

Stock and Catch Assessment of *Ruditapes* Populations and Awareness-Raising Activities for Recreational Fishers Along the Western Coast of Cotentin (French Coast of English Channel)

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Abstract: For several decades, the western coast of Cotentin has been colonized over a length of about 80 km by the Manila clam *Ruditapes philippinarum*. This species has become established due to the development of clam farms in the Chausey Archipelago. This paper summarizes the main ecological patterns of the clam populations and describes approaches to assess the stocks subject to high pressures caused by recreational and professional harvesting along the western coast of Cotentin (WCC). *Ruditapes* show low densities (from 0 to 52, but often <10 ind.m⁻²). An annual one-day survey was carried out in August estimates there to be roughly 6500 fishers present along the WCC. According to the mean clam size (37.5 mm) and mean weight (13.6 g), it is possible to approximate the biomass of the clams living in five identified patches (15% of the total surface occupied by clams on the WCC): 816 t in 2015 and 1142 t in the early 2000s. The estimated biomass of minimum fishable clams (>40 mm for a mean weight of 16.8 g), is assessed at between 648 and 907 t: i.e., 79% of the total biomass. The total annual clam catches by recreational and professional fishers are assessed at 300 t for the years 2000. Awareness-raising actions by a shore mediator have been implemented to inform the public about regulations during fishing activities (100 clams of more than 40 mm per day and per fisher) and have proven very efficient since the beginning of these actions 10 years ago. An experiment of non-fishing carried out on an area of 6 km² for five years failed to identify any interannual difference in terms of abundance and size either inside or outside the reserve. At present, the stock does not appear to be endangered and has supported a considerable fishing effort over several years.

Keywords: Manila clam; Cotentin; sampling design; fishing effort; stock assessment

1. Introduction

The Manila clam *Ruditapes philippinarum* (Adams and Reeve, 1850) was introduced into France during the early 1970s to make up for the deficiency of European clams [1,2]. Soon after the installation of a clam farm on the tidal flats of the Chausey Archipelago in 1989, the Manila clam began to colonize the intertidal zone of the

Western Coast of Cotentin (WCC) [3,4]. The wide dispersal of larvae originating from the Chausey population then led to the settlement of post-larvae along an 80-km stretch of the WCC [4].

Due the easy access to these consumable intertidal species, as well as their diversity and abundance, there are nearly two million shellfish harvesters in France and the number of fishers is constantly increasing [2].

The great diversity of fishing activities (many different species, tools and techniques) is well represented on the WCC, where there is an extensive intertidal zone with a wide range of different substrates (sandy to gravelly, heterogeneous and rarely silty) [3]. Moreover, a considerable and growing number of shellfish fishing activities have been observed for several years mainly focused on the clams as target species. During spring tides, when the vast intertidal zone of the WCC is uncovered, the attraction of these activities is greatly enhanced [3].

Successive studies since the beginning of 21st century have focused on the clam populations of the WCC, including both the non-native species *R. philippinarum* and the native European clam *Ruditapes decussatus* (Linnaeus, 1758). The native European species remains present but makes up a low proportion of about 1.5% [2–9]. These previous studies have improved our knowledge of this resource on a heterogeneous coast. It shows an alternation of sandy and rocky shores influencing the distribution of clams in an area characterized by high-energy hydrodynamic conditions and a high diversity of intertidal sediment types from clean sand to gravel [7–9].

At the same time, raising awareness among shellfish harvesters mainly consists of informing recreational fishers about the regulatory sizes and preservation of the natural environment [3,7]. This awareness-raising is carried out directly (articles, television news, billboards, stands at local events ...) or indirectly (questionnaires, day events dedicated to tides). It should be noted that direct awareness can only be set up by the goodwill of the project support structure, unlike indirect awareness. An assessment of the numbers of harvesters during spring tides is carried during one day out every year in August; moreover, the number of sampled clams per harvester and per day have been estimated at the scale of the WCC. All these approaches allow us to obtain an indication of the biomass harvested by recreational fishing. At the same time, professional fishers are required to submit a monthly declaration of their catches, so the fishing production can be theoretically determined. Nevertheless, it should be noted that difficulties are encountered when collecting these declarations, and professional fishers do not provide sufficiently accurate spatial information for local areas. Moreover, clams are often sold directly (to wholesalers, restaurants ...), and only small quantities are auctioned. As a result, the quality of the declarations may be affected because there is less opportunity to cross-check with other sources such as sales data [2]. This gives rise to a measurement bias and a high level of uncertainty concerning the quantities of clams harvested by professional as well as recreational fishers.

The aim of this paper is to summarize our knowledge of the ecological patterns of the clam populations of the WCC; to give the results of a field experiment carried out in a reserve; to present the awareness-raising approaches used towards recreational fishers; and provide for the first time an assessment of clam stocks and catches by recreational and professional fishers.

2. Materials and Methods

2.1. Study Area

Located in the Normano-Breton Gulf, the wide intertidal zone of the WCC (Figure 1) corresponds to a mixture of sandy, gravelly, sandy-rocky and rocky substrates [6]. With a tidal range of more than 12 m during equinox spring tide, the tidal flats extend up to 5 km from the coastline. This zone is favourable for the important development of oyster and mussel farms all along the coast from the Mount-Saint-Michel Bay in the south to Portbail in the north (Figure 1). Cockle and Manila clam farms are also present in the Chausey archipelago. The total area dedicated to aquaculture activities is about 80 ha, of which 34 ha are mussel farms, 9 ha are oyster farming and 38 ha are clam farming with a production of about 300 t (<https://www.manche.gouv.fr/Services-de-l-Etat/Mer-et-littoral/DDTM>, accessed on 1 October 2025).

