mussel processors.

5.5 Mussel Processing

This covers both shucking to provide fresh, canned, bottled and/or frozen meats, or, sorting and bagging for the fresh trade.

5.5.1 Shucking Operations

This is best described by observation made on a visit.

Visit to Roem Van Yerseke b.v.

This is a family firm processing 100 tons mussels per day.

The mussels are brought to the plant, which is about 600m from the sea, by truck in skips which are tipped for unloading onto a system of elevators. These lead to a washing operation after which the mussels pass to a bank of three de-byssing machines. From here they are fed automatically to a horizontal cylinder cooker. This cooker was fed from the top at one end, the mussels falling onto an internal conveyor which, after the cook, discharged the cooked mussels from a simple hatch at the other end of the cooker.

Cooking was in live steam at 3 bar for a period of about 30 seconds. The total cycle was about one minute.

The mussels were subsequently conveyed to a riddle where meats, broken shell and barnacles were separated from whole shell which exited from the factory via a picking belt where meats adhering to the shell were recovered.

The meats from the riddle were conveyed to a brine floatation tank which separated the meats from shell and barnacles. The meats were then washed and packed. Packing on the day of the visit was into either:

(i) Polystyrene boxes (3kg) or (5kg)
or (ii) Glass bottles and covered with vinegar

The fresh meats were to be transported and sold under chilled conditions. No evidence of chilling was seen apart from chill stores but with the outside temperature as low as +1^{o}C (max), the final rinse water in the process probably brought the temperature down to 5^{o}C.

The bottling line had an automatic filler (simple overflow and re-cycle) followed by a vinegar flood filler leading to a capper. The jars were then conveyed to a continous pasteuriser operating with a holding time of 30 minutes at 80^{o}C.

Other packs were produced for sale including:

"Pasterurised mussels in vinegar or with various sorts of vegetables and herbs" (jars)
"Cooked mussels in vinegar" (med density polythene tray heat sealed with clear film) (100g)
"Cooked mussels in vinegar with lemon" (clear polypropylene(?) base with polythene clip-on lid)(130g)
"Cooked mussels in vinegar" (polythene tubs 3 litres -25 litres)
"Sterilised mussels in brine" (256g cans)

"Fresh kitchen ready live mussels" (2kg polythene bag)
I.Q.F. mussel meats (0.5kg, 1kg, 5kg polythene bags)
(Freezing by liquid nitrogen, followed by glazing by water spray).

It is worth noting that though approximately 600m from the sea, this factory was using re-cycled, filtered sea water for de-gritting operations. It was understood that the water was tanked in to the plant. Presumably some form of chlorination must be used for keeping this re-cycled water 'clean'?

This company has made a considerable investment in equipment and cold storage facilities and though some working practices left much to be desired in terms of personal hygiene (lack of overalls, head covering and smoking allowed), the general area was clean and spacious.

No formal quality control was carried out. Samples were sent to T.N.O. for testing once a week. This apparently took the form of microbiological checks only.

5.5.2 Processing for Live Sale

There is a purpose built quay for offloading the skips from the dredgers using large travelling cranes.

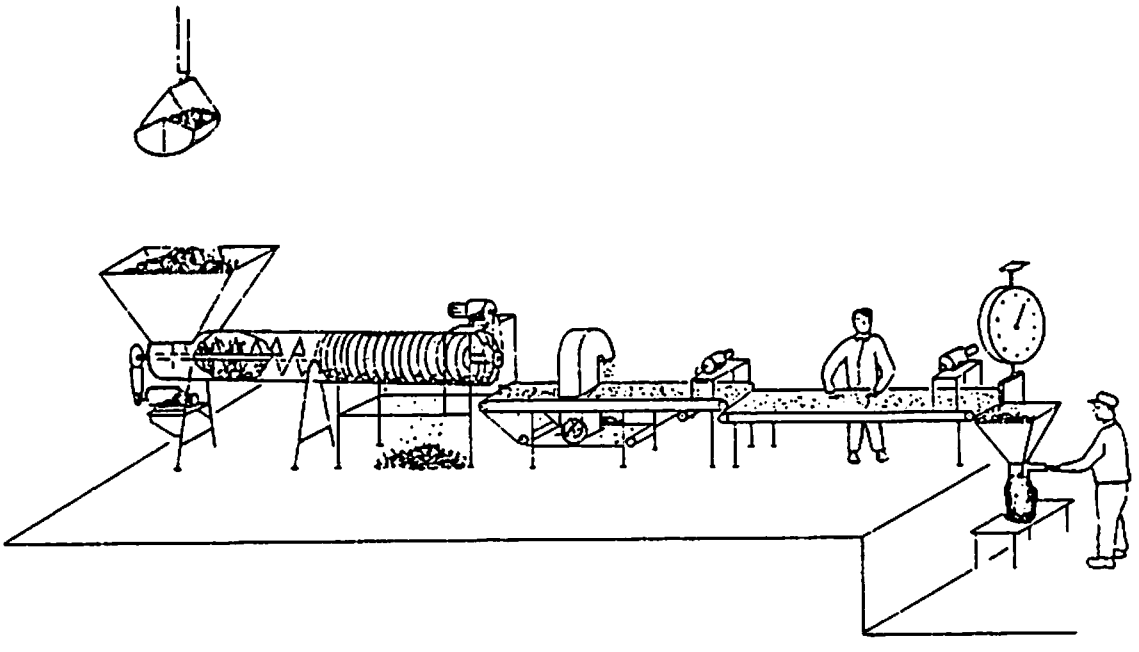
There are about ten companies with factories on this quay. Each company represented an amalgamation of a number of smaller companies which invested with the aid of F.E.O.G.A. grants to build new mussel plants with de-gritting and processing equipment.

