Recommendation on carbon sequestration by molluscs

AAC 2022-16

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1 Background

Carbon storage takes place in the shells of the main European shellfish products (oysters, mussels, clams). As they form and develop, molluscs naturally build their shells from calcium carbonate, in this way sequestrating carbon. The Aquaculture Advisory Council (AAC) highlighted this ecosystem service in its Recommendation of June 2021, specifying certain divergences in the scientific community as to the actual role of bivalves as potential carbon sinks[1].

On 19 October 2021, the Commission announced its Work Programme for 2022, a proposal for certification of carbon removals with a view to proposing a European regulatory framework in this area by the end of 2022. On 7 February 2022, the Commission launched a call for public contributions as part of this initiative aimed at proposing rules on the certification of carbon removals and developing methods for monitoring, reporting, and verifying the reliability of these absorptions. In its Communication on sustainable carbon cycles of 15 December 2021, the Commission briefly mentions blue carbon in Chapter 2.3 and its high storage potential by marine plants.

These recent developments should be considered in the context of the European Climate Law (Regulation (EU) 2021/1119) which requires the European Union to achieve a balance between emissions and removals of greenhouse gases (GHGs) by 2050 at the latest and to achieve negative emissions thereafter.

This AAC recommendation is intended to be a consensus contribution from all its constituent parts on the sequestration potential of farmed molluscs. Forced by the deadline set by the Commission, the AAC endeavoured to convene a dedicated Focal Group as soon as possible and to initiate an urgent written consultation of the "Shellfish Farming" Working Group, followed by an urgent written consultation of its Executive Committee.

2 Raw data

The three main shellfish products of the European Union are:

- Oysters
- Mussels
- Clams

EUROSTAT indicates that the declared production of these products and their marketing in the European Union in 2019 was 580,044 tonnes, broken down as follows:

Shellfish product	Tonnage marketed in the EU in 2019
Oysters	124,357
Mussels	430,708
Clams	24,979
Total live weight	**580,044**

On these tonnages expressed in live weight, the meat rates for each product group are established on average as follows and make it possible to deduce the weight of the shell alone for products marketed for human consumption:

[1] R. Filgueira, T. Strohmeier & Ø. Strand (2019). Regulating services of bivalve molluscs in the context of the carbon cycle and implications for ecosystem valuation. In Goods and services of marine bivalves (A.C. Smaal, J.G. Ferreira, J. Grant, J.K. Petersen and Ø. Strand, Eds.). Cham, Switzerland: Springer, pp. 231–251.

Shellfish product	Average meat rate	Live weight tonnage	2019 shell tonnage
Oysters	8.5%[2]	124,357	113,687
Mussels	25%[3]	430,708	323,531
Clams	14%[4]	24,979	21,482
Total in shells			**458,700**

To this volume of shells at consumer level, the volume of farmed shell debris must be added, which is estimated, on average, per shellfish product as follows:

Shellfish product	% of debris	Live weight tonnage	2019 debris tonnage
Oysters	25%	124,357	31,089
Mussels	20%	430,708	86,142
Clams	4%	24,979	999
Total debris			**118,230**

It should be noted that this average depends on the evolution of mortality rates, which can be significant. The weight of the shell of products that have suffered mortality depends on the age at which the mortality occurs. When mortality occurs at adult age and market size, the weight of shell debris is more or less equal to the weight of shells that would have been marketed without the mortality. In such a case, the overall shell weight remains the same. On the other hand, when mortality occurs at a younger stage, the weight of the shell debris is much lower than the weight that the same adult product would have had on the market.

The total weights presented below therefore correspond to the total weight of shell debris in the farming phase and the weight of shells of products marketed for human consumption. Given the remark in the previous paragraph, these totals should be considered as indicative maximum values for the three leading products of European shellfish farming.

