Stock assessment and spatial distribution of the smooth clam *Callista chione* (Linnaeus, 1758) exploited in the occidental Mediterranean Sea of Morocco

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Abstract. Mapping the distribution of marine species plays a particularly important role in resource management. Prospecting campaigns were carried out between 2015 and 2017 along the Fnideq-Tamernout area of the occidental Moroccan Mediterranean Sea, through artisanal boats equipped with hydraulic dredges for shellfish fishing. A total of 1526 samples of *Callista chione* were measured and weighed to estimate and thematically map the density of this species. The population structure, the length-weight relationship and the stock status were studied in total area. Results show that there was a significant difference of size structure distribution of the studied subareas. Mean length of all subareas was 69.15±1.13 mm with a minimum of 24.17 mm and a maximum of 105 mm. The large majority of the individuals (93%) sampled presented the exploitable fraction of the stock. Length-weight relationship revealed a negative allometry for all subareas indicating that length grows faster than weight, except that of Amsa with positive allometry. Total biomass of *C. chione* records 17 million individuals for 1636 tons distributed over 8 subareas of homogeneous concentrations of different densities. Martil and M'diq present the most productive subareas with 78% of total stock. These findings can be used to put rigorous and rational rules for fishing and stock management of this species so as to ensure the preservation of the *C. chione* resource and the sustainability of the socio-economic activity it generates in the region.
Key Words: biomass, *Callista chione*, density, Moroccan Mediterranean Sea, thematic mapping.

Introduction. In Morocco, bivalve molluscs are the subject of a large harvest on the western littoral area of the Moroccan Mediterranean region. Shellfish fishing activity was developed mainly through the exploitation of bivalves of commercial interest, notably the smooth clam *Callista chione* (Linnaeus, 1758), the tuberculata cockle *Acanthocardia tuberculata* (Linnaeus, 1758) and incidentally the little venus clam *Chamelea gallina* (Linnaeus, 1758) (Shafee 1999; INRH 2008). *C. chione* is distributed in the Mediterranean Sea and even in the Atlantic coasts, from the southern British Isles to Morocco (Tebble 1966). In Moroccan Mediterranean coasts, *C. chione* is distributed from Fnideq to Jebha (INRH 2008). The annual production of this species, in Morocco, was estimated at 592 tons and 31 tons in M'diq bay and Martil area respectivelly during 2007-2008 (El-Yassimi 2009).

The bivalve *C. chione* is a species of almond shape from the Veneridae family. It is characterized by its glossy, smooth appearance, with brown highlights and lives buried in the shallow water from where it is found from 1 m (Leontarakis & Richardson 2005) to 180 m in depth (Poppe & Goto 1993). In Moroccan coasts, reproduction of *C. chione* is continuous throughout the year with a polymodal cycle; the highest amplitudes of gametic emission are in April and May (Rharrass 2015). The growth of the smooth clam is faster during the first three or four years of life and then is reduced with increasing age (Keller et al 2002; Metaxatos 2004; Damianidis et al 2010; Ezgeta-Balic et al 2011; AbouElmaaty 2016). This species is characterized by a long lifespan reaching 44 years (Ezgeta-Balic et al 2011). Historically, it has been noted that *C. chione* is a gonochoric species (sex separation); a single study has reported the first cases of hermaphroditism for this species (Galimany et al 2015).

C. chione is highly required in the Mediterranean markets due to its economic importance (Del-Piero 1994; Charles et al 1999; Gaspar et al 1999; Sarda et al 2000). Minimum landing size (MLS) authorized for its fishing by European Community legislation is 60 mm (Official Journal N° L148 2000) and it is 50 mm in Morocco by Ministry of Maritime Fisheries (Official Bulletin N° 5866 2010). Marketing of these species occasionally suffers from prohibition periods (sometimes long periods) due to contamination by biotoxins (Rijal-Leblad 2012). When a species is declared toxic on some areas of Mediterranean Sea, fishing of *C. chione* becomes prohibited (Official bulletin N° 5810 2009) for a long period and the date of lifting of its prohibition remains uncertain depending on the decrease of toxins in shells flesh. During prohibition of this activity, several fishermen in the endangered zone practice other artisanal fishing or other work.

Several studies were conducted on the population dynamics, reproduction, growth and age of *C. chione*, the majority of which have focused on its population dynamics, reproduction, growth and age (Metaxatos 2004; Leontarakis & Richardson 2005; Moura et al 2009; Damianidis et al 2010; Ezgeta-Balic et al 2011; Galimany et al 2015; Rharrass 2015; AbouElmaaty 2016). Studies on the spatial distribution of the abundance and biomass of this species are limited (Noël et al 1995; Derbali et al 2008; Coglievina et al 2014). In Morocco, Shafee (1999) studied the bivalve fishing on the Mediterranean coasts with a general mapping of fishing areas of *C. chione*. Rijal Leblad (2012) focused on the variability of the contamination of *C. chione* by paralyzing and amnesic phycotoxins (PSP and ASP, successively) in the Mediterranean littoral (M'diq bay and Oued Laou estuary).

The first study of stock assessment with spatial distribution in Moroccan Mediterranean Sea was carried out in 2007 (INRH 2008). The present study is part of research program of Fisheries Laboratory in Tangier Regional Center of the National Institute of Fisheries Research (Institut National de Recherche Halieutique, INRH) initiated in 2007.

This work satisfies the objectives of comparison of the size structure and the length-weight relationship of different populations of the smooth clam *C. chione* and the stock assessment in several subareas of total area, with mapping of the spatial distribution of the species.

Material and Method

Description of the study sites. This study was conducted in the Occidental Mediterranean Sea. It is located off the northwest coast of Morocco between 35°85’ N and 35°53’ N, and 5°34’ W and 5°15’ W, from Fnideq to Tamernout region over 43 km² along the coast (Figure 1). The study area is characterized by a succession of shore, bay and caps with a sandy, rocky and mud bottom.

Sampling. A sampling network was established using a Geographic Information System (GIS). A total of 150 points over 36 radials were sampled during June 2015 and August 2017 (Figure 2). Radials are perpendicular to the coastline with a distance of 1 km from each other. Each radial is composed of 3 to 5 equidistant sampling points of 500 m. Samples of *C. chione* were collected through hydraulic dredges for fishing bivalves aboard an artisanal fishing boat (6 m in length) and transported to the laboratory of the National Institute of Fisheries Research (INRH).

