Shellfish Association of Great Britain

Advisory Note on Crustacea Storage and Transport

How the ecology and physiology of brown crab and lobster influence their response to capture and live transport.

September 2021

1. Preamble

Exporters of live crustacea to the EU, who have been experiencing transport hold-ups affecting the quality and longevity of their products, may be interested in this brief non-technical refresher on factors that influence how live brown crab and lobster respond to capture, storage, and live transport. We briefly summarise the relatively stable environment that crab and lobster normally occupy; some physiological tools and processes that govern their well-being; key factors that can affect their durability; and end by comparing the benefits of vivier and misting systems.

2. The Basics of Physiological Life on the Seabed

Crab and lobster are cold-blooded animals that are unable to regulate their internal body temperature independently of the environment. As a result, their body temperature rapidly follows whatever temperature changes take place around them, whether in or out of sea water. During the early stages of life, the larvae of crab and lobster drift and disperse at the surface, but after a few weeks they settle to the seabed where water temperature is generally several degrees cooler than at the surface, and to which they become habituated. In our temperate seas the seabed is usually a stable regime where the main changes are a gradual warming of a few degrees in spring, a gradual cooling in autumn, and a winter minimum round about March. Such changes happen slowly, so the physiological effect of sudden changes in temperature in the sea is usually absent or rare. Nor are individuals subject to handling until they reach the size where they are first retained by potting gear.

For metabolism and energy production, crabs and lobsters need the oxygen that is dissolved in seawater, which they therefore pump continuously through the gill chambers. Gills separate the seawater outside the animal from the blood circulating inside, but because the gill membrane is permeable to gases, oxygen can diffuse across the gills into the blood, and the products of respiration (carbon dioxide) and metabolism (toxic ammonia) diffuse out into sea-water. These two-way exchanges continue day and night, keeping crabs and lobsters alive and physiologically stable. In the sea, the large volume of water around the animal means that carbon dioxide and ammonia normally diffuse and disperse quickly, with minimal energy cost, and there is minimal build up in the water.

Gills are very efficient heat exchangers, so that crabs and lobsters will respond to any new temperature very rapidly, the warmer the water the more rapid the adjustment. Also, metabolic rate and oxygen consumption are directly related to the surrounding temperature and oxygen level in the water. The higher the temperature the more oxygen the animals need, the higher their metabolic rate, and the more ammonia they produce as waste, thus increasing the toxicity of their immediate environment, as described further in Section 4. Sudden water temperature changes of more than a degree or two should therefore be minimised wherever possible by managing the impact of the various different stages along the capture, storage and transport chain (for example by using chilled conditions when possible, and managing stocking density, as described later).

3. Key implications of Capture, Storage, and Transport

For the reasons just described, capture, storage and transport impose novel physical, environmental, and physiological changes with cumulative consequences for the condition, longevity and hence marketable value of crab and lobster at the end of the export trail. All parties should remain fully aware that these events require forethought and management to limit their cumulative effects, particularly if abnormal delays are foreseen.

At point of capture, crustaceans are exposed to changes not normally experienced previously: a change (usually an increase) in temperature as pots reach the surface; emergence into air; daylight that may be unnaturally bright compared to the seabed; exposure to the drying effects of wind; physical handling when removed from pots, gauged and banded, and then boxed or re-immersed in an onboard vivier system. *Such transitions should be thought about and carefully managed to minimise any potential impact.*

Handling on deck requires care to avoid causing limb loss or impacts to the shell, and it is important to prevent the gills from drying, since oxygen uptake and the outward transfer of CO_2 and ammonia all require a moist gill chamber. As is well known, velvet crabs are particularly vulnerable to drying out on an open deck or quayside, especially in a breeze, as the structure of their gill filaments is more prone to collapse than the more robust gills of lobster and brown crab. When an on-board vivier tank is used some changes will later be reduced or reversed, but, as is widely understood, a day-boat that boxes the catch on deck should maintain humidity around the gills using damp sacking between the layers, or at the very least over the top of an otherwise open box, in order to prevent longer-term physiological consequences that undermine the later stages of the supply chain. Although brown crab and lobster are at their most vigorous and highest quality at point of capture, and can tolerate some exposure to air (up to 24h or more if the temperature is lowered and the atmosphere is kept moist) the sooner the animals are submerged in cool flowing sea-water the better. When air temperature, or even the temperature of sea water in an on-board vivier tank, or later a vivier lorry, is higher than that on the seabed, the internal body temperature increases in a matter of minutes to match the new surroundings. This increases oxygen consumption, metabolic activity, and hence ammonia production. The latter is potentially toxic to the animal, and can only be released by circulating it to the gills for excretion. This causes an increase in energy expenditure that begins to deplete body reserves.