In this WCC intertidal zone, some remarkable natural habitats have been recognised such as the *Lanice conchilega* beds, the *Zostera marina* meadows and *Sabellaria alveolata* reefs [10–12]. Clam populations therefore live in direct interaction with shellfish farms and share the same areas of the WCC intertidal zone. Both clam species are present

from +4 to +6 m [above the NGF elevation datum] in a wide variety of sediment habitats; the clam sampling sites are located within the intertidal zone about 1–2 km from the tide line, being accessible at each mean spring low tide [3,8].

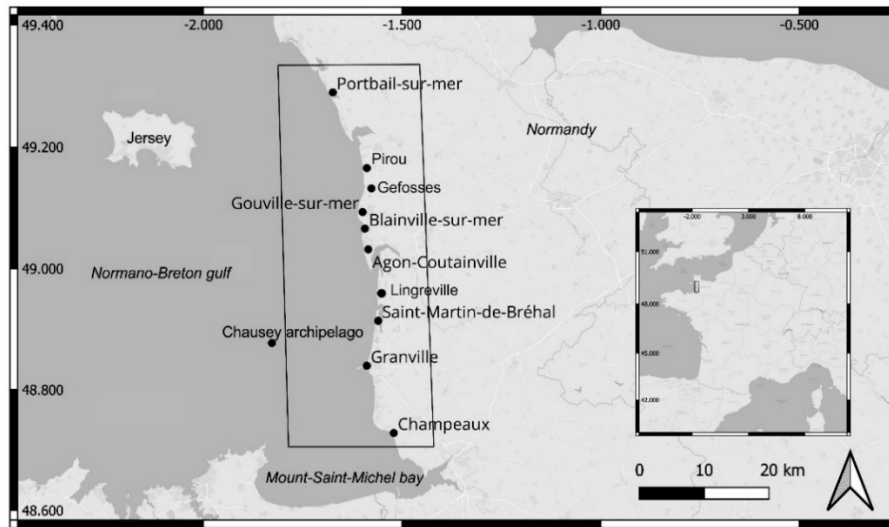


Figure 1. Location of the sampling sites on the central part of the western coast of the Cotentin (English Channel).

2.2. Sampling Design

Several sampling methods have been used during the last two decades mainly in the central part of WCC from Saint-Martin-de-Bréhal (SMDB) in the south to Gouville-sur-Mer (GOSM) in the north, thus allowing us to estimate the density of the population [3,6–9]. As the European clam represents very low abundance and low % of harvested clams, we assume that our results concern the introduced non-native species *R. philippinarum* species.

For most of the studies, clams are raked with a professional rake (16.5 cm width; seven teeth with length 7 cm; distance between teeth 2.8 cm), over the entire surface and to 15 cm depth [3,6–9]. Then, the target clam species are identified and their maximum length is measured using a digital calliper with a precision at least of 0.1 mm.

2.2.1. Clam Abundances at the Scale of the WWC

To assess the abundance of the clams at the scale of 30 km from SMDB in the south to Gefosses in the north, the sampling strategy from February to May 2015 has consisted in dividing the zone into sectors of 1 km of latitude along transects extending from +4 to +6 m [above the NGF elevation datum] where clams have been high reported along the WWC [8]. On each sector, the geographical coordinates of 10 points are chosen randomly for a theoretical number of 451 stations, but only 424 stations could be sampled. 172 stations are added in sectors showing the highest abundances, for a total of 596 sampling stations. At each point, sampling is performed using a 1 m × 1 m square PVC quadrat, and the sediment was raked to a depth of 0.15 m depth and then sieved on a 5 mm mesh size to collect all the clams.

2.2.2. Clam Displacement

A surface-area of 10 m² (3.16 m × 3.16 m) was used in 2014 to identify clam displacement at Blainville-sur-Mer (BLSM) on three sediment type habitats [3,9]. In 2016, always to analyse clam displacement, the raked surface-area remains 10 m² but corresponds to quadrates of 5 m × 2 m in three sites BLSM, Agon-Coutainville (AGON) and SMDB [8]. All clams were collected visually (hand-picked) directly by rakers rather than by sieving the different sediment types from each station within a site.

In 2018, again to assess distance of clam displacement a 9 m × 9 m quadrat is deployed at the sand site of BLSM [9]. This quadrat contains 25 squares of 1 m on a side, with each square being separated from its

neighbour by 1 m. The raked sediment is collected with a shovel, deposited on a 5-mm mesh sieve and sieved to collect all the clams living in the 25 sampled squares [9].

2.2.3. Reverse Effect

In 2015–2016, many fishers (both professional and recreational) reported a decrease in clam stocks in several fishing areas without being able to quantify it. To study the effect of a cessation of shellfish harvesting, a scientific reserve was created at the ‘Pointe d’Agon’ by prefectural decree on 18 May 2018 (Figure 2). This decree forbade the fishing of all endobenthic bivalves including clams until the end of 2022. The clam populations were monitored from 2018 to 2022 in the reserve and also in two fished zones, to the north and to the south of the reserve, to determine whether the scientific reserve had any measurable effect. In this way, four study areas were defined (Figure 2): zones A (Blainville-sur-Mer, 2.2 km²) and D (Lingreville, 0.5 km²), which were subject to normal fishing pressure, while zones B (1.8 km²) and C (3.9 km²) within the scientific reserve, were not subject to fishing pressure. For each area, 16 stations were sampled during each sampling campaign (winter, summer and autumn during five years on a total of 15 dates from 2018 to 2022), giving a total of 64 samples (1 m²). The four zones and the sampling stations in each zone were chosen according the identification of spot of clam abundances during the previous study [7]: i.e., 12 stations in areas with high abundances of clams and four stations outside the spots. The distance between the stations is at least 200 m.