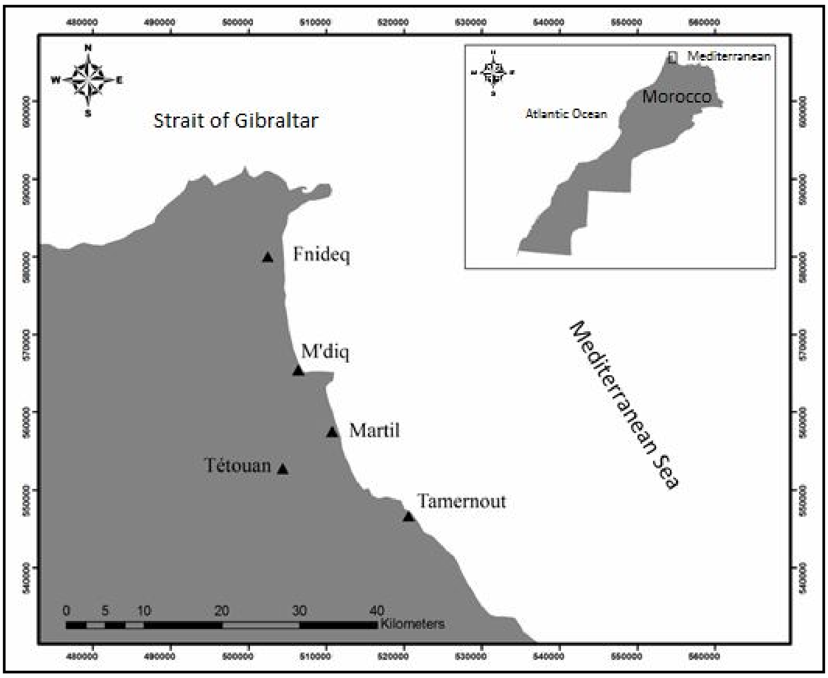

Figure 1. Map of the study area between Fnideq and Tamernout, NW Mediterranea Sea of Morocco.

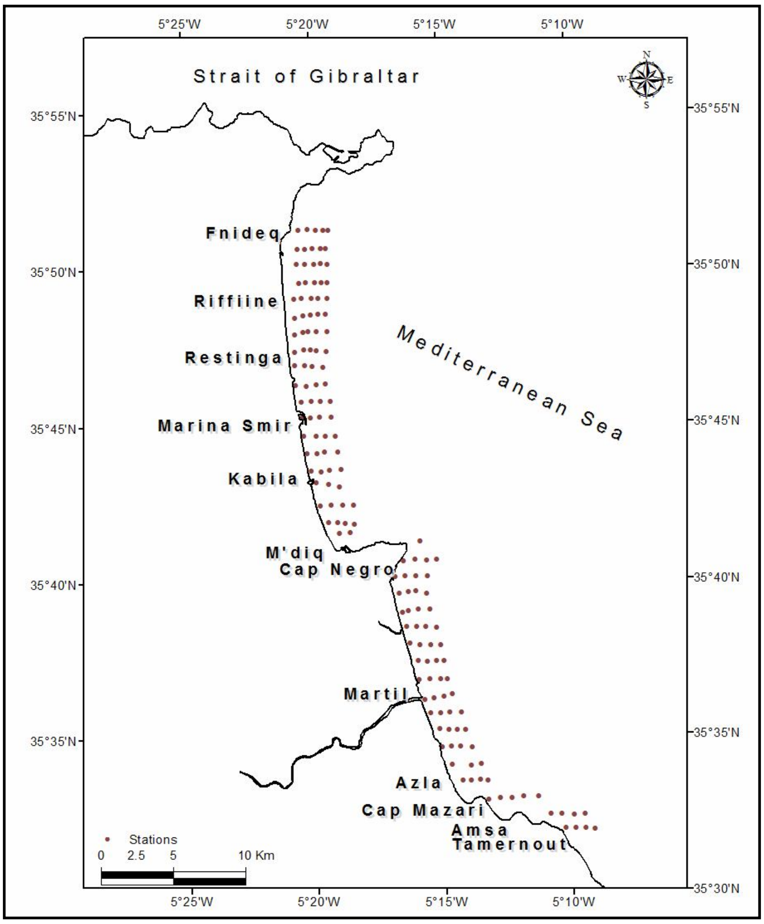

Figure 2. Map of the sampling stations in the study area of Moroccan Mediterranean Sea.

Laboratory analysis. Samples of *C. chione* were transported to the laboratory alive to be counted, measured and weighed. Three morphometric measurements were taken with a caliper to the nearest 0.01 mm (total length, width and height) and total weight was recorded with an electric balance to the nearest 0.01 g.

Statistical analysis

Population structure. Length-frequency data of the sampled individuals were grouped into shell classes by 10 mm interval to construct graphical presentations of length structures. The Kruskal Wallis test (Kruskal & Wallis 1952) was established for testing whether samples originate from the same distribution (the null hypothesis H0). If the calculated p-value is less than the significance level $\alpha = 0.05$, we must reject H0. Tukey test (multiple comparison test) was used to see which populations are different. Statistical analysis were performed using SPSS statistics 21 software.

Length-weight relationship. Morphometric relationship between length and weight was established for each population, to identify the nature of relative growth using power function $Y = aX^b$ (Zar 1984) who was transformed into a linear form:

$$\ln W = \ln(a) + b\ln(L) \text{ (Arshad et al 2008)}$$

where: W = weight of the samples (g);
L = length of the samples (mm);
a = constant (intercept);
b = constant (slope of regression line).

Statistical analysis were executed through Excel of Microsoft Office software.

Density and biomass. The density was measuerd for each sampling point in g m^{-2}. The estimation of biomass in numbers and in weight was carried out at each sampling point according to the following formula adopted by Gulland (1969):

$$Bi = Ni(Ai/ai)(1/Xe)$$

Where: Bi = stock biomass (number of individuals or weight);
Ni = index of abundance by sampling (number of individuals or weight);
Ai = total area of the site or stratum;
ai = sampling area (dredged surface);
X_e = proportion of detentions;
$1/X_e$ = escape factor of the considered species.

Maps of abundance and biomass of the species in the study area were made through the Geographic Information System (GIS) using ArcGis (10.6) software.