Such effects will accumulate at a variety of scales throughout the sequence of handling and storage on the catching vessel, landing at the quayside, temporary storage, onward transport, and the final transfer to a purchase reception facility, with cumulative implications for vigour, durability and quality.

4. The impact of ammonia

Ammonia is a transparent, odourless nitrogenous product of metabolism that is very toxic at high concentrations. In nature a crab or lobster maintains a higher internal concentration of ammonia in the blood than in the surrounding water, creating an energy-efficient downhill gradient across the gill membrane to the sea, where it is diluted to harmless baseline levels by the surrounding volume of seawater. The confines of a storage tank or an onboard or transport vivier tank change this scenario. In a vivier tank with an approximate 1:1 ratio by weight of water and animals, ammonia is entering a much smaller and fixed volume of holding water, and over a long journey the blood ammonia concentration can increase more than a thousand-fold. This reverses the normal downhill ammonia gradient, so the animal responds by expending energy to maintain ammonia excretion, further increasing the concentration in the confines of the tank. The extra energy cost depletes the condition of the animal, and unless tank water is changed regularly, ammonia accumulation in the tank will become a physiological threat, and affect the long-term commercial value. Ultimately, unless managed as described later, this could be fatal to a proportion of the load, depending on the volume and temperature of the tank, the number of animals, and the length of immersion. By the end of a vivier trip, when the waste products of metabolism have accumulated in the tank, a final hazard occurs when crustacea are transferred to the clean water of a reception tank, since their first act is to dump the excess ammonia that accumulated in the blood during transport. Unless the reception tank has a through-flow of clean water it too can rapidly become contaminated by ammonia - roughly within 10 minutes. Ideally the water temperature in a reception tank/pond should therefore either be matched to the temperature of the sea water in the transport vehicle, so that the final temperature change and metabolic impact are minimised, or preferably a few degrees below the storage/transport tank temperature. Reception tank water should also be either flow-through, or recirculating with biofiltration, or regularly exchanged with unused seawater.   Physiological impacts are most likely to occur towards the delivery end of a vivier transport trip, or when quayside storage tanks are overstocked in summer when ambient temperatures peak, metabolic rate rises, and ammonia accumulates most rapidly. For a storage tank it is helpful to counter this by reducing stock levels, exchanging the water more regularly, and increasing the through flow of cooled water, all of which should be customised as a result of experience and regular monitoring (see Section 6).

Similar principles and disciplines should be applied to vivier transport when ambient temperatures increase seasonally, or when it is anticipated that disruption will create above-average journey times.

5. Summary of the Golden Rules

- Despite their robust physical appearance, brown crab and lobster are physiologically sensitive to shocks and changes in external conditions;
- Avoid or minimise physical and temperature shocks wherever possible, including at the point of capture, and guard against desiccation;
- Don't overstock holding and transport tanks, especially in summer;
- Monitor temperature and the ammonia content of the water (see Section 6) so as to develop routine best practice for your expected journey time;
- Where possible minimise the temperature difference between successive stages of the supply chain, and try and prevent increases;
- If delays are expected adjust the loading, temperature, and water changes, within the limits permitted by the economics.

6. Testing in order to Adapt or Modify the Supply Chain

Vigour is obviously highest when an animal is first removed from a pot, and then gradually diminishes across the post-harvest environment. Consequently, the overall aim should be to reduce or minimise the changes at every step. To identify where there is most need and most scope for improvement, managers/operators should co-operate to review the key stages (capture, on-board handling, landing, temporary storage, collection and onward transportation, transfer at the reception centre), and organise appropriate monitoring trials. *At the start and end of each stage, grade the vigour of the animals, and record key data on body and water temperature, ammonia, stocking density, and mortality. A simple format for recording monitoring data is shown in Table 2 in the Annexe, while Table 3 shows one example of a vigour index table that the physiology authors devised for studying product quality changes across live crustacean supply chains. These can be adapted to suit the needs of individual businesses.*

Measurements should ideally be repeated at different seasons, and kept as a database so that future ambient differences can be taken into account.