Shellfish product	Shell tonnage	Debris tonnage	2019 total tonnage
Oysters	113,687	31,089	144,776
Mussels	323,531	86,142	409,673
Clams	21,482	999	22,481
Total	**458,700**	**118,230**	**576,930**

The rate of CO_2 sequestered in each product makes it possible to estimate the total carbon sequestered in the shells and shell debris of farmed molluscs in Europe in 2019, i.e. **a little over 45,000 tonnes which,** on the low assumption of 10€/T, **corresponds to a carbon credit of 450 K€/year**:

Shellfish product	2019 total tonnage	C % sequestration	Total C sequestered
Oysters	144,776	8.3%[5]	12,016
Mussels	409,673	7.5%	30,725
Clams	22,481	10.6%	2383
Total	**576,930**		**45,124**

[2] Interprofessional agreement on the denomination of Pacific oysters (meat index of a fine oyster: 6.5%, meat index of a special oyster: 10.5%, average used here: 8.5%) made compulsory by the order of 2021

[3] Meat content of a bouchot mussel from Mont-Saint-Michel Bay PDO – PDO specifications

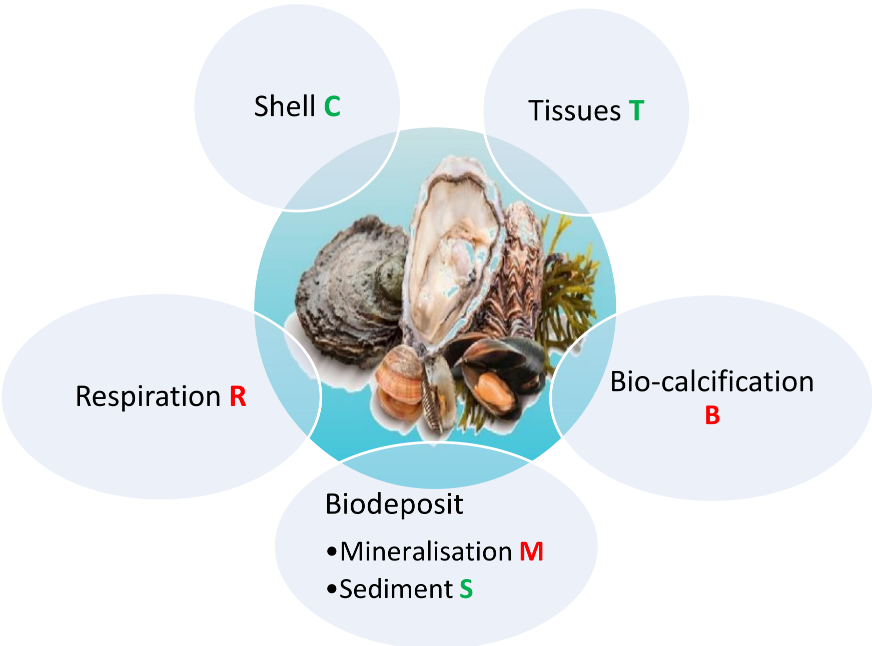
[4] The meat content varies according to the season: from 10% (in winter, lean period) to 18% (in June, breeding period), average used here: 14%

[5] Tidal areas – Wadden Sea (oyster and mussel), Dutch coastal zone (Stripped venus clam) – Blue carbon by marine bivalves – Henrice Jensen & Lisanne van den Bogaart – December 2020

3 Discussion

3.1. Life cycle of farmed molluscs

While the previous chapter presents carbon storage by the shell of the main European shellfish farming products, the following elements are intended to complete the description of the whole life cycle of the product. Without going into the details of the debates between scientists, it is possible to present the various phases that make up the calculation of carbon sequestration by the shellfish, beyond its shell alone: some fix the carbon, others manufacture it. **Sequestration aims to calculate the resulting net value.**



The scientific literature differs on the equation to use to calculate the Carbon Sequestration Potential (CSP). The various options are summarised by Jansen and Van den Bogaart[6]:

- **CSP = C**
- **CSP = C - B- R**
- **CSP = C – B- 10%R**
- **CSP = C + T + S – B – R – M**

Whatever formula is used, the authors agree that shellfish farming is a slight carbon sink[7] [8] or very close to neutrality[6] and that it constitutes a climate change damping factor by increasing the level of

[6] Jansen, H., & van den Bogaart, L. (2020). Blue carbon by marine bivalves: Perspective of Carbon sequestration by cultured and wild bivalve stocks in the Dutch coastal areas. (Wageningen Marine Research report; No. C116/20). Wageningen Marine Research

[7] Aubin, J., Fontaine, C., Callier, M., Roque d'orbcastel, E., 2018. Blue mussel (Mytilus edulis) bouchot culture in Mont-St Michel Bay: potential mitigation effects on climate change and eutrophication. Int. J. Life Cycle Assess. 23, 1030–1041

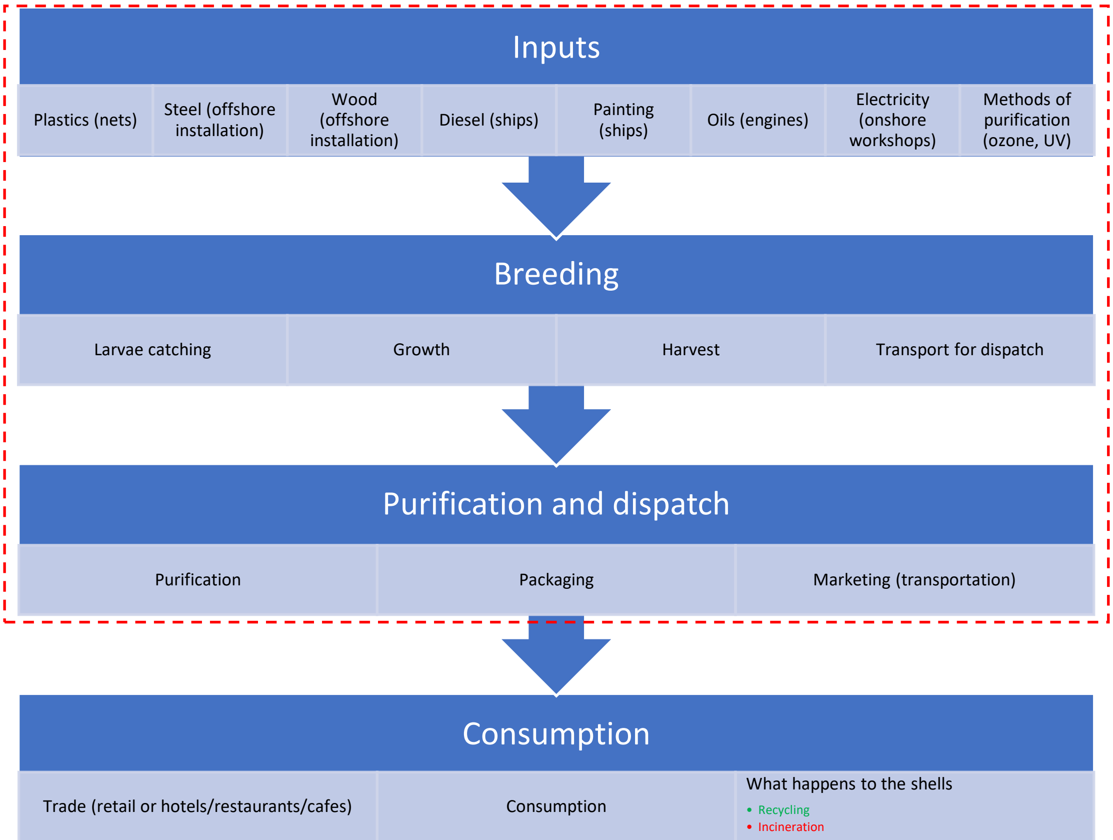
[8] Filgueira, R., Byron, C.J., Comeau, L.A., Costa-Pierce, B., Cranford, P.J., Ferreira, J.G., Grant, J., Guyondet, T., Jansen, H.M., Landry, T., McKindsey, C.W., Petersen, J.K., Reid, G.K., Robinson, S.M.C., Smaal, A., Sonier, R., Strand, Strohmeier, T., 2015. An integrated ecosystem approach for assessing the potential role of cultivated bivalve shells as part of the carbon trading system. Mar. Ecol. Prog. Ser. 518, 281–287