To identify the reserve effect at AGON (Figure 2) from 2018 to 2022, clams are collected in 1 m² quadrats using a professional rake; the sediment is sieved through a 5-mm mesh sieve [3].

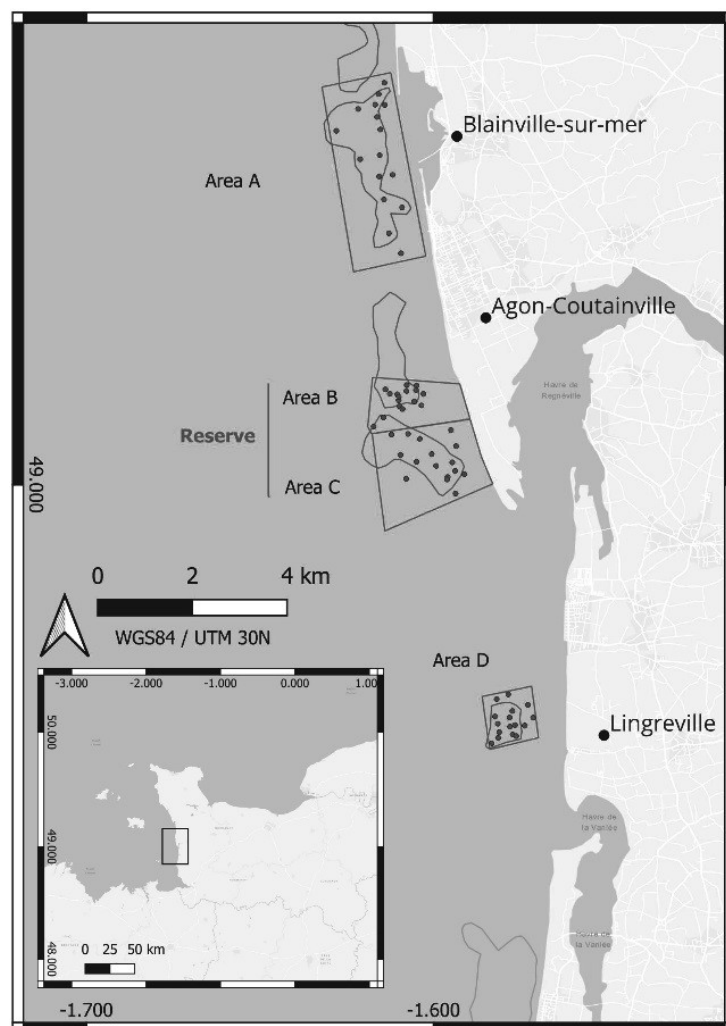


Figure 2. Sampling areas (A, B, C, D) of the study site as part of the monitoring of the Agon-Coutainville (AGON) reserve, showing clam sampling points for 2018 to 2022.

2.2.4. Effect of Sampling Surface on Clam Abundance Assessment

To assess the effect of sampling surface on clam abundance assessment, two other strategies have been adopted [8]. A stainless-steel hand corer (0.20 m diameter) is used to collect samples each covering an area of 1/32 m². During the winter 2014, four stations has been sampled for each of the three habitats of BLSM corresponding for a total surface-area of 0.25 m² per station and a total of 1 m² per habitat type. The sediment of each corer is sieved through a 1-mm circular sieve.

The sampling protocol proposed by the ‘*Fédération Nationale des Pêcheurs Plaisanciers et Sportifs Français, FNPPSF*’ [13] is investigated to estimate the abundance of *Ruditapes* spp. populations of the western Cotentin. In a first step, an area of 100 m × 50 m has been delimited and a sampling station is placed at the each of its corners plus an intermediate station at 50 m on the long side of the rectangle. At each of the six selected stations, three random samples were collected with a professional rake from a 0.30 m quadrat to depth of 15 cm depth, corresponding to a total area of 0.27 m² per station and 1.62 m² per site. The sediment is sieved through a 9-mm mesh sieve.

These both last sampling designs are developed at five sites: one at GOSM, two at BLSM, one at AGON and the last one at SMDB.

In summary, sampling strategies correspond to area of 1/32 m², 0.25 m², 0.5 m² and 1 m² for core sampling, 1.62 m² for quadrat sampling, 1 m² and 10 m² for quadrates rake.

2.3. Growth

Speed of growth was studied using monthly biometric data collected at GOSM on a gravelly habitat from March 2015 to March 2016, i.e., over a period of 13 months, sieving of sediment on a 5-mm mesh sieve. We assume that this site was representative of the clam population present along the WWC: same type of sediment, same environmental conditions of salinity and temperature, same tidal range.

Cohort analysis was performed on all the clams collected, using the method of Bhattacharya [14] and the FISATII software. The individual growth of each cohort is displayed using the seasonalized Von Bertalanffy model [2]. The height/weight relationship was established from 1771 clams collected between 2020 and 2021 in all seasons along the Cotentin coast from SMDB in the South to GOSM in the North.

Based on the size increase of the identified cohorts from the beginning to the end of the study (2015–2016), a growth model was carried out using the R software. The geometric least squares method is used to estimate the parameters of the seasonalized Von Bertalanffy equation. This model, with slowed growth in winter, is described by the equation:

$$L = Linf * \left(1 - e^{\left(-K * (t - t_0) \right) - \left(\frac{CK}{2\pi} \right) * \sin(2\pi * (t - ts))} \right)$$

where:

L = height in mm at time (t);

Linf = asymptotic size in mm;

K = growth coefficient in y⁻¹;

C = amplitude of the seasonal oscillation of growth;

ts = point of change between winter and summer growth, in years;

t = time in years;

t0 = age at recruitment (end of larval stage), in years.