Results

Population structure. A total of 1526 samples of *C. chione* were collected from the area Fnideq-Tamernout, during the period from June 2015 to July 2017. The number of individuals collected from each geographical subarea with descriptive statistics of length and weight are shown in Table 1. During sampling operations, a number of 516 and 473 individuals were collected successively from M'diq and Martil subareas indicating the largest parts of total samples. Medium parts of individuals were recorded at the level of Fnideq, Amsa and Restinga with 160, 139 and 116 individuals respectively, while the lowest numbers of samples were 75, 34 and 13 individuals recorded successively in Cap Mazari, Marina and Azla. The mean length values vary from 64.00±1.94 mm to 80.13±1.09 mm with a maximum value of 105 mm in Restinga and a minimum value of 24.17 mm in M'diq. The mean weight values were found between 67.06±2.20 g and 150.31±5.04 g with the highest value of 280 g in Restinga and the lowest value of 5.71 g in Marina. The highest mean values of shell length and weight were mainly registered in the first and the second subareas (Fnideq and Restinga). For the structure analysis of studied populations, samples were divided according to shell length intervals between 20 and 110 mm and graphical representations of the size structure for each subarea were illustrated in Figure 3. In fact, it should be noted that the two populations of Marina and Azla were eliminated due to their very small numbers of individuals, which did not allow a correct study of the population structure. Results show that all studied populations are characterized by a single well-defined cohort, except the two populations of Fnideq and

M'diq which their frequency distributions are bimodal. Histograms of length distribution of *C. chione* presented by subarea show different cases. The dominant mode for Restinga is represented by the class 80-90 mm with 53% while that of Amsa and Cap Mazari are represented by respective classes 70-80 mm and 60-70 mm with successive parts of 45% and 61%. Indeed, Martil subarea is characterized by equality of the two classes 60-70 mm and 70-80 mm with a percentage of 38% for both.

Table 1

Length and weight measured parameters of sampled individuals of *C. chione* in different geographical subareas

Subareas	*N*	*Parameters*	*Min*	*Max*	*Mean ± SE*	*SD*	*Variance*
Fnideq	160	Length (mm)	36.39	97.00	73.05±1.06	13.46	181.26
		Weight (g)	14.74	237.30	111.72±4.10	51.88	2691.27
Restinga	116	Length (mm)	44.10	105.00	80.13±1.09	11.70	136.95
		Weight (g)	21.51	280.00	150.31±5.04	54.32	2950.74
Marina	34	Length (mm)	37.00	97.32	64.20±2.68	15.63	244.17
		Weight (g)	5.71	208.70	80.23±9.57	55.78	3111.30
M'diq	516	Length (mm)	24.17	94.43	67.12±0.55	12.50	156.35
		Weight (g)	12.03	216.00	81.60±1.73	39.38	1550.42
Martil	473	Length (mm)	41.67	92.50	70.19±0.39	8.39	70.37
		Weight (g)	17.20	200.00	92.71±1.34	29.14	849.23
Azla	13	Length (mm)	54.75	74.15	64.00±1.94	7.01	49.17
		Weight (g)	40.90	106.90	68.14±5.84	21.06	443.72
Cap Mazari	75	Length (mm)	50.22	81.22	64.81±0.74	6.39	40.86
		Weight (g)	20.91	128.20	67.06±2.20	19.07	363.77
Amsa	139	Length (mm)	44.45	90.76	69.75±0.66	7.82	61.20
		Weight (g)	16.40	153.40	85.48±2.28	26.88	722.66

Contrary to the previous subareas, Fnideq and M'diq are differentiated by the presence of two distinct modes. The main mode consists of the class 70-80 mm for both subareas with parts of 29% for Fnideq and 33% for M'diq. The second mode is represented respectively by the classes 50-60 mm (18%) and 40-50 mm (12%). The exploitable fractions (≥ 50 mm) of these populations are represented by the parts of 94%, 96%, 86%, 98%, 99% and 97% respectively in Fnideq, Restinga, M'diq, Martil, Cap Mazari and Amsa.

To test the null hypothesis of having the same distribution for all the studied subareas, the Kruskal Wallis test was established. Results show that the calculated p-value of Kruskal Wallis test (< 0.0001) is less than the level of significance (0.05), the null hypothesis is therefore rejected. We conclude that the means of the six populations are significantly different and they do not have the same distribution or at least one population comes from a distribution with a different mean. To find out which populations have a different distribution, the Tukey test (multiple comparisons) was carried out and showed the existence of 4 homogeneous groups, with the same distribution, made up of different populations:

- first group: M'diq and Cap Mazari;
- second group: M'diq, Martil and Amsa;
- third group: Amsa, Martil and Fnideq;
- fourth group: Restinga.