The mussels are unloaded from the dredgers directly into the de-gritting skips. One very large building housed 30-40 of these skips for de-gritting as its sole function. Many factories had covers over their skips to avoid contamination by gull faeces.

After the de-gritting which may take as little as 12 hours in warm weather (when mussels are filtering well) or as long as 48 hours in cold weather (do they really open at those low temperatures?) the skips are placed on hydraulic tilts which allow the contents to fall through a hatch at one end onto a conveyor feeding a hopper or directly into the factory.

The mussels are de-clumped, washed/sorted in a trommel followed by a blower, to remove empty shells, de-byssed; graded in a second trommel (sometimes) and then inspected prior to bagging (as shown in Figure 7).

Figure 7 MUSSEL PROCESSING LINE



The largest (hessian) bags seen contained 50kg live mussels and sizes varied downwards 30, 25, 15, 10, 5 kg bags or nets to 2 and 1 kg plastic (polythene) bags which were packed into larger nets.

The mussels after packing were loaded into the back of refrigerated (chill) containers for transport to the markets in Belgium, Northern France and also Germany, Holland and Denmark.

During warmer weather, the refrigerated containers are relied upon to cool the mussels to below $10^{o}C$ (required by Belgian Authorities). This is achieved by closing the container in the afternoon, running the refrigeration plant until leaving and continuing this cooling procedure during transportation during the night to the markets.

All these processors seemed very profitable concerns though any quality control which was carried out was by the operators themselves.

5.6 Yerseke Mussel Auction

All the mussels dredged for processing and marketing are sold through the mussel auction at Yerseke.

The 'hall' consists of three main rooms:

i) an office
ii) a tiled sample testing area
iii) the auction room.

The auction is carried out under the auspices of the 'Producktschap Vis en Visprodukten' an organisation consisting of the mussel growers and processors.

A committee of this organisation fixes a minimum price (for the season 1984/85 this price was Hfl 35/100 kilos) and any lot failing to reach this price is withdrawn and the grower paid the minimum price. The "P.V.V." buys such a lot and re-lays the mussels on its own lays. Such a lot will remain there until the end of the season when it may be sold at auction or, as has been the case with some lots over the past year, the mussels may be used for the "Mussel festival". This is a marketing promotion taking place in Yerseke on one day in August when cooked mussels are provided free to all visitors.

As already mentioned <u>all</u> mussels must be sold through the auction at Yerseke. They may originate from the Wadden Sea in the north of Holland (a journey of about 18 hours through the canals and inland waterways) or from the Oosterscheldt in the south.

On arrival by boat in the harbour in Yerseke the mussels are sampled by a crane with a grab. The crane is on a pontoon moored in the harbour.

The sample is analysed in the auction hall for the following:-

i) % rubbish (tare)

ii) Count per 2.5 kilos
There seemed no basis for this figure other than historic though a lesser weight would probably be un-representative)

iii) Shell length

This was by classing into size grades by numbers.

> 6cm, 6 to 5.5, 5.5 to 5, 5 to 4.5, 4.5 to 4, 4 to 3.5, < 3.5cm

These size ranges may change from year to year.

iv) Meat weight after cooking as % of total weight.

Here cooking was in a covered pan over a gas flame where the mussels were cooked just long enough to release the meats from the shell.

v) A measurement of shell thickness was done on some mussels.

The results of the above tests are tabulated on an auction sheet together with the grower's name and the source (e.g. Wadden Sea).

The sheets are distributed to the merchants (processors) who sit at benches to the front of the auction room, and also to the growers who sit at the back of the hall.

The front benches have computerised terminals enabling the buyer to 'log in' his identity and his bid.

A computer displays the lot number and tonnage on a display monitor at the front of the hall. Bids are then logged in by the processors and the computer after analysing the highest bid displays the buyers identification number and the price paid.

Where for example, one brother is a grower and a second brother is a processor and wants the mussels fished by the former, i.e. a family business, then the word is passed around the auction and the lot bought at the minimum price.

After auctioning, the mussels are re-laid on mussel re-watering plots at Yerseke. "Mussels processed without a period on the re-watering lays give a poor yield on processing due to loss of shell water".

A second reason is obviously to allow buffer stock to be available for the processors. Even while no mussels are being fished from the Wadden Sea, the mussel dredgers still work the re-watering lays to provide mussels for the processors.

A third objective, and possibly just as important as the first objective, is to ensure that the mussels have been taken from an area of clean seawater for processing. The sea water is sampled by the scientists at RIVO, Yerseke, and sent for analysis (for coliforms) to T.N.O. at Ijmuiden.

The purity of the sea water is the basis on which health certificates are issued for export of live mussels to Belgium, France and Germany. It would appear that it is the recipient countries that sample the mussels for polution levels.

5.7 General Observation

The Dutch mussel processors are very professional in their approach. Highly organised, they operate in an obviously competitive market with amazing efficiency compared to the U.K. mussel industry.

Undoubtedly the main reason for this is the power behind the Mussel Office of the Industrial Board of Fisheries.

This is a grower/processor organisation which works by close co-operation between the two parties and its links with the Government research establishments, (RIVO).

Though, as stated previously, quality control as understood in food processing factories is not apparent in Holland, the quality is controlled. However the quality is determined mainly by where and therefore how, the mussel is grown.