2.4. Awareness-Raising Actions towards Recreational Fishers

Since 2014, a shore mediator has been engaged for the intertidal zone of the WCC from the Mount-Saint-Michel Bay to Pirou. He has three main missions: leading activities, awareness-raising and mediation around recreational fishing.

The mediator’s mission is also intended to be educational: to give advice on the most responsible and species-friendly methods of recreational fishing and inform fishers about the standards to be respected. To succeed in this mission, mediators have various tools at their disposal: flyers, posters, bill-boards ... It is indeed

important to have concrete support media to convey this information, particularly on fishing grounds.

The mediator thus participates at the national monitoring of shellfish gathering conducted by the Littorea network, which forms part of the European Life project on Recreational Fishing 2013–2017 “Experimentation for a concerted and sustainable management of recreational fishing “with the aim of supporting recreational shellfish harvesters to preserve their fishing activity while respecting the intertidal zone (<https://www.pecheapied-loisir.fr/>).

In fact, there are two types of harvester counts: simple (regular) which counts which make it possible to estimate the number of shellfish harvesters to a site, and collective (punctual) counts. During collective counts, the shellfish harvesters from all the sites monitored are counted exhaustively. Volunteers, equipped with binoculars and a count sheet, assess the number of shellfish harvesters based on previously defined counting points. These counts are carried out when the number of fishermen is highest, i.e., during summer spring tides (coefficients greater than 95) during the hour before low tide. This participatory approach permits to obtain an “instantaneous” but partial snapshot of the number of harvesters fishing on several sites in a given situation (tidal conditions, fishermen’s availability, meteorology, etc.). Collective counts are particularly interesting for assessing peaks in attendance at the territorial level.

Stock assessment involves the implementation of a scientific protocol that is quite cumbersome and expensive to carry out, particularly in heterogeneous areas with low densities as observed along the WCC [3,8]. Although essential, this assessment can be supplemented on a more regular basis by indicators that involve the fishers themselves.

A participatory index based on Catches Per Unit Effort (CPUE) (i.e., the number of clams fish per hour) has been implemented along the WCC. This index allows us to estimate the “catchability” of clams by sector and assess its evolution in time. This information is distributed through a participatory approach involving clam fishers; it is voluntary, anonymous and simple to implement in order to obtain broad support and participation. Two campaigns per year (spring and autumn) are carried out to take into account the temporal variability of the presence of clams. During some spring tides with an average coefficient (70–90), flyers are distributed to the recreational fishers to collect the following information: date, access location, fishing gear, time when first clam caught, end of fishing time, number of clams sized 40–50 mm, 50–60 mm and >60 mm, number of fishers present within a radius of approximately 50 m and their use of clam fishing areas (Table 1). At the end of this first stage, the information is entered into a databank that can be used for further analyses.

Table 1. Characterization of the clam fishing site based on size index and number of clams caught per hour. Green: good status of the clam population; Orange: moderate status of the clam population; Red: bad status of the clam population.

Size of the Clams/Number of Clams per h	0–19	20–39	≥40
A: 50% of clams > 60 mm	Green		
B: 50% of clams > 50 mm			
C: 20–49% of clams > 50 mm	Orange	Green	
D: 5–19% of clams > 50 mm	Red		
E: 100% of clams < 50 mm	Red		Orange

3. Results and Discussion

3.1. Growth

The mean relationship between clam size in mm and the fresh weight is represented by: $\text{Log}(\text{weight}) = 3.351 \text{ Log}(\text{length}) - 4.142$ ($r^2 = 0.99$) (Figure 3).

The size of 40 mm (minimum fishable clams) is reached in three years and four months [2]. There are few very old clams in the samples from the WCC populations and, during our samplings, the maximal size observed is 69 mm at AGON. For a 40 mm clam, the weight is 16.8 g, for a 50 mm clam the weight is 35.6 g and for a 60

mm the weight is 65.6 g.

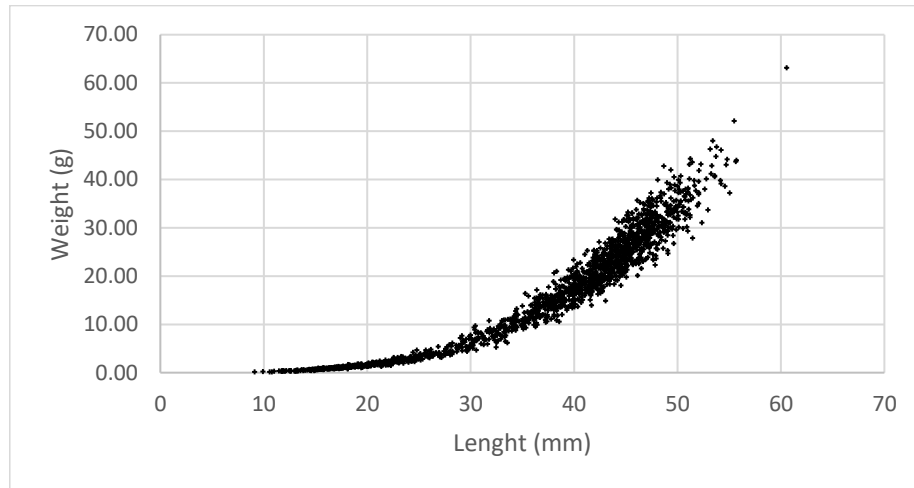


Figure 3. Relationship between clam size in mm and the fresh weight established from 1771 clams collected between 2020 and 2021 along the WCC from SMDB to GOSM.