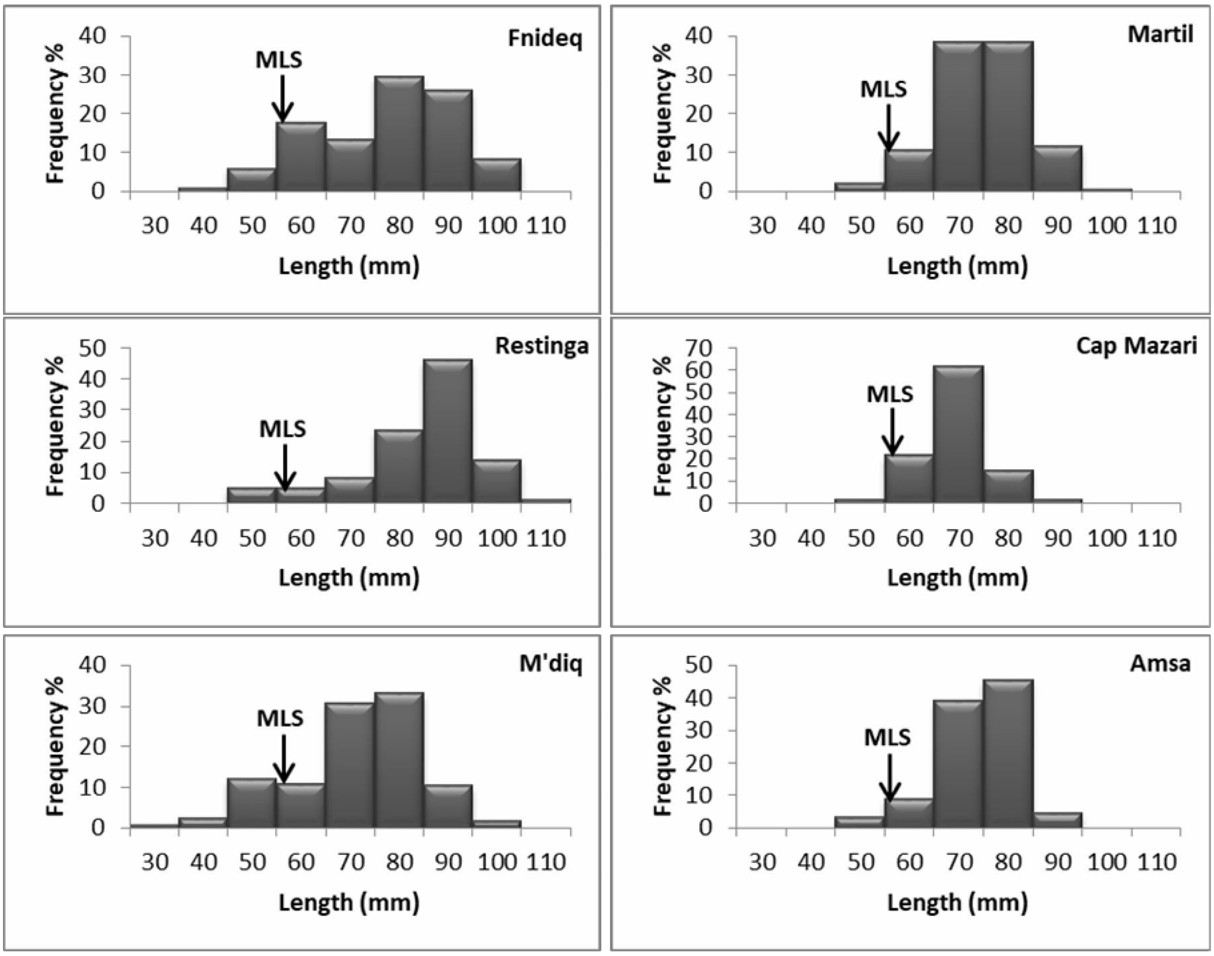

Figure 3. Population size structure of *C. chione* by subarea (N: number of individuals; Min: minimum, Max: maximum; SE: standard error; SD: standard deviation).

Length-weight relationship. The length-weight relationships were realized and presented for the six subareas in Table 2 and graphical representations of power model were shown in Figure 4. All the relationships showed a negative significant growth ($b < 3$, $p < 0.0001$) except that of Amsa subarea which indicates a positive significant growth ($b > 3$, $p < 0.0001$). Negative allometry shows that length and weight of individuals of *C. chione* in Fnideq, Restinga, M'diq, Martil and Cap Mazari do not grow at the same time, while length grows faster than weight. Then, in Amsa weight grows faster than length. The determination coefficient (R^2) of the power models is between 0.90 and 0.96 (close to 1), where the minimal value was observed in M'diq while the maximal value was recorded in Fnideq and M'diq. The highest R^2 values indicate a good fitted data.

Table 2

Length-weight relationship parameters of *Callista chione* by subarea

Subareas	*Allometric Equation*	*b*	*R²*	*t-test*	*Relative growth*
Fnideq	$y = 0.0005x^{2.8303}$	2.83	0.96	S	Negative allometry
Restinga	$y = 0.0003x^{2.9916}$	2.99	0.96	S	Negative allometry
M'diq	$y = 0.001x^{2.6642}$	2.66	0.90	S	Negative allometry
Martil	$y = 0.0008x^{2.7257}$	2.73	0.94	S	Negative allometry
Cap Mazari	$y = 0.0003x^{2.9458}$	2.95	0.91	S	Negative allometry
Amsa	$y = 0.0002x^{3.0946}$	3.09	0.94	S	Positive allometry

b: coefficient of the slope regression; R^2: determination coefficient; S: significant for p-value < 0.05.