So we have the old adage "if you want a top quality product you must have top quality raw material".

The handling ashore is very efficient and it is undoubtedly this efficiency which, by reducing time out of water or out of chill facilities after the water is drained from the mussel, that results in a good product to the consumer.

The New Zealand Code of Practice points out that "once the beard is removed, the mussel will die". The Dutch are selling all their live mussels this way! No problems seem to result from this. Is this because the time scales are so much shorter? For example are the mussels sold and consumed within 48 or 72 hours of removal from water? Are there such large quantities sold that daily deliveries are the norm rather than twice weekly as we have in this country?

One trader in the U.K. when interviewed, stated that he keeps mussels for up to five days. (After two days his mussels on display showed clear signs of mortality!)

The Dutch appear to have quality problems only from plankton blooms in the North Sea which may close the fishery, or from pollution in the Wadden Sea which necessitates re-laying in the re-watering beds. Their efficiency of handling ashore with the incorporation of temperature control assures the best quality produce reaching the consumer.

6 THE NEW ZEALAND MUSSEL INDUSTRY CODE OF PRACTICE

6.1 Introduction

The New Zealand Fishing Industry Board have prepared 'A Code of Practice for Mussel Processing". However, the New Zealand green lipped mussel is a somewhat different and far larger animal than the European native mussel. The code concerns:

I Handling and storage of live mussels

II Handling, processing and storage of cooked mussels and mussel products.

Much emphasis is placed on handling of live mussels as a major market in the export market, where air freight is used.

The document is well written using simple grammar which makes it readable and easy to understand.

6.2 Harvesting

As with the Dutch Industry, control is exercised over the growing areas from a microbiological viewpoint.

Comment is made on the greater problems of handling farmed mussels because of their thinner shells due to faster growing rates.

Grading 'on board' is recommended to reduce handling at a later stage. This is only applicable if the mussels are growing in microbiologically clean sea water where purification is not required before sale.

Whereas the Dutch remove the byssus or beard of the mussel completely prior to live sale, the New Zealand Code of Practice urges caution: "If the beard is pulled out the mussel will die". The difference between the two industries may be the variety of mussel, or, the time involved in transport to market. (New Zealand green lipped mussels are exported to the West Coast of the U.S.A.).

The mussels should be chilled as soon as possible, however, the holding temperature and method of chilling appear to be important with regard to both shelf life and flavour changes in the meat (see Figure 1).

Holding in ice, or under ambient conditions of 15-18^{o}C both result in a shelf life of less than 2 days with a similar loss of flavour.

Holding in a high humidity chiller at 5-7^{o}C extends the shelf life by a further two days.

However, covering the mussels with a piece of perforated material e.g. sacking and covering this with a good layer of ice has extended the shelf life to 12 days with little loss of flavour.

Reducing the temperature to 0^{o}C is to be avoided as this kills the mussels.

6.3 Transport and Storage

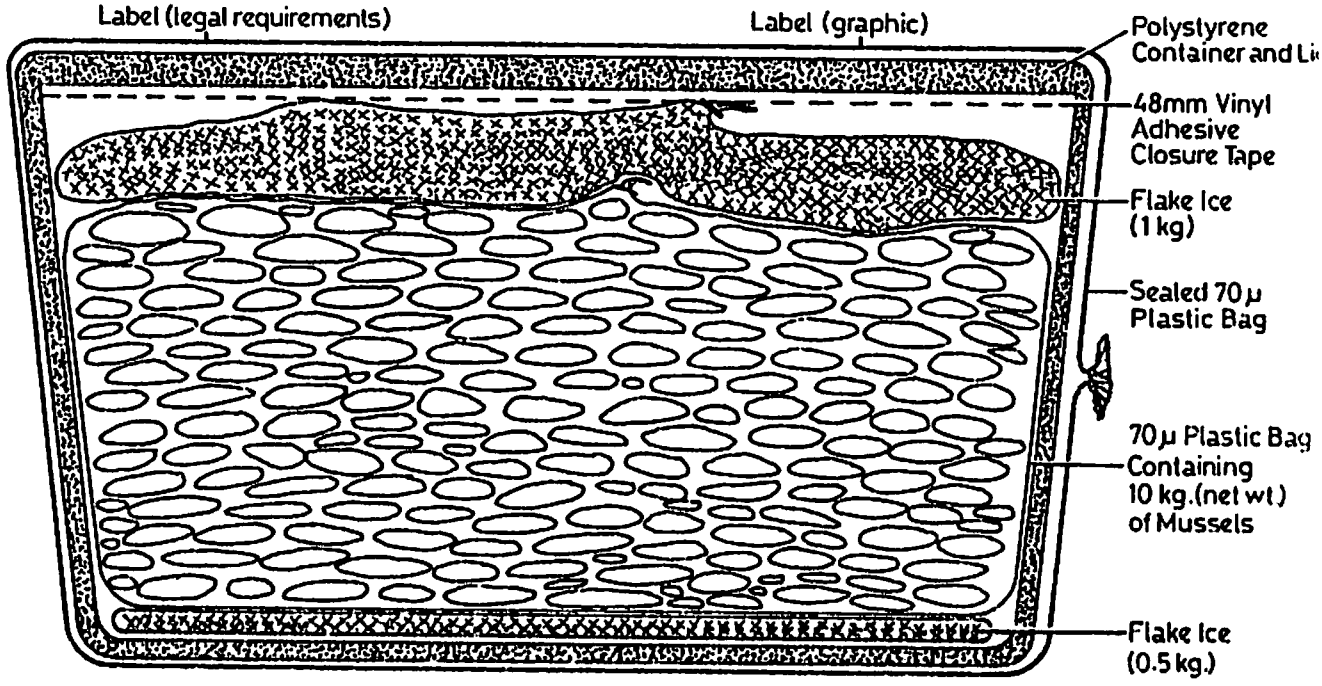
Emphasis is placed on moving the mussels as quickly as possible minimising exposure to sunlight, rain and wind.