6.1 Measuring temperature

A digital thermometer can be used to measure the blood temperature of samples of the animals. Digital probe thermometers accurate to 0.1 °C, and with a fine/narrow tip to the probe, can be found on various websites for £25 to £50. Temperature is measured by carefully inserting the probe of the thermometer about 1 cm (1/3 inch) into the soft tissue where the rear leg of the crab or lobster joins the main body. Blood temperature measured immediately after capture should correspond to the seabed temperature, and will therefore be a guide to the temperatures required to slow down quality loss in successive post-harvest stages. Keeping a log of the temperature readings will build a database of the effects of seasonal and tank density changes for future reference.

6.2 Measuring ammonia

Measuring ammonia to a scientific level of accuracy can be expensive and time consuming. We therefore suggest that it is best to measure water ammonia levels in day-to-day operations using marine aquarium saltwater indicator kits, which are cheap and readily available from aquatics shops and online websites. The kits involve watching colour changes in liquids, which only take about 10 minutes. Testing can therefore be done quickly and easily on the quayside, and during stops for driver or other breaks on a journey. Students who use these kits to monitor their laboratory stock tanks have shown them to be adequate for maintaining appropriate conditions. Again, the data collected should be logged for future reference.

6.3 Logging the data

Individual work patterns, routes, and trips all have their own particular features, variations, and peculiarities. Logging of data throughout the various different stages is therefore strongly recommended, so that the impact of factors such as density, temperature, stage duration and trip duration can all be monitored and adjusted as circumstances, experience, and unforeseen changes dictate. It is highly likely that the impact of these various factors during any given journey also depends on the original quality of the animals when landed from the catching vessel. As mentioned earlier, examples of monitoring criteria to be recorded and measured during live transport are shown in Annexe Tables 2 and 3, which can be adapted to suit individual needs.

7. Comparing Transport options

7.1 Vivier lorry

The vivier lorry, which transports the product in tanks of aerated seawater plumbed inside an air-cooled trailer, is currently the main transport mode for shellfish exported live from the UK. A typical consignment features a seawater/product weight ratio of about 1:1, and a total payload of about 20 tonnes. As an example of one of the longest routes, the journey time from Orkney to Spain and Portugal is likely to be about 72 hours, without hold-ups, which is very close to the maximum safe duration for crab and lobster under 'best practice'. This illustrates the lack of slack in the live supply chain, and the obvious implications of the unscheduled delays and abnormal product losses first caused by the additional Customs requirements experienced at continental border posts early in the first post-Brexit year. Since ambient temperatures in the summer will be much higher than in the winter, the importance of monitoring and adjusting loads and densities is obvious. As recommended earlier, managers could look carefully at their normal routines by applying a condition index study based on a version of Table 2 and 3 in order to identify where best to reduce or slow down the accumulation of ammonia. The control options are either to adjust the known factors (stocking density, water temperature, aeration rate, and frequency of water changes) or to explore the use of an alternative transport technique, such as misting (next section).

7.2 Misting

A preliminary but very promising study of brown crab was carried out a few years ago under the auspices of ACRUNET (Smyth & Uglow, 2015, cited after Table 3 in the Annexe).

The experiment showed that a chilled, moist, ultrafine mist can:

a) fill the interior of a large-volume vehicle,
b) delay the physiological deterioration of brown crab kept in pierced box-ware,
c) produce very good survival rates,

all whilst avoiding the burden of carrying and changing large volumes of seawater that would normally accumulate ammonia detrimentally.

At the temperature of 2°C used in the trial, the super-fine chilled mist maintained a humid atmosphere in the gill chamber of brown crab, thus preventing loss of body water across the gill membrane. At the accompanying low body temperature of 3-4°C the crab produced and retained lower amounts of ammonia, and more of the less toxic urea than normal.

An experimental sample of 217 brown crab kept in a cold mist experienced zero mortality up to 48 hours, and only 2 deaths after 48 hours, whilst nearly 90% survived 72 hours of misting followed by 24 hours re-immersion in seawater to simulate the reception tank. Examination of the corpses revealed that all had only minor impact features typical of freshly-landed crab, which emphasises that good post-catch handling is relevant to long-term survival prospects. The quality criteria used at the start of the ACRUNET trial are shown in Table 3 in the Annexe.

Note that misting means using a super-fine droplet seawater fog – this is much finer than a shower, which has much larger droplets that do not have the same physiological benefits. A fog or mist is very pervasive and will penetrate everywhere, including the gill chamber.