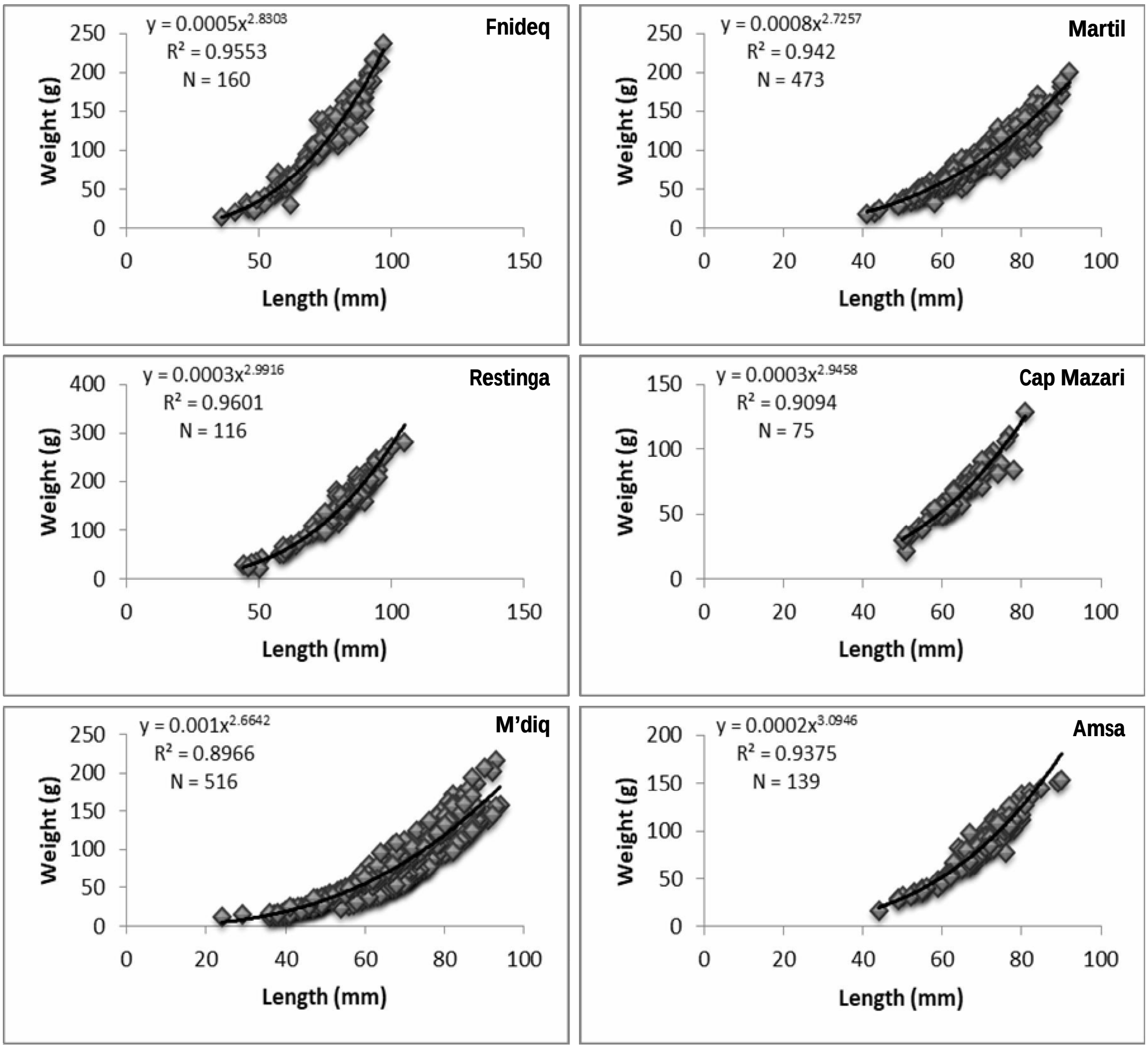

Figure 4. Length-weight relationship of *C. chione* by subarea.

Density. The integration of geographic coordinates, in ArcGis software, of all the sampling points (stations) with the data of the bottom nature, the depth and the weighted mean values which were obtained, there made it possible to establish maps of the spatial distribution of *C. chione* densities by sampling points (Figure 5).

Spatial analysis of the distribution of *C. chione* throughout the study area shows a discontinuous subdivision of natural deposits whose spacing is more or less important depending on the physical nature of the bottom. This heterogeneous distribution required the delimitation of eight subareas of homogeneous concentrations with different densities. Density in number of individuals and in weight per m² is presented by subarea in Table 3. Results show that the total density values by subarea vary between 0.5 and 39 ind m^{-2} and between 66 and 3327 g m^{-2}. In fact, Martil and M'diq subareas reveal the highest concentrations with more than half of the total density while the smallest concentrations were observed in Marina and Azla subareas. Others (Fnideq, Restinga, Cap Mazari and Amsa) recorded medium density values by subarea. Depth of these concentrations varies from 3 to 22 m with a predominance of the species between 5 and 15 m, on sandy and muddy bottoms.

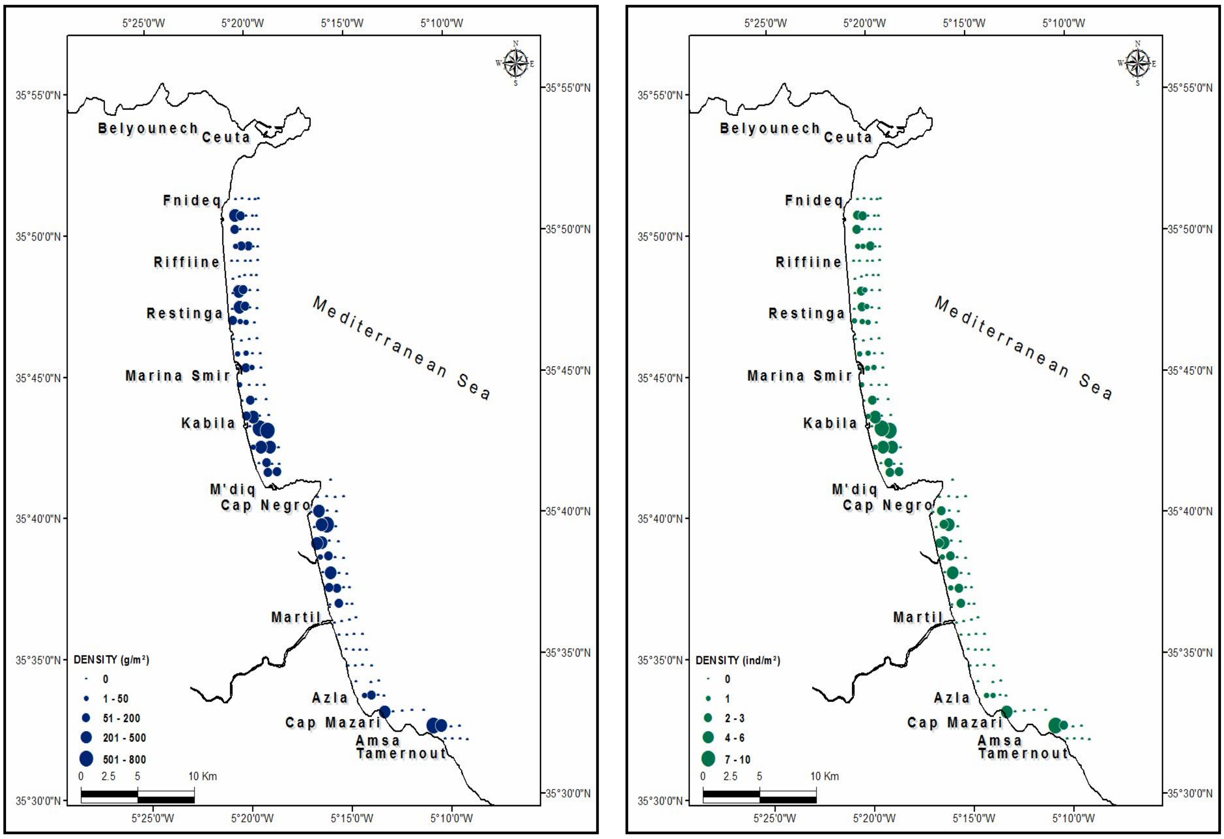

Figure 5. Spatial distribution of *C. chione* in total area.

Table 3

Density of *C. chione* by subarea

Subareas	*Density (ind m^{-2})*				*Density (g m^{-2})*			
	Total	*Mean ± SE*	*SD*	*Var*	*Total*	*Mean ± SE*	*SD*	*Var*
Fnideq	8.04	1.34±0.36	0.88	0.79	863.22	143.86±31.64	77.51	6009
Restinga	6.77	0.7±0.31	0.81	0.66	978.48	139.78±43.30	114.58	13129.1
Marina	0.56	0.11±0.05	0.1	0.01	88.87	17.77±10.19	22.79	519.4
M'diq	39.4	3.58±1.03	3.42	11.72	3326.66	302.42±74.19	246.06	60545.79
Martil	30.52	2.54±0.52	1.81	3.29	2869.35	239.11±44.24	153.25	23487.9
Azla	0.96	0.48±0.33	0.46	0.22	65.62	32.81±26.28	37.16	1381.28
Cap Mazari	5.65	5.56			371.83	371.83		
Amsa	10.3	5.14±2.19	3.09	9.55	880.15	440.07±277.36	321.54	103389.69

SE: Standard error; SD: standard deviation; Var: variance; ind: individuals.