Maintenance of chilled conditions is also emphasised.

If, however, the mussels are to be processed, then premium quality produce will result from mussels which have been processed as soon as possible after harvesting.

A recommended packaging system for air freighting is shown in Figure 8.

Fig. 8 A SUGGESTED ARRANGEMENT FOR A POLYSTYRENE BOX OF LIVE CHILLED MUSSELS



6.4 Recommendations for Control Procedure

The Code of Practice notes items for planning and control of mussel handling as follows:

1. Harvest only mussels in peak condition

2. Harvest only from approved growing areas

3. Chill rapidly after harvesting

4. Grade mussels (size)

5. Organoleptic evaluation

6. Inspect packaging material

7. Keep inventory control on mussels to be packed

8. Check mussel temperature

9. Grade to specifications (market)

10. Check weights

11. Label correctly

12. Check storage conditions

13. Carry out regular checks to ensure no breaks in the distribution system

14. Obtain feedback from end user to ensure product is being handled and stored correctly.

The last point is important in ensuring that the quality demonstrated by the consumer is being met by the suppliers.

(See also Appendix II Tasmania Mussel Storage Tests).

7 DISCUSSION

7.1 Organisation

It is probable that the mussel cultivation in the U.K. could be increased to a level where the whole of the U.K. market for live mussels and preserved meats could be satisfied.

However such an ideal is unlikely to become fact unless some organisation is applied to the industry as a whole.

There are few mussel fishermen who rely solely on mussels for a living and there is no co-ordinated long term plan for the fishery. Those fishermen that do try to plan beyond the present, find that they must do so alone and without much assistance from controlling agencies or the financial side.

It is useful to contrast the approach of the Dutch industry with that of the U.K. The Dutch industry is a highly professional capital intensive operation whilst in the U.K. it is little more than a cottage industry.

Such a comparison is useful in as much as it shows how organisation can bring success. The Dutch Industry began its re-organisation thirty years ago under the guidance of government agencies notably the Department of Coastal Fisheries. Today it is the world's largest producer of bottom cultivated mussels and has a team of scientists whose knowledge of mussels is aclaimed worldwide.

To re-organise the U.K. mussel industry to a similar level of sophistication and success is not impossible, but it requires a unity of purpose which, at present is sadly lacking.

7.2 Growing

It would appear that the correct management of the mussel lays is the key to developing the industry.

Sources of good quality seed mussels must be located and assistance given in re-laying in identified areas where growth potential is good.

It is necessary to persuade the fishermen to become 'growers' and of course once this is achieved there must be adequate policing of the mussel lays and stocks.

For this to be effective it will be necessary for the British Industry to work to a set of guidelines for mussel production.

7.3 Purification

Because many of the best mussel cultivation sites are in polluted areas, purification is necessary. Figure 9 overleaf shows how this has affected the value of mussels fished by Kings Lynn fishermen compared with those landed and subsequently purified by the Boston fishermen.

The present method of purification requires large areas of land and high capital investment for the purification tanks. If the Dutch de-gritting process can also purify the mussels, then it seems likely that costs would be reduced.

It should be noted however that whilst purification can sort out bacterial problems, there is still a question over the viral contamination in mussels.

7.4 Quality

The ultimate aim is a good quality mussel. There is no accepted definition of what a good quality mussel should be. Nor is there a great deal of accepted research knowledge on the characteristics of mussels in terms of acceptable spoilage levels. Such knowledge will be essential in preparing a set of guidelines for the handling of mussels.

At this point in time, the three major problems in the U.K. would appear to be:

1) Insufficient good quality raw material

2) Damage due to mechanical sorting

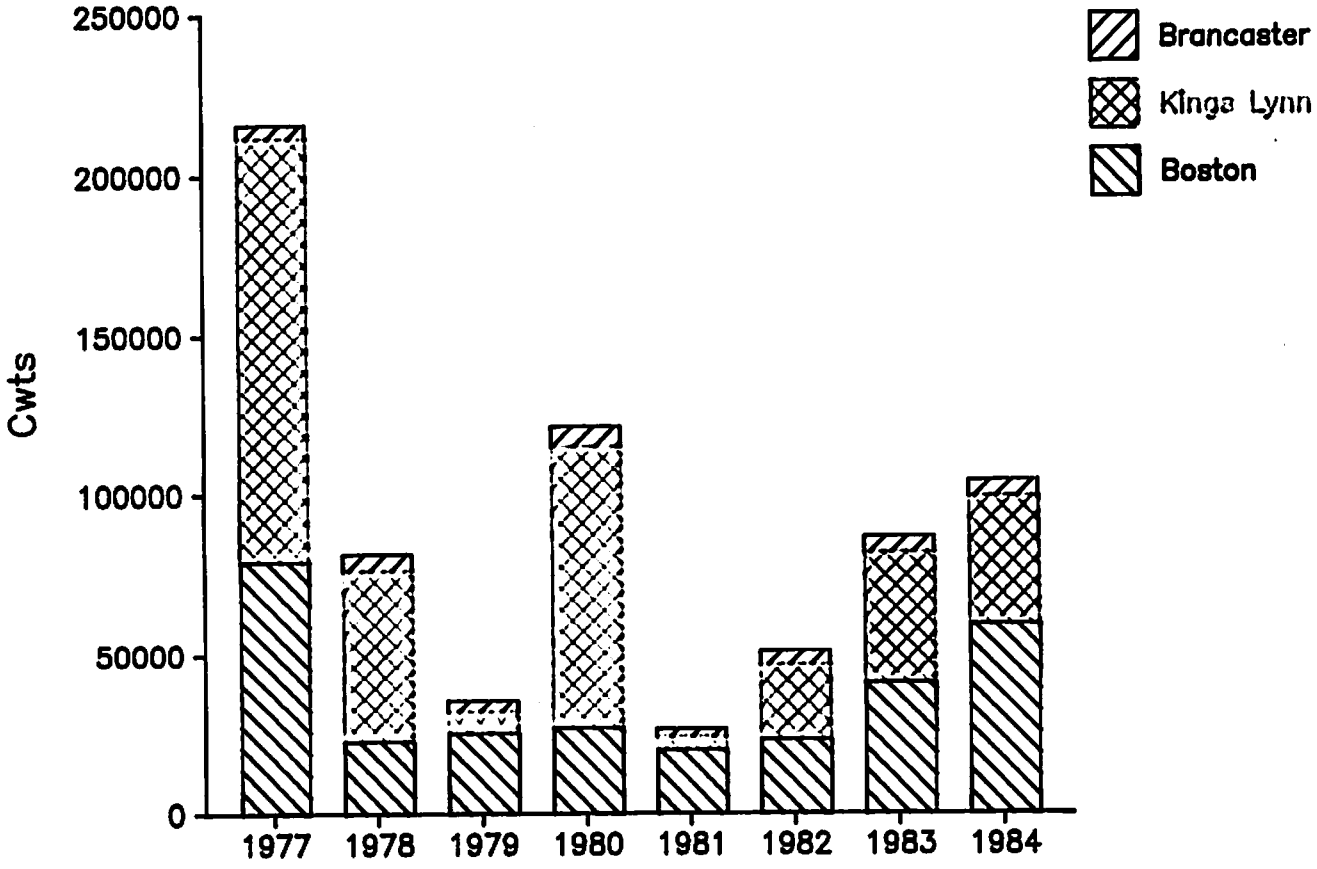
3) Poor climate control in distribution.

Improved organisation should lead to better quality raw material and research into physical handling of mussels during harvesting and processing should produce a better quality product for the retailer.

We must also consider the problem of reduced shelf life of mussels packed in polythene bags. The Dutch have developed a market for mussels in polythene bags which is obviously viable and two companies in the U.K. are selling in this manner. However, the complaints on shelf life reduction are real and must be considered as a problem to be overcome.

If we are to achieve the desired situation where the U.K. can supply its mussel requirements, we must get the supply situation sorted out first. Spatfall is not guaranteed each year, and allowance for this is essential requiring the assistance of M.A.F.F., S.F.I.A., and Sea Fisheries Committees in stock assessment and control. The marketing of the mussel follows the establishment of adequate supply of a quality product.