Figure 4 shows a histogram of clam size frequency and modes determined in March 2016 at GOSM. Four cohorts can be identified with 2 mm frequency classes.

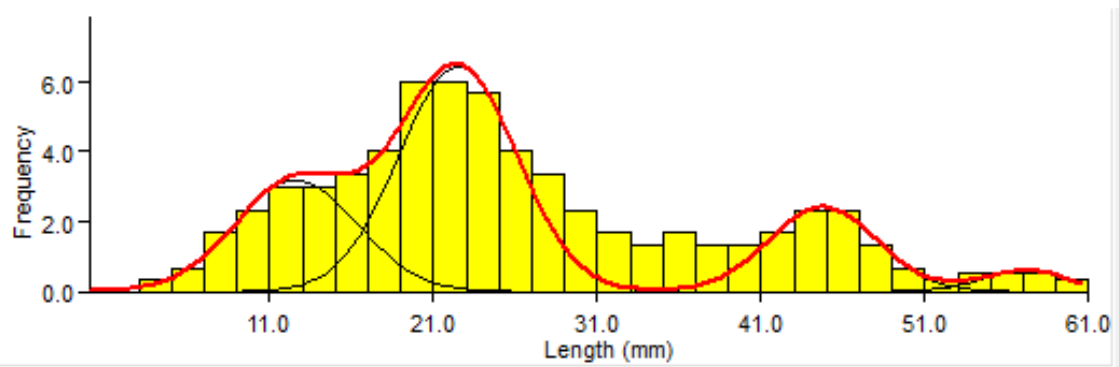


Figure 4. Histogram of clam size frequency and determination of modes using FISATII software in March 2016 at GOSM.

This type of distribution with four size classes appears more complete than the size classes used for the clam population in Bourgneuf Bay in May 2011 [15] where two or three cohorts were identified for a maximum size of 45 mm. Similarly, in the Arcachon Bay, most of the clams show a maximum size of less than 40 mm during a 2005–2007 survey, with only some individuals reaching 50 mm [16].

The results of the growth model are as follows: $L_{inf} = 80.2751$ mm; $C = -0.1$; $K = 0.2253$ y^{-1} ; $t_0 = 0.2$ y^{-1} ; $ts = 0.8847$ y^{-1} .

3.2. Reserve Effect

The sediment is heterogeneous in the four zones and corresponds to a mix between sandy gravel and gravelly sand. No seasonal and annual granulometric changes have been observed during the study [3]. Overall, the sediments are very poor in organic matter on the four zones. The minimum organic matter content is $0.63 \pm 0.15\%$ (Zone C in 2019) and the maximum organic matter content is $1.58 \pm 0.33\%$ (Zone A in 2018). The average densities of clams within the four zones within and outside the reserve do not exceed 8.6 ind. m^{-2} , except for zone D where it reaches 16.2 ind. m^{-2} during the winter of 2021 [3]. The estimated abundances do not show significant differences over the five-year monitoring period between areas inside the reserve and the two reference areas outside that continued to be fished.

In addition, after five years of non-fishing, there are no differences in clam size, whereas larger sized clams

would be expected in the reserve. However, the population size structures show similar patterns between areas. In addition, over the 5 years of study, only 1.6% of the clams are larger than 50 mm, the majority being located in zone D (fishing zone, Figure 2). The results show a high proportion of small clams < 40 mm in the four study areas, with clam populations mainly made up of young individuals. This indicates a suitable level of recruitment in all four areas outside or inside the reserve [3].

In summary, the reserve covers a total surface-area of about 6 km², but with the sampling protocol applied here, it is impossible to distinguish any effect due to non-harvesting in the experimental reserve, either regarding the abundances and stock of clams or the size of clams in the reserve compared with sites elsewhere on the WCC [3]. Moreover, although these results are disappointing, they have required a significant effort in terms of staff and laboratory work. This effectively raises the question of measuring the effect of a reserve in the case of low clam population densities and a high local variability in abundance. An adequate sampling design and effort must be carefully considered before providing a new experimental reserve.

3.3. Stock Assessment

Based on the successive sampling campaigns, we can summarize the clam abundances per m² as follows. The major survey in 2015 (about 600 sampling points of 1 m²) shows densities that vary between 0 and 52 ind. m⁻², and reveals the presence of four patches of high abundance (at BLSM/GOSM; AGON; Lingreville and SMDB) with densities higher than 10 ind. m⁻² [8]. In 2014, the clam abundance at BLSM was 10.5 ± 2.5 ind. m⁻² on a gravelly habitat, 6.6 ± 2.3 ind. m⁻² on a deep gravelly habitat and 2.2 ± 2.0 ind. m⁻² on a sand habitat [9]. In 2016, the clam abundance was 10.0 ± 4.2 ind. m⁻² on a sandy habitat at BLSM, 2.4 ± 2.4 ind. m⁻² on a deep gravelly habitat at BSSM, 1.7 ± 0.7 ind. m⁻² at AGON and 5.8 ± 1.0 ind. m⁻² at SMDB [9]. In 2018, on the sandy habitat of BLSM, the mean clam abundance was 12.5 ± 4.8 ind. m⁻² [9].

Taking into account all these results, the mean clam abundance can be estimated at 5.0 per m² in the high-abundance patches as against 1.5 for the whole intertidal zone of the WCC. This mean abundance includes the four patches identified in 2015 where clams showed a mean size of 37.5 mm and a fresh weight of 13.6 g (Figure 3). For the last sampling period, the mean abundance is slightly higher and can be estimated at 7.0 per m² [3,8,9]. About 45% of the clams are fishable (length > 40 mm).