Biomass. Total biomass in number of individuals and in tons was estimated from densities (ind m^{-2} and g m^{-2}) depending on the surface of each subarea. Surface was measured by grouping the stations of homogeneous concentration of the species distribution. The general status of the stock of the smooth clam in the study area is summarized in Table 4.

The total apparent biomass of *C. chione* in total study area is of the order of 17 million individuals for 1636 tons, with 46 stations and 8 km² in surface. The highest values were recorded in Martil with 7 Million individuals for 667 tons and in M'diq with 7 Million individuals for 599 tons, with half of total stations (23 stations) and total surface (4 km²). Fnideq and Restinga revealed medium biomass with successive parts of 1 million of individuals for 211 tons and 700 thousand of individuals for 105 tons making 19% of total biomass; whereas the lowest values were showed respectively in Azla, Cap Mazari, Marina and Amsa with range of biomass between 48 and 360 thousand for 3 and 31 tons. The four subareas represented only 3% of total stock.

Table 4

Total biomass of *C. chione* by subarea and in total area

Subareas	*Surface (km²)*	*Stations*	*Total biomass*	
			Individuals	*Tons*
Fnideq	1.47	6	1 970 517	211.49
Restinga	0.75	7	725 169	104.84
Marina	0.88	5	97 680	15.64
M'diq	1.98	11	7 091 868	598.8
Martil	2.79	12	7 095 556	667.12
Azla	0.1	2	48 148	3.28
Cap Mazari	0.01	1	56 500	3.72
Amsa	0.07	2	360 370	30.81
Total	8.05	46	17 445 808	1635.70

Discussion

Population structure. The population of *C. chione* studied along the occidental meditteranean coasts of Morocco showed a relativelly similar structure encounterd by Rharrass (2015) in the same area, in Croatia (Ezgeta-Balic et al 2011) and in the Atlantic Ocean (Forster 1981; Gaspar et al 2002; Moura et al 2009) (Table 5). In other mediterranean areas (Greece and Spain) and in Suez Canal (Egypt) population structures of the species were smaller (Metaxatos 2004; Leontarakis & Richardson 2005; Damianidis et al 2010; Baeta et al 2014; AbouElmaaty 2016). The structure population studied by Rharrass (2015) in M'diq bay showed smaller length values of minimal length in comparison with the results obtained in this study. This is related to the characteristics of the fishing gear used where samples were taken with a modified dredge fitted with a 20 mm mesh net (Rharrass 2015) allowing an efficient sampling of juveniles. In contrast, only professional dredge was used in the this work. According to Gaspar et al (2003), the teeth of the dredge and the mesh of the net used play a very important role in individuals selectivity. According to Baron & Clavier (1992), the efficiency of catches increases with the length of the individuals. The results of the length frequency distribution in each subarea showed that all population distributions are characterized by a single mode with the exception of the populations of Fnideq and M'diq Bay which are bimodal. Baeta et al (2014) and AbouElmaaty (2016) recorded too a single mode of the length distribution of populations respectively in Maresme coast (Spain) and in Timsah Lake (Egypt) while Caill-Milly et al (2006) recorded that population structure in off the coast of Aquitaine was bimodal.

In our study, the six populations of *C. chione* showed a significant difference of samples distribution (Kruskal Wallis test) with four homogenous population groups (Tukey test) for alpha = 0.05 (Cap Mazari with M'diq, M'diq with Martil and Amsa, Amsa with Martil and Fnideq and finally Restinga). Each group is charachterized by the same distribution of the individuals. This difference of population structures of *C. chione* can be related to the availability and quality of food, in general phytoplankton which was considered as primary food source for bivalves (Dame 1996; Gosling 2003). The variation of phytoplankton is governed by several processes biological, chemical, physical and geomorphological (Rijal-Leblad 2012). According to Fogg (1991), many factors influence the development of this primary production (phytocplankton) from an area to another, such as temperature, turbidity, light or nutrient salts. In fact, the contents of suspended matter (organic and inorganic) in the study area depend on the prevailing winds (west winds), the richness of the area in nutrients, the discharge of "Oueds" , currents and the general circulation of waters in maritime area.

Table 5

Population structures of *C. chione* in different geographical areas

Study area	*Depth (m)*	*Mean length (mm)*	*Length range (mm)*	*Source*
Whitsand Bay, UK	-	-	73-94	Forster (1981)
Algarve Coast, Portugal	> 25	-	19-101	Gaspar et al (2002)
Euboikos Gulf, Greece	3.5-8	55.6	-	Metaxatos (2004)
Thassos Island, Greece	1-3	-	16-72	Leontarakis & Richardson (2005)
Arrabida, Portugal	15-20	-	22.7-92.5	Moura et al (2009)
Sani, Greece	-	-	29.5-73	Damianidis et al (2010)
Platamonas, Greece	2.5-6	-	47.3-75.3	
Rab Island, Croatia	-	-	30-88	Ezgeta-Balic et al (2011)
Maresme Coast, Spain	5-25	31	-	Baeta et al (2014)
	5-25	28	-	
Maresme Coast, Spain	5-30	-	17-95	Galimany et al (2015)
	5-30	-	17-59	
M'diq, Morocco	3-24	68.4	7.4-98.9	Rharrass (2015)
Kaa Srass, Morocco	3-24	64.2	16.2-91.5	
Timsah Lake, Egypt	-	35	10.7-57.8	AbouElmaaty (2016)
Fnideq, Morocco	3-25	73	36.4-97	Present study
Restinga, Morocco	3-25	80.1	44.1-105	Present study
M'diq Bay, Morocco	3-25	67.1	24.2-94.4	Present study
Martil, Morocco	3-25	70.1	41.7-92.5	Present study
Cap Mazari, Morocco	3-25	64.8	50.2-81.2	Present study
Amsa, Morocco	3-25	69.7	44.4-90.8	Present study