E.S.F.J.C. Mussel Landings



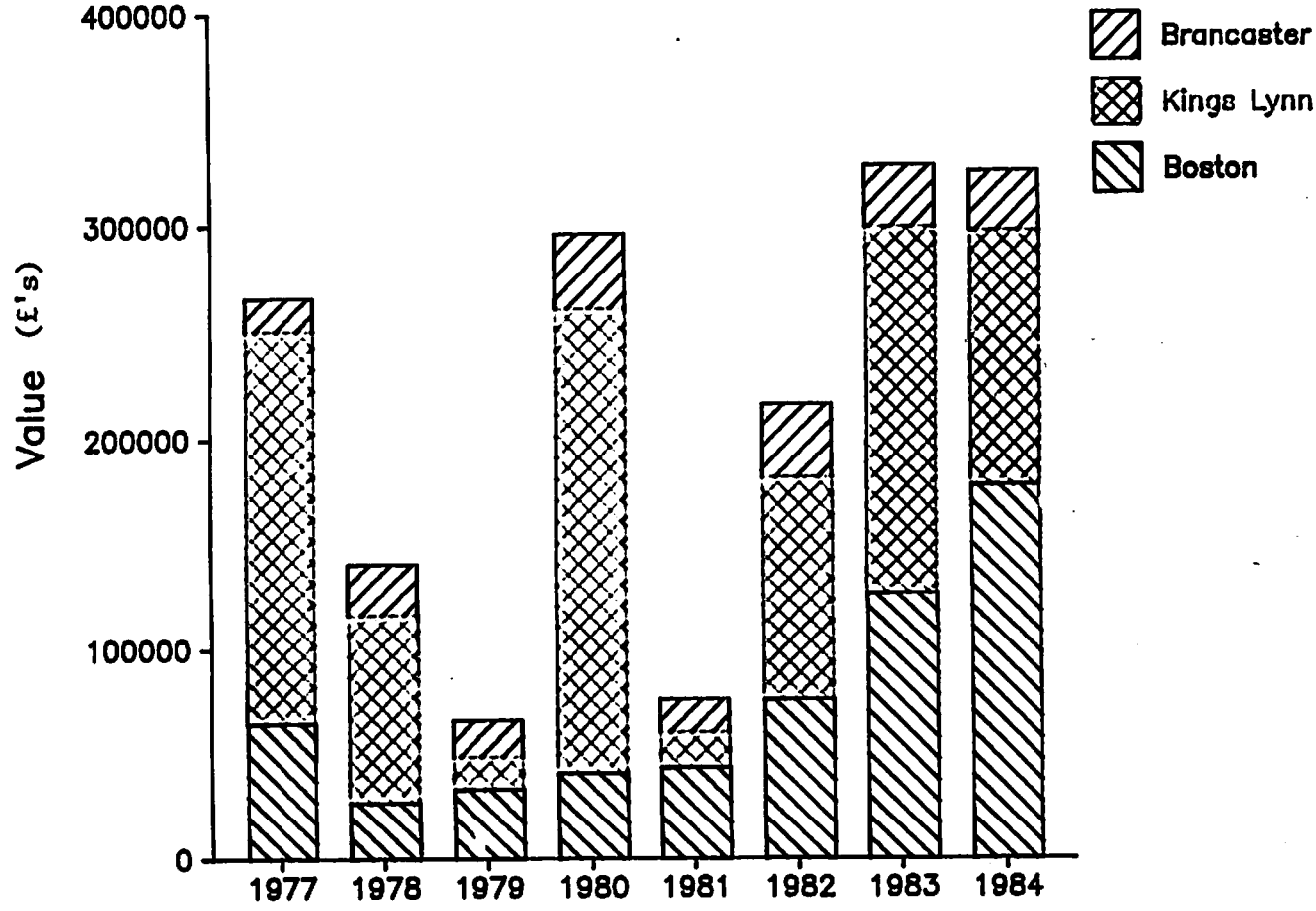


Fig 9

8 RECOMMENDATIONS FOR FURTHER WORK

8.1 Organisation

8.1.1 To investigate the feasibility of establishing a Mussel Industry Controlling Body, to co-ordinate the major mussel fisheries within the U.K.

8.1.2 To identify areas of sea bed which will be suitable for use as re-laying areas for bottom culture mussels.

8.1.3 To provide security of tenure for areas of re-laid mussels.

8.1.4 To identify sources of seed mussels to stock the lays identified in 8.1.2. above.

8.1.5 To design a label identifying the origin of mussels offered for sale together with a date of purification or certificate of purity. This should be made part of a voluntary guideline.

A certificate of purity may be necessary for mussels fished from 'clean' sea water, e.g. Brancaster or Hebrides, where purification after fishing is not required.

Such a 'certificate' may take the form of a seal of approval. It is unlikely that the issue of such approval will be readily granted by Local Environmental Health Offices as such offices are reluctant to make definitive statements. Such a seal will almost certainly need to be issued by M.A.F.F. or S.F.I.A.

8.1.6 To prepare a quality specification sheet similar to that used by the Dutch Industry which may be used as a reference for the U.K. industry.

8.2 **Equipment/Practices**

8.2.1 To design equipment for washing, sorting and grading which will be inexpensive and gentle in its handling of the mussels.

If deep water lays (sub littoral) are used, it may be necessary to consider different handling techniques because of the resultant reduced shell thickness.

8.2.2 To investigate the efficiency of the de-barnacling machine developed at Boston, noting any effect on shelf life of the resultant 'cleaned' mussels.

8.2.3 Should de-barnacling be effected soon after harvesting or after purification? How does this affect the shelf life?

8.2.4. To assess the validity of returning undersize mussels to the lays.

8.3 Shelf Life of the Mussel

8.3.1 To investigate the shelf life of live mussels by means of a series of storage tests incorporating flavour acceptabilty, mortality, microbiology and weight loss, resulting in a recommendation for the wholesale retail chain.

Such work could usefully be based on the work undertaken by Boyd and Wilson (1978) on New Zealand green lipped mussels.

8.3.2 The effect of storing live mussels in extremes of temperatures should be assessed. Such a series of investigations could appraise the use of water sprays on sacks of mussels to reduce the possibility of freezing during frosty weather.

8.3.3 To investigate and identify the reasons for reduced shelf life of live mussels in polythene bags. These experiments should compare polythene bags with bulk 25 Kg sacks. The use of net outers should be checked.

8.3.4 To compare the practices of washing/grading prior to and post purification with respect to shelf life.

8.4 **Purification**

8.4.1 To consider a new design of purification system based on the de-gritting tanks as used by the Dutch Industry. Such experimentation should include measurement of flow rate at various points in the tank and the change in microbial load during the process.

Consideration should be given to varying sizes of tank or possibility of partitions to allow for purification of smaller catches.

8.4.2 Concern must be expressed about the monitoring of purification plants. "Shellfish from certain plants have been implicated in viral and gastro-enteritis problems. Invariably this is attributable to plant mismanagement...." (P. West, M.A.F.F, Journal of Royal Soc. Health...1.1985). Whilst M.A.F.F. are actively involved in recommending layout and operation of purification plants throughout the U.K., the monitoring of such plants is carried out by the Local Environmental Health Office. It is likely that such an authority has only one purification plant under its jurisdiction and as such cannot be expected to be expert in this field. Where the plant is run by someone with little knowledge of microbiology and the LEHO is operating to "maximum permitted levels of E.coli" only, then trends are possibly missed.

It is only by invitation that the M.A.F.F. microbiologist may inspect an operational plant. The wisdom of such a situation should be most seriously questioned where prevention of food poisoning outbreaks is the object of the purification process.