Although preliminary, the ACRUNET trial showed that misting is not only a suitable physiological alternative to a vivier system, but will also have a significant advantage in the costs and time incurred because containers of clean seawater can be chilled at the packing site, and much less will be needed since the 72-hour experiments used less than 2 tonnes of seawater. This indicates that 80% less water needs to be carried, so that exporters could utilise the interior of a trailer more effectively by holding and packing more rapidly and efficiently, thus either reducing haulage costs or increasing payload. It is worth noting that in the high volume North American lobster trade misting is now used routinely and successfully rather than traditional vivier transport.

Table 1: The comparative advantages of misting and vivier systems

Vivier systems	Misting systems
Payload very weight-inefficient	Payload weight-efficient
Inefficient use of payload space	Efficient use of payload space
Requires dedicated vehicle	Vehicle need not be dedicated
Little possibility of back-loading	Back-loading an option
Prepacking impractical	Prepacking and palletizing practicable
Repetitive handling likely	Repetitive handling avoidable
Loading/unloading cumbersome	Loading/unloading simpler
Distribution radius 48/72h	Distribution radius 48/72h
Part loads/small deliveries impractical	Part loads/small deliveries practicable

Annex: Brown Crab Transport and Quality Criteria

Table 2. A simple possible format for recording animal condition score and transport conditions monitored at selected journey locations (Katie Smyth).

Suggested Vivier Monitoring Log Sheet									
Date	Time	Locality	Condition Score from Table 3	Outside air temp (°C)	Inside air temp (lorry / facility (°C)	Water temp (tank) (°C)	Body temp (crab / lobster) (°C)	Tank ammonia level (*)	Water pH
xyz	0530	xyz	4	14	9.5	9.6	9.6	0.5	8.1

* Insert units as per the test kit e.g., ppm / mg/L / µmol....

Not all crabs landed have the same standard of quality – in any catch some will inevitably be better than others and it is important to have a method for choosing the animals that are most likely to retain their quality throughout the journey. The selection should be quick and easy to use and comprise a number of easily measured criteria, as in Table 3 used in the ACRUNET study, which can be adapted or trimmed to suit individual needs.

Table 3: Brown crab vigour index (Smyth & Uglow, 2015).

Every crab was scored on each of the criteria and the score determined by the column with the most matches.

Acceptable for live trade	Acceptable for live trade	Unacceptable for live trade but OK for processing	Unacceptable (almost dead)	Unacceptable (dead)
Score 5	Score 4	Score 3	Score 2	Score 1
Rapid limb movements	Limited limb movements	Minimal limb movements	No limb movement	No limb movement
Actively attempts to nip handler	Some claw activity	Weak claw activity	No claw activity	No claw activity
Frequent eye movements	Eyes slightly sunken	Eyes sunken into sockets	Eyes dry and sunken	Eyes dry and sunken
Rapid antennae movements	Slow antennae movement	Weak, infrequent antennae movement	No antennae movement	No antennae movement
Rapid closure of mouthparts if opened by handler	Able to close mouthparts slowly	Able to close mouthparts only if aided	Mouthparts gaping, crab unable to close them	Mouthparts gaping, crab unable to close them
No drooping or limpness if lifted	Slight drooping of limbs when lifted	Limbs droop when lifted but able to control claws	All limbs droop when animal lifted	All limbs droop when animal lifted
Rapid bubbling at mouth when re-immersed	Bubbling at mouthparts when re-immersed	Little bubbling when re-immersed	No bubbling when re-immersed	No bubbling when re-immersed
Free movement around the re-immersion tank	Some movement when re-immersed	Stationary when re-immersed	Stationary when re-immersed	Stationary when e-immersed
Blood can be removed via hypodermic	Blood can be removed via hypodermic	Blood can be removed via hypodermic	Blood can be removed via hypodermic	Blood cannot be removed via hypodermic

Reference: Smyth and Uglow (2015) A novel, low-cost method for distributing live brown crabs (*Cancer pagurus*) in European supply chains.
ACRUNET 2012-2015 Activity 6 Action 1.

Available online at: https://tinyurl.com/yaxn4xcx

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Our aim is to assist and promote the sustainable development of the Shellfish Industry in the United Kingdom, throughout the entire supply chain.

The SAGB represents the views of its members in debates with the Government and its agencies, other users of the sea and environmental organisations. We are striving to ensure a more viable and sustainable future for UK shellfish operations, from Sea to Plate.

With the increasing legislation and financial constraints facing the industry, our role is more vital than ever.

Alongside our lobbying activities, the SAGB also promotes the sustainability of your operations, the health benefits of eating shellfish, brings together buyers and sellers of shellfish and sells the story of this magnificent industry to the public.

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