Our large database allows us to obtain an approximation of the biomass of the clam population along the WCC. The clams are present along a 1 km-wide swath of the intertidal zone, i.e., 80 km² for the whole intertidal zone from Chapeaux in the south to Portbail in the north. The four northern patches cover an area of 10.5 km² for [8] plus 1.5 km² for the Champeaux patch (M. Spagnol, personal observation), making a total of 12 km²: i.e., 15% of the intertidal zone. The remaining 65 km² show very low densities, probably less than 1 ind. m⁻² and often even zero. The clams in this part of the intertidal zone are unfavorable for fishing because their abundances are too low to attract fishers. In addition, clams in these areas do not participate in population renewal [4].

Therefore, our stock assessment is based only on the high-abundance patches, taking account of a mean density of 5 ind. m⁻² in 2015 and 7 ind. m⁻² at the beginning of the years 2020s. As an index of stock increase during the last decade, the mean number of clams per recreational fisher was around 45 in 2015 and 90 in 2022 (OB and MS, personal observations).

According to a mean clam size (37.5 mm) and a mean weight (13.6 g), it is possible to assess the biomass of the clams living along the WCC: 816 t in 2015 and 1142 t for the years 2000. Taking into account the proportion of minimum fishable clams (>40 mm for a mean weight of 16.8 g), the biomass of fishable clam can be assessed at between 648 and 907 t: i.e., 79% of the total biomass. In their study of the density and spatial dispersion of intertidal macroinfauna in Brazilian mangroves, ref. [17] points out that such assessments should be taken with some caution when the numbers of individuals are converted to larger areas than the sample unit area.

The latest assessment from the DDTM (*'Direction Départementale des Territoires et de la Mer of the Manche'*) was issued on 4 November 2024, accounting for 79 licenses for professional fishers in 2023 and 86 licences in 2024. The number of fishing days is estimated at 10–13 per month, with a seasonal activity ranging from less than 10 days in April to a higher number of days from September to December. The declaration of

catches reaches 97 t in 2023 with a mean daily catch of between 17 and 20 kg; from January to September 2024, the declared catches reach 92 t for a mean daily catch of between 17 and 18 kg.

During the spring tides between 31 August and 3 September 2023, 8250 recreational fishers were counted on the WCC; assuming eight spring tides in 2023 (coefficient > 100), and 3 kg as the weight of 100 clams > 40 mm (maximum of clams per day and per fisher), we can calculate the total catch as 197 t.

Thus, the total catch including professional and recreational fishers is close to 300 t, representing between 30 to 50% of the biomass of fishable clams in patches of high abundance that would allow the sustainability of stocks for the clam population on the western coast of Cotentin.

In addition to these assessments of catches on the intertidal zone, some intrusions by trawlers have been reported near Hauteville-sur-Mer for a few days during the winter of 2024, in an area where high abundances were noted at the beginning of the years 2020s. Nevertheless, there is no information about the quantities of clams caught by these professional fishers. Similar trawl intrusions have been observed at the beginning of 2020 at Champeaux without any information of clam catches (MS personal observations).

Ref. [2] estimates that the French total production is 2900 t, with around 70% originating from the Atlantic coast and 30% from the Mediterranean coast. Considering this assessment, the total Cotentin production is about 10% of the national production. Since the last decade, the proportion of the professional production represents a higher proportion of the clam catches, showing that the clam stock is in a good state and can support such annual captures.

3.4. Awareness-Raising Actions towards Recreational Fishers

An annual one-day survey was carried out during spring tide in August over the period from 2019 to 2024. These counts show large fluctuations in the number of fishers from one year to another, mainly due to meteorological conditions such as in 2021 (Table 2). The mean number of fishers is nearly 6500 (Table 2), with 43% of them at SMDB which represents a hot spot along the WCC; the second hot spot is Champeaux with 13%. We estimate a total of 287,680 shore fishing sessions took place per year over the period from 2020 to 2024, with 89,824 sessions at SMDB representing 31% and 56 746 at Champeaux representing 20%. These two sites concentrate more than 50% of the shore fishing sessions carried out on the WCC. Most of the recreational and professional fishers use rakes for clam fishing. Although impacts on the sediment are clearly visible, no significant sediment and macrofauna changes occurred after rake harvesting on three different sediment habitats at BLSM [6]. Nevertheless, the number of clams decreased significantly after raking on the gravelly habitat, whereas in the other two habitats, sediment transport in this high-energy hydrodynamic environment is able to transfer clams and other macrofauna species across the fishing sites, thus minimizing the effects of rake harvesting [6,9]. Although few fishers look for the presence of siphon marks at the sediment surface, this soft technique, which is non-destructive to sediment and macrofauna, is mainly used in the Agon-Coutainville-Gouville-sur-Mer sector.

In total, more than 700 surveys have been carried out among recreational fishers by the shore mediator since 2015. The results show average yields of about 50 clams (>40 mm) per hour of fishing. The yield is lowest at AGON. Overall, the catchability of clams is improving (Table 3). AGON was classified as red in 2015 and 2016, but came back to green status owing to higher yields in 2018. All sites are classified green in 2022. The average basket also shows an improvement over time. In 2015 and 2016, fishers caught an average of 50 clams per day [7], with numbers increasing from 2018 to 2021 to an average of between 71 and 78 clams per day. The average basket reached 88 in 2022. It should be noted that, at Lingreville, the average basket reached 100 in October 2022 and 102 at Saint-Martin-de-Bréhal in June 2022.

3.5. Non-Compliance of Catches

Before June 2019, voluntary declarations by recreational fishers show a virtual absence of non-compliance. On the other hand, from September 2019, the counts carried out by the mediator show high non-compliance in certain sectors. SMDB is particularly sensitive, with at least 25% non-compliance that can rise to more than 60% (June 2022, September 2019). Many of the non-compliant catches contained slightly more than 100 clams,

while almost a third (29%) of the fishers had caught more than 110 clams [in a single session], and several catches were observed with more than 175 clams.