Whereas before formal approval for operation of a purification plant is issued by DHSS, the provision of detailed technical approval by M.A.F.F. on disolved oxygen profiles, salinity, and flow rate together with bacteriological assessment is required. After approval M.A.F.F. suggests bacteriological sampling at least every week, if possible, when uncleansed and cleansed samples from the same batch should be examined for counts of total coliform and E.coli.

It would seem reasonable to require inspection of tank logs which include salinity and water temperature, together with regular checks on flow rate (seasonal) and correct management of the plant. (The later would include checks on cleaning of UV tubes to remove debris buildup).

8.5 **Meat Extraction**

8.5.1 For poor quality mussels, some consideration may be given to processing to remove meats for incorporation in animal feeds.

8.5.2 Shucking is the eventual aim of some Boston and Kings Lynn companies. No one in Boston or Kings Lynn are shucking at present. Little is known of the effect of pressure, temperature and time on the shucking of mussel meats from old mussels. Machinery available on the British market capable of cooking, should be assessed.

Fig. 10 Dutch Mussel 5.5cm from re-watering plots

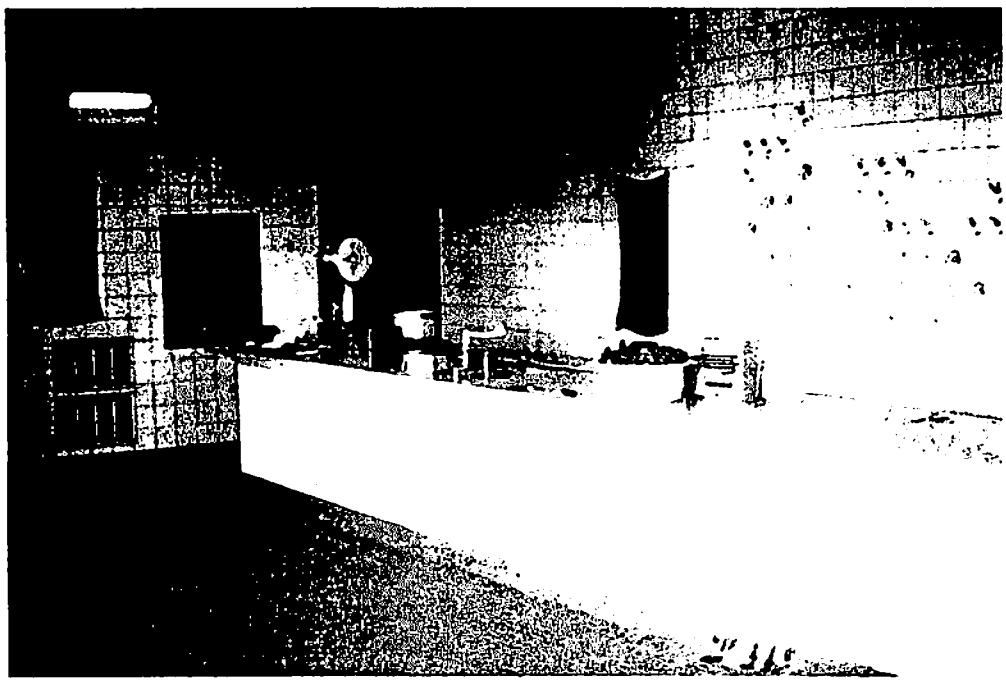


Fig. 11 Quality Testing Laboratory Yerseke

APPENDIX I

VISIT TO FRANKEN B.V. GOES

MR. CEES KOOLE (MANAGING DIRECTOR)

Franken B.V. is the best known of the mussel processing equipment firms in Holland. The company which proudly claims to have been founded in 1892 was originally a specialist in grain handling but developed into shellfish handling equipment with the growth of the Dutch mussel industry, based in the Scheld, close by.

The machinery offered by this company includes:

1. De-clumping/washing/grading machines
2. De-byssing machines
3. Continous cookers
4. Auto claves
5. De-shelling machines (vibrating screens)
6. Meat washers.

Franken's brochures on these machines are included at the end of this Appendix.

1. **De-clumper/washer/grader**

This is a combination machine the first stage of which (declumper) is used for separating the clumps of mussels into individuals. This is achieved by feeding the mussels into one end of a hollow drum inside which a central shaft fitted with (blunt) knives rotates. There are versions available where the drum is perforated and is partially surrounded by a water bath thus providing bouyancy during the de-clumping operation. This is

stated by the company to be "completely harmless to the shelf life of the product". The machine is certainly effective in separating clumps of mussels into individuals. There is however a considerable amount of impact during this operation. The de-clumper feeds into a trommel reel consisting of special wound metal rod of circa 5mm diameter. This has sparge pipes placed strategically to wash the mussels as they move along the trommel. Silt, mud, broken shell and small mussels are removed in this operation.

Movement along the drum and trommel is achieved by means of a slight inclination of the rig (circa 5-10^{o}).

Capacities range from 15m^{3}/hr to 6m^{3}/hr. Many of these machines were seen in use in Yerseke by the mussel processors.

De-byssing Machine

This is one of the better items in the Franken range. (Though guarding is not adequate for U.K. standards).

It consists basically of a series of contra-rotating knurled bars over which the mussels pass after being de-clumped and washed. The knurled bars grip the bysuss threads and pull them out of the mussel. Such machines are very efficient if the rate of feed ensures only a single layer of shells passing over the bed of rotating bars. Efficiency should be greater than 90%. Capacities range from 0.25m^{3}/hr to 3m^{3}/hr. A much smaller version is available recommended for 'follow up cleaning in the restaurant'.