carbon stored in the sea[9] [10] [11] [12] when this analysis is based on the well-established chemical balance approach in the literature:

$$Ca^{2} + 2HCO_{3} \rightleftharpoons CaCO_{3} + CO^{2} + H_{2}O$$

3.2. Problems identified regarding the end of the life cycle of farmed molluscs

The absence of consensus mentioned above is linked to the debate on the use of the sole stoichiometric approach to evaluate the carbon fluxes resulting from calcification. An approach based on the full life cycle assessment (LCA) or the product's environmental footprint (PEF) makes it possible to integrate the LCA into the calculation of biogenic carbon fluxes to explore the potential role of bio-calcification processes in seawater carbon sequestration during shell formation, using ad hoc environmental data.



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[9] Alonso, A.A., Álvarez-Salgado, X.A., Antelo, L.T., 2021. Assessing the impact of bivalve aquaculture on the carbon circular economy. J. Clean. Prod.

[10] Smaal, A.C., Ferreira, J.G., Grant, J., Petersen, J.K., Strand, Ø., 2019. Goods and Services of Marine Bivalves, Goods and Services of Marine Bivalves. Springer Nature

[11] Suplicy, F.M., 2020. A review of the multiple benefits of mussel farming. Rev. Aquac. 12,204–223.

[12] Zhang, Y.Y., Zhang, J.H., Liang, Y.T., Li, H.M., Li, G., Chen, X., Zhao, P., Jiang, Z.J., Zou, D.H., Liu, X.Y., Liu, J.H., 2017. Carbon sequestration processes and mechanisms in coastal mariculture environments in China. Sci. China Earth Sci. 60, 2097–2107

The recent work by Martini et al[13] in 2022 focuses on the part circled in red in the life cycle diagram below, i.e. they analyse the farming phase alone (A) and the shellfish rearing and dispatch phases (B). The fate of the shells from consumption (C) will be discussed in the next chapter. The results of this study show that CO2 emissions amount to 0.07-0.12 kg CO2 equivalent for phase A and 0.53 kg CO2 equivalent for phase B. Biogenic calcification fixes 0.19 to 0.20 kg of CO2 per kg of mussels, fixed in the shells, while 0.12 kg of CO2 per kg of mussels is released at the same time. Altogether, these life cycle flows correspond to a net sequestration of about 0.08 kg of CO2 per kg of mussels. The good environmental performance of mussel farming is therefore confirmed and the carbon from seawater fixed in the mussel shell in the form of calcium carbonate can therefore be considered as a small carbon sink. The environmental data collected during the study support this hypothesis.

However, the life cycle or environmental footprint analysis is a long, complex, and costly method for a company or a geographical production sector. It is necessary that the work carried out, such as that mentioned in this Recommendation, leads to the adoption of a harmonised and validated algorithm for each type of farming to enable each company or group of companies, or even an entire geographical sector, to calculate its carbon sequestration.

3.3. The fate of shells after the consumption of products on land

The work mentioned above stops when the shellfish is sent to market for human consumption. Indeed, the fate of shells after consumption is beyond the control and means of intervention of shellfish farmers. It is, however, an important step if we want to calculate the complete environmental footprint of the product.