The population structures vary from one geographical area to another between Atlantic (Uk, Portugal), occidental Mediterranean (Morocco, Spain) and oriental Mediterranean (Greece, Croatia, Egypt). The closest population structures are observed between Atlantic and Western Mediterranean precisely in Whitsand Bay, Algarve coast, Arrabida and Moroccan coasts. The mediterranean to the west is open on the Atlantic which is highly influenced by Atlantic waters (Thiam et al 2009), but is very elongated towards the east on more than 4000 km between the grounds, from there, a decreasing oceanic influence is produced towards the east. Functioning as a geographical and hydrological barrier (Zenetos et al 2002), the Strait of Sicily divides Mediterranean Sea into two major basins: the Western Basin and the Eastern Basin. Hydroclimatic factors in the occidental basin are different from those in the oriental basin. According to Hassoun (2014), the waters of the Eastern Mediterranean are warmer, more saline, more oxygenated and have higher concentrations of total alkalinity than the waters of the Western Basin. Generally, temperature, salinity, dissolved oxygen and total alkalinity have the same tendency of increase from the West towards the East. The study area is located in the Alboran Sea (occidental Mediterranean) which is a meeting point between outgoing Mediterranean waters and incoming Atlantic water. All the nutrient salts in these waters accumulate and move with Atlantic surface water (upwelling), thereby stimulating phytoplankton production; what most characterizes the studied area. On the other hand, despite the opening of the Strait of Gibraltar, the Mediterranean presents characteristics very distinct from those of the Atlantic Ocean. Compared to the Atlantic, the Mediterranean is characterized by low tidal range, high temperature and then greater evaporation, resulting in higher salinity and warmer water temperatures than in the Atlantic (Encyclopedia Britannica 1999). This can explain the differences observed between the populations of different geographical areas, which are attributed to the physical and biogeochemical properties specific to each maritime area that influencing the population structure of the species.

Length-weight relationship. Length-weight relationships were all significant with high values in coefficient of determination ($p < 0.001$, $R^2 \geq 0.90$). The values of the coefficient (b) ranged from 2.66 to 3.09. All morphometric relationships presented negative allometric growth ($b < 3$) except that of Amsa subarea ($b > 3$). Negative allometric growth means that the length is increasing comparatively faster than weight (X increases faster than Y; Gould 1966). According to Froese (2006), the big individuals changed their body shape to become more elongated or that the small individuals were in better nutritional state during sampling. In contrast, positive allometric growth means that the organism gains weight faster than length. The calculated values of the allometry coefficient (b) and the determination coefficient (R^2) of length-weight relationship were compared to those reported in other studies in Table 6. The negative allometry recorded in five subareas (Fnideq, Restinga, M'diq, Martil and Cap Mazari) of total study area is in agreement with that revealed by INRH (2008) but contradicts with Rharrass (2015), in the same region (Fnideq-Jebha, Morocco). In other meditteranean region, this species showed also negative and positive allometric growth (Leontarakis & Richardson 2005; Damianidis et al 2010; AbouElmaaty 2016). This may be due to the environmental variations in the study area. According to Béthoux et al (1999) and Béthoux & Gentili (1999), the temperature and salinity of deep waters are continuously increasing and warming of coastal waters in the North-Western Mediterranean is recorded (Salat & Pascual 2002; Romano & Lugrezi 2007). In addition, because of its geographic location in the middle of the continents, the Mediterranean is a very vulnerable sea to changes induced by anthropogenic activity. In fact, these are likely to be changes in climate and/or environment throughout the Mediterranean Sea (Krahmann & Schott 1998; UNEP-MAP-RAC/SPA 2008). This can show that, marine organisms can experience significant environmental variations due to their habitat conditions and that different biotic and abiotic factors can influence the growth of these species (Lemaire et al 2006). General condition of bivalves can be modulated by a set of factors such as temperature, turbidity, salinity, quality and abundance of food (especially phytoplankton) as well as the duration of exposure to air (Beaudry 2016). Joubert et al (2014) showed that environmental conditions, such as food and temperature, directly influence the oyster *Pinctada margaritifera* (Pteriidae) shell growth in Vairao lagoon (Tahiti) while Beukema et al (2017) recorded that three suspension-feeders bivalves: *Cerastoderma edule* (Linnaeus, 1758), *Mya arenaria* (Linnaeus, 1758) and *Mytilus edulis* (Linnaeus, 1758) showed a positive relationship of seasonal weight gain with temperature in the westernmost part of the Wadden Sea. According to Gaspar et al (2002), the allometry coefficient (b) varies according to the different hydrological and sedimentological characteristics in different areas. Moreover, the physiological and genetic characteristics of the species can also change its growth (Gosling 2003). According to Rhoads & Pannella (1970) and Gaspar et al (2002), variations in morphometric relationships of bivalves are habitually related to maintenance of an area/volume ratio that is physiologically appropriate for the dominant environment conditions. Accordingly, the obtained results about relative growth of *C. chione* are specific to the study area and characteristic of the environmental factors. Additional research is needed to identify the environmental factors most involved in variations of *C. chione* relative growth.

Table 6

Length-weight relationship of *C. chione* in different geographical areas

Country	*Location*	*Species*	*b*	*R^2*	*Relative growth*	*Source*
Morocco	Fnideq	*C. chione*	2.83	0.96	Negative	Present study
	Restina	*C. chione*	2.99	0.96	Negative	Present study
	M'diq	*C. chione*	2.66	0.90	Negative	Present study
	Martil	*C. chione*	2.73	0.94	Negative	Present study
	Cap Mazari	*C. chione*	2.95	0.91	Negative	Present study
	Amsa	*C. chione*	3.09	0.94	Positive	Present study
Egypt	Timsah lake	*C. chione*	2.75	0.90	Negative	Abou Elmaaty (2016)
Morocco	M'diq	*C. chione*	3.03	0.98	Positive	Rharrass (2015)
	Kaa Srass	*C. chione*	3.04	0.89	Positive	
Greece	Platamanos	*C. chione*	2.88	0.89	Negative	Damianidis et al (2010)
	Sani	*C. chione*	3.12	0.84	Positive	
Morocco	Fnideq-Jebha	*C. chione*	2.85	0.85	Negative	INRH (2008)
Greece	Thassos Island	*C. chione*	3.08	0.94	Positive	Leontarakis & Richardson (2005)

Density and biomass. *C. chione* is distributed at the level of the entire coastal coasts between Fnideq and Tamernout of variable densities, over a length of 43 km. In our investigation, the bivalve *C. chione* was encountered between isobaths 3 and 25 m as in other studies (Shafee 1999; INRH 2008; Moura et al 2009; Baeta et al 2014; Galimany et al 2015; Rharrass 2015). The shallow depths were recorded between 1 and 8 m by Metaxatos (2004), Leontarakis & Richardson (2005) and Damianidis et al (2010), in Greece (Table 5). However, *C. chione* in the study area dominates the depths between 5 and 15 on sandy and muddy bottoms.