Mono Bloc

The two above machines are available mounted on a frame work with the de-clumper/washer situated above the de-byssing machine feeding by gravity and conveyor.

This is of course ideal for a situation where space is at a premium.

It is worth pointing out at this stage that the above mentioned machinery is used extensively by the Dutch processors for pre-treatment of live mussels before bagging and transport. This is worth comparing with the New Zealand Code of Practice which specifically states:-

"(1.6) If the beard has to be trimmed, (depending on market specifications) then this should be carried out with extreme care. IF THE BEARD IS PULLED OUT THE MUSSEL WILL DIE".

The New Zealand Code of Practice does recommend holding under ice at 2-4^{o}C which will give a shelf life of up to 12 days. This compares with the expected shelf life of circa 2-3 days for the Dutch product, though it is believed this was because of the supply/demand situation rather than the life of the mussel.

Cookers

Although Franken call one of their cookers continuous, it is in fact a batch cooker which is fed by conveyor and has a discharge conveyor. The cooker is a top loading pressure drum fed from a hopper with a load cell. Cooking is by direct steam injection at pressures up to 4 bar. After cooking, the drum rotates about a central horizontal axis to unload.

Throughput is claimed up to 5000 kg/hr with a steam requirement of 750 kg/hr.

This cooker can be compared with a cooker seen in operation at a processing company 'Roem van Yerseke' which consisted of a horizontal cylindrical pressure vessel with an end outlet and at the oposite end a top inlet. The mussels fell through the inlet onto a conveyor inside the cooker. When the conveyor was full, the entry and exist ports were closed automatically and the mussels cooked by direct steam injection under pressure (3 bar). After cooking the internal conveyor commenced discharging prior to the feed port opening, thus avoiding possible mixing of raw and cooked shellfish. Total cycle time was in the order of 70 seconds.

De-sheller (1)

This consists simply of a vibrating screen which separates the meats from the shell. The meats fall through the stainless steel mesh onto a conveyor. (This is a marked improvement on the tray system which was used in the 1970s and caused damage to meats in some instances).

De-sheller 2 (Brine floatation)

This uses difference in specific gravity to separate meats from small pieces of shell and barnacles using saturated brine. This system is certainly effective if used properly. Difficulties are however encountered in:

a) Continual dilution of the brine by fluids from the meats

b) Necessity to re-charge completely twice a shift

c) Suspicion of build up of contamination though with such high salt concentrations bacterial problems should be minimal

and

d) Uptake of salt by the meats. (This problem may be reduced by subsequent washing).

De-sheller (3)

The latest method of speparation of small pieces of shell from meats is to use a sedimentation technique.

From de-sheller (1) the meats fall onto a conveyor travelling along a shallow trough in which water is being pumped in the opposite direction. The mussels are carried with the water stream whilst the shell particles sink and are caught in the ribs of the conveyor and removed in the opposite direction. Such a system is being used successfully in Denmark at Vjile mussels. An obvious problem with such a system is the usage of fresh water and there will be a temptation to re-cycle fresh water. If this is done then:

a) the water should be chlorinated
b) water should be completely changed regularly, probably every hour.

Meat Washers

This machine consists of an Archimedes screw enclosed in a perforated drum which is horizontally half submerged in a water bath.

Water enters through a sparge pipe which forms the central axis of the screw. Meats are conveyed gently along the drum bouyed up by the water.

This removes the brine which may be picked up from de-sheller (2).

With the introduction of the third de-sheller system it would seem likely that the demand for this unit will decrease.

Personal experience of using Franken equipment leads me to observe that whilst some of the equipment is very good and performs its function well, there are a few items which are difficult to clean easily. The design of ancilliary equipment such as elevators is based on the company's experience of grain handling. As such it is not ideal for use in the wet conditions encountered in shellfish processing. Such equipment would probably be better purchased from firms specialising in this area.

However, Franken do offer a 'complete package' designing the complete processing plant for interested companies.

APPENDIX II

TASMANIA MUSSEL STORAGE TESTS

A series of storage tests based on the New Zealand storage methods of packing live mussels into insulated (draining) containers, laying a perforated barrier over them and packing ice on top of the barrier, were undertaken.

Such a system was found to extend the storage life of Tasmanian blue mussels from four days under ambient conditions to eleven days 'under ice'.

Assessment used the following techniques:

1. Incidence of gaping - checking speed of the closing reflex which becomes slower until the point of death where the shells remain permanently open.

2. pH monitoring of adductor mussel and shell liquor. These proved unrelated to different storage systems used.

3. Test for gill function as used in the Tokyo fish market, (for oysters) using Triphanyle traxonium (TTC).

4. A taste panel to rate odour, flavour and overall acceptability.

   Cooking was by immersion for two minutes in boiling water.

5. Microbiological assessment by aerobic plate counts. (Presumptive Pseudomonas spp.).

Storage conditions were:

a) at ambeient temperatures (mussel temperature 17-18^{o}C).

b) under ice (mussel temperature 2.6 - 8.9^{o}C).

   The range of temperature reported here was dependant on the position in the box.

Results for gaping, the TTC test, taste panel and microbiological assessment were mainly in agreement and it was concluded that holding farmed Tasmanian blue mussels under a 'curtain of ice' will significantly extend shelf life.

Meltage of ice was considerable but this could be reduced by using chill rooms and insulated containers.