Table 2. Number of recreational fishers counted during a one-day session at spring tide from summer 2019 to summer 2024. 2022 (SMDB: Saint-Matin-de-Bréhal; AGON: Agon-Coutainville; BLSM: Blainville-sur-Mer; GOSM: Gouville-sur-Mer).

Site	08/02/19	08/21/20	08/23/21	08/13/22	09/01/23	08/21/24	Mean	%
Champeaux	580	1244	893	349	-	1158	845	13
S Granville	745	850	773	974	707	1503	925	14
N Granville	391	635	200	359	465	665	452	7
SMDB	2706	2952	839	3001	3795	3278	2762	42
AGON	317	454	198	351	932	626	480	7
BLSM	332	332	364	379	344	192	324	5
GOSM	317	516	253	324	355	625	398	6
Other sites	400	489	182	370	238	773	409	6
Total	5788	7472	3702	6107	6836	8820	6455	100

Table 3. Number of clams harvested per hour by recreational fishers at five sites on the Western coast of Cotentin from 2015 to 2022 (SMDB: Saint-Matin-de-Bréhal; LING: Lingreville; AGON: Agon-Coutainville; BLSM: Blainville-sur-Mer; GOSM: Gouville-sur-Mer). In red: <20; in orange: <40 and in green: >40.

Date	Number of fishermen	SMDB	LING	AGON	BLSM	GOSM
November 2015	19	-	44	13	27	40
June 2016	105	42	31	15	28	32
May 2018	55	53	64	43	69	36
September 2018	84	45	48	39	47	52
June 2019	34	57	30	48	65	85
September 2019	92	65	57	36	49	35
July 2020	113	46	48	27	60	54
October 2020	55	55	60	22	46	30
June 2021	64	48	22	38	61	59
September 2021	64	46	56	22	38	32
June 2022	68	58	61	-	43	50
October 2022	75	60	64	40	47	52

Figure 5 illustrates the increase of compliance of catches at two sites (BLSM and SMDB) from 2015 to 2024. This increase is probably due to the educative work of the mediator through time.

However, in the southern sector of the WCC, knowledge of the regulations (minimum size > 40 mm; and quota: 100 clams per day and per fisher) remains rather poor among shellfish harvesters, with 34 to 64% being aware of the minimum size and 22 to 54% being aware of the quota, except on the Champeaux patch where the level of knowledge is 86% for the quota and 76% for the minimum size.

During the first years of surveys between 2015 and 2019, shellfish harvesters showed little level of knowledge of the regulations, which could explain why catches did not comply with the regulations. Very quickly, awareness-raising, information and communication actions have led to an improvement in the level of compliance with the regulations, rising from 10% to 30% at some sites such as BLSM in ten years (indicator: minimum catch size).

In the WCC, the clam is the species most sought after by recreational fishers, since it accounts for 50% of the fishing activity between 2016 and 2019 and almost 60% between 2020 and 2024. There has been an intensification of shellfish gathering in recent years for the harvest of this species.

One of the shore mediator's actions in support of the APP2R association is the introduction of sustainable and non-aggressive fishing techniques on the foreshore. Thus, in 2023 and 2024, an evaluation was carried out of the fishing techniques and gear used by recreational fishers. The results obtained show the strong interest in sustainable fishing practices on the site where these support actions are carried out (BLSM). Indeed, up to 1/3 of the fisher's harvest clams with a technique that is not very aggressive for the foreshore at BLSM. This initiative also generates a dynamic in neighboring sectors, such as AGON and GOSM. On the other hand, non-aggressive practices are almost non-existent on other clam fishing sites.