Maps of the spatial distribution of *C. chione* previously represented (Figure 5) showed a heterogeneous distribution of the species resulting from the heterogeneity of the bottoms nature and, on other hand, highlight the presence of eight remarkable and homogeneous concentrations distributed separately (by subarea) with different densities (Table 3). The most important densities are found in Martil and M'diq bay with 3327 g m^{-2} and 2869 g m^{-2} successively, representing 65.6% of total density. The lowest densities were recorded in Azla and Marina subareas with only 1.6% of total density. In fact, the importance of the density increases as a function of the subarea surface, the larger the surface the higher the density. The distribution of densities shows that the different subareas of homogeneous concentrations appear to be more restricted than the total area surveyed. The absence of *C. chione* individuals in several sampling points in different depth levels is mainly due to the rocky bottom. In this case, the presence of the species is strictly impossible. Along the study area, rocky bottoms take different places in a non-continuous form, mostly between 15 and 25 m deep and occupy more than half of its total surface then influencing the species distribution (INRH 2008). Therefore, bathymetric repartition of the smooth clam in the studied coastal area is limited not exceeding 20 m in depth, while it can reach very significant depths up to 180 m in other geographical areas (Coglievina et al 2014).

Total biomass of *C. chione* in total study area recorded 17 million individuals for 1636 tons, of 8 km² in surface. The highest biomass was recorded in the same high density subareas (Martil and M'diq bay) with 77% of total stock while, the smallest deposits was recorded in Azla, Cap Mazari, Marina and Amsa with only 3% of total biomass. The first bivalve prospecting and sampling campaign in the same study area, carried out in 2007 by the "Institut National de Recherche Halieutique", recorded the first results of stock assessment of three species of interest commercial: *C. chione*, *A. tuberculata* and the *C. gallina* (INRH 2008). Results of the stock assessment of *C. chione* reported a total biomass of 2915 tons in the same total study area (Fnideq-Tamernout). At the time, they subdivided the area concerned into two subareas according to the physical characteristics relating to the morphology and topographical profile of the coast (Fnideq-M'diq bay and Cabo Negro-Cas Mazari, successively). The first and the second subareas recorded respective biomass of 1456 (50%) tons and 1460 tons (50%), indicating equal biomass. In the present study, the biomasses noted in the two subareas are 931 tons and 674 tons respectively (Table 4). In fact, for more than a decade, it seems that the study area has experienced an apparent regression of the *C. chione* stock with a decrease of 44% in total biomass. A diminution of 36% was recorded between Fnideq and M'diq while it was 54% between Cabo Negro and Cap Mazari. This last subarea marked the greatest stock degradation between 2007 and 2018, whereas currently, the first subarea presents the most productive zone of *C. chione*. According to the artisanal fishermen of the region, the smooth clam is the most demanded bivalve in fishery market. Then, the degradation of the stock (2915 tons in 2007, 1636 tons in 2018) may result from over-exploitation by artisanal fishermen in the region. In fact, regression of the stock is probably due to the absence of significant recruitment which results from an excessive fishing effort. In effect, average fertility declines in exploited populations. Indeed, for several species fertility is related exponentially to the size of the individual (Birkeland & Dayton 2005). Once the largest individuals are caught, only those with lower relative fertility remain. The recruitment, presented by the number of juveniles which replace the natural deaths and the individuals captured each year, is determined by the spawning biomass. By removing the larger adults by exploitation, this therefore disrupts the reproductive process of the entire population (Laubier 2003). Over-fishing then leads to a decrease in recruitment and, consequently, a decline in the exploitable stock in the years to come.

Furthermore, the variability of the stock biomass is due to different recruitment successes according to environmental conditions and anthropogenic alterations (pollution, physical degradation of habitats, climate change). Studies on the evolution induced by fishing have concluded that the evolution of the life history in stocks of marine organisms can be mainly attributed to fishing pressure and environmental changes (Sharpe & Hendry 2009; Lorenzen 2016). It is therefore unfair to attribute the reduction in the stock with certainty to the fishery only, without knowing whether this decline in biomass results from poor environmental conditions (Laubier 2003). The influence of environmental factors such as temperature, salinity, oxygen, food availability and population density (Pauly 2010; Cheung et al 2012; Rueda-Roa 2012; Baudron et al 2014) on the variability of reproduction and growth has been studied (Brander 1995; Mollet et al 2013; Baudron et al 2011, 2014). Population progression has responded to the variability of all of these environmental factors.

The decrease in stock of *C. chione* can also be influenced by the pollution that affects the region. Waters of Oued Martil are showing a sign of degradation, following the results of analyzes which revealed levels that exceed Moroccan standards in force (Belhaj & Kettani 2013). Despite this awareness, the degradation of the marine environment is intensifying with the strong demographic growth and tourist and industrial development in the region (ABHL 2015). In this context, significant and diversified pollution loads, of domestic and industrial origin, deeply affect the quality of coastal waters (Belhaj & Kettani 2013) thus disturbing the living environment of several marine organisms. Moreover, the stock reduction can also be explained by the pressure of predation, which seems to be very active in the study area. The presence of empty valves in sampling points reflects considerable predation which can be an important factor influencing the restocking of the species.

Conclusions. Moroccan Mediterranean coasts constitute an environment of great importance in terms of the biological production of bivalve molluscs, particularly the smooth clam *C. chione*. The overall wealth of *C. chione* between Fnideq and Tamernout area is estimated total stock of 1636 tons. The present study showed a decrease of *C. chione* stock with 44% of total biomass between 2007 and 2017. This significant degradation of the stock could be related to the several environmental factors. The most influencing environmental conditions are presented by water temperature, salinity, quality and density of phytoplankton, and population density. Anthropogenic factors (overexploitation, pollution and tourism) that know the region also have a strong influence on the decline of the species stock.

From the point of view of biometric considerations, the length decompositions make it possible to identify important characteristics in the structuring of existing and marketable individuals. These results will strongly be useful for the evaluation of total and exploitable quantitative potentialities. The exploitation of the resource increases with the demand while the commercial interest of *C. chione* becomes more interesting. Considering the dynamic of the populations, it would be advisable to maintain a constant stock and to fish only the correct fraction to ensure the renewal of the population. Consequently, it is necessary to establish a management plan by quotas and control of the fishing effort for the conservation of this resource for a sustainable exploitation.

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