Today, there is no systematic and organised system for sorting shellfish waste in place in the European Union. Local initiatives can be seen here and there (during the summer periods at certain major summer tasting sites and direct sales in both tourist and shellfish producing areas, such as in Morbihan in France or during festive events such as certain fairs during which the consumption of shellfish products is honoured for local cultural and historical reasons, such as the Braderie de Lille street market in France) or even a pilot project at the recycling centres in Saint-Nazaire in France.

If not sorted, the shells from consumption are therefore treated as waste for incineration. The sequestered carbon is then released into the atmosphere. It is therefore imperative to organise some sorting, as there are already many ways of recovering farmed shells, all of which help to maintain effective carbon sequestration and promote a virtuous circular economy. Without being exhaustive, the following uses can be cited:

- Industrial limestone improver
- Organic limestone improver for gardens
- Mortar production
- Concrete production
- Ecological paint to combat heat in homes
- Painting the surface on roads
- Wetsuits for surfers
- Interior decoration and garlands

[13] Arianna Martini, Massimo Calì, Fabrizio Capoccioni, Marco Martinoli, Domitilla Pulcini, Luca Buttazzoni, Thomas Moranduzzo, Giacomo Pirlo, Environmental performance and shell formation-related carbon flows for mussel farming systems, Science of The Total Environment, Volume 831, 2022, 154891, ISSN 0048-9697

- Porcelain objects

Recycling by means of limestone improver is already the subject of local industrial processing, which these entrepreneurs would only like to develop if larger volumes of shells were to become available at well-identified geographical focal points.

The massive use of shells can also be envisaged to help reconstitute natural banks (base of the bank to be reconstituted before reseeding and progressive colonisation by live oysters), to fight against coastal erosion and to mitigate exceptional oceanic climatic phenomena as has been the case for many years in New York, while contributing to the purification of the surrounding coastal waters. Another original initiative to report in the same spirit: to transform one's ashes after death into an oyster reef.

4. Recommendations

4.1. On carbon sequestration by farmed molluscs

The Aquaculture Advisory Council recommends that the Commission:

1. Create a high-level Group of Experts composed of experts from the Member States, recognised scientists in the field of carbon sequestration (Italy and the Netherlands in particular), and members of the two colleges of the AAC, of which the mission will consist of:
    a. Defining and harmonising the standard and proposing algorithms for carbon sequestration in molluscs throughout their farming cycle until they are first marketed: by type of farming, simple and easily used by companies or groups of companies,
    b. Proposing a method allowing the simple and harmonised assessment of the carbon footprint on the life cycle of farmed molluscs,
    c. Considering the interest of assessing the carbon storage potential of wild shellfish beds,
    d. Considering the interest of assessing the carbon storage capacity of zooplankton on shellfish farming concessions and the integration, for this purpose, of one of the algorithms used by the IPCC in a Copernicus service in order to assess, in an unambiguous and harmonised way, this sequestration by plankton at the level of the public domain granted for shellfish farming purposes.
2. Establishing an external certification for the carbon sequestration data obtained by using the algorithm referred to in 1 for an environmental claim or one of the corresponding carbon credit payment mechanisms recommended in 4.2.
3. Organising, with the Member States and their relevant territorial entities, the selective collection of waste shells from human consumption with a view to their recovery (circular economy).

4.2. About the Payment of "blue carbon" credits

1. To suggest immediately to the Member States to integrate a payment mechanism in their EMFAF Operational Programme via, for example, the Open Method of Coordination.

2. To consider the interest of a dedicated mechanism for direct payment for the ecosystem service of carbon sequestration by farmed molluscs.

3. To evaluate the feasibility of a financial engineering mechanism to pay for carbon credits certified in 2 in a simple and fast way, under the Blue Invest platform, backed by co-financing:

    a. Option 1: national funding backed by the European instrument and the EMFAF shares of each Member State,

    b. Option 2: from EMFAF under direct management by the European Commission.

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