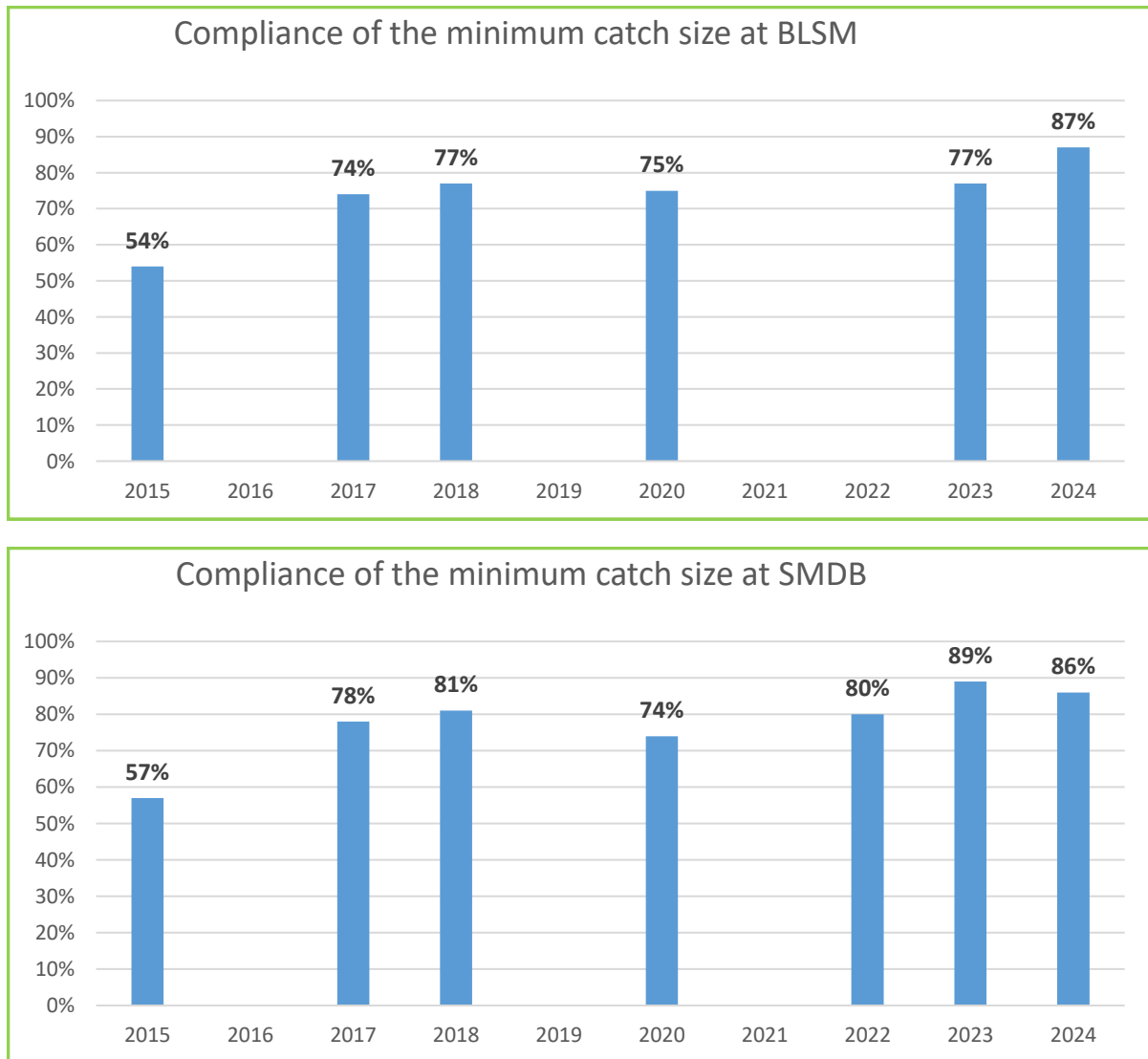


Figure 5. Compliance of the minimum catch size of clam (> 40 mm) at two sites (BLSM: Blainville-sur-Mer; SMDB: Saint-Martin-de-Bréhal).

According to our results, a clam takes less than 3 years and 4 months to reach fishable size (>40 mm). This growth is faster than on other parts of the Atlantic coast such as the Morbihan and Arcachon bays [2]. The minimum fishable size (standard) of 40 mm is unique for the Manche Department, nowadays there is currently no question of reducing the 40 mm minimum fishable size as in the Arcachon Bay where the Minimum Conservation Reference Size was reduced to 32 mm.

In spite of the low abundance, mainly lower than 10 clams per square metre, the stock appears to be substantial because of several favorable factors. First at all, the colonization of clams along the WCC in the

1980s was due to the establishment clam farms in the Chausey Archipelago [4].

Using the total surface-area of clam patches (12 km²), the mean number of clams per square metre, the mean clam size and their mean weight, we can estimate—for the first time in the WCC—a biomass of between 816 and 1142 t fresh weight with shell. Taking into account the proportion of minimum fishable clams, the biomass of minimum fishable clams is assessed at between 648 and 907 t: i.e., 79% of the total biomass. For the three last years, the total catch including professional and recreational fishers has been close to 300 t (1/3 fish by professional and 2/3 by recreational fishers). This catch represents between 30 and 50% of the biomass of minimum fishable clams, which would allow the sustainability of the present-day stock of the WCC population.

For the WCC, we can estimate that there were 288,000 fishing sessions per year over the 2020–2024 period, which is considerable (MS personal observation). This approach to estimating the number of recreational activities is also carried out on other sectors of the French mainland coast. Equivalent estimates have been recorded for two other locations in the Marine Natural Park of the Gironde Estuary and Pertuis Sea. Here, the number of recreational fishing sessions has been estimated at 195,684 per year (2014–2016), but this applies to a much longer coastline than the territory of the WCC (<https://www.pecheapied-loisir.fr/>). Similarly, on Oléron island, there are 200,000 to 220,000 fishing sessions per year, on about 90 km of coastline (2010–2011). (<https://www.pecheapied-loisir.fr/>). Moreover, the Gulf of Morbihan, the Bay of Morlaix and the Arcachon basin have coastline lengths similar to the WCC, but with estimates of up to 100,000 recreational shellfish gathering sessions per year (<https://www.pecheapied-loisir.fr/>).

As 55% of clams are represented by juveniles and young clams under the minimum fishable size, there is a good renewal of the population which thus supports the maintenance of high fishing pressure. Nevertheless, large clams with a size of 60 mm are rare, reflecting their disappearance from the population, while a large proportion of harvested clams have sizes between 40 and 50 mm.

As part of the continuation of awareness-raising and education of recreational fishers, the mediator and fishers' associations are concerned with the use of non-destructive practices.

Moreover, a sampling strategy needs to be implemented to estimate the effectiveness of 0-y settlement and the abundance of +1 y clams at the scale of the entire colonized area, with actions taken in time and space at a reasonable cost. So, ref. [18] has developed a cost-effectiveness analysis of alternative survey methods used for the monitoring of marine recreational fishing in France. But such an approach appears difficult to implement along the WCC in a zone of a large clam population with low local abundances which is not nowadays currently in danger of overfishing.

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Author Contributions

J.-C.D. conceptualization, methodology, writing—original draft preparation, supervision; O.B. conceptualization, methodology, visualization, investigation software, data curation, writing—reviewing and editing; M. S. conceptualization, methodology, visualization, investigation, data curation, writing—reviewing and editing. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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