EastMed TECHNICAL DOCUMENTS 20




A STUDY TO INVESTIGATE THE POTENTIAL EXPLOITATION OF THE VENUS CLAM *CHAMELEA GALLINA* IN EGYPT

FOODAND AGRICULTURE
ORGANIZATION
OF THE UNITED NATIONS

A STUDY TO INVESTIGATE THE POTENTIAL EXPLOITATION OF THE VENUS CLAM *CHAMELEA GALLINA* IN EGYPT

ITALIAN MINISTRY OF AGRICULTURE, FOOD AND FORESTRY POLICIES

Hellenic Ministry of Foreign Affairs

Hellenic Ministry of Rural Development and Food

GCP/INT/041/EC – GRE – ITA

Athens (Greece), April 2014

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Preface

The Project “Scientific and Institutional Cooperation to Support Responsible Fisheries in the Eastern Mediterranean - EastMed is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by Greece, Italy and EC.

The Eastern Mediterranean countries have for long lacked a cooperation framework as created for other areas of the Mediterranean, namely the FAO sub-regional projects AdriaMed, MedSudMed, CopeMed II and ArtFiMed. This made it more difficult for some countries in the region to participate fully in international and regional initiatives for cooperation on fishery research and management. Following the very encouraging experience of technical and institutional assistance provided to countries by the other FAO sub-regional Projects,

EastMed

was born to support the development of regional cooperation and the further development of multidisciplinary expertise necessary to formulate appropriate management measures under the FAO Code of Conduct for Responsible Fisheries and the principles of the Ecosystem Approach to Fisheries (EAF) to ensure rational, responsible and participative fisheries management.

The project’s **longer-term objective** is to contribute to the sustainable management of marine fisheries in the Eastern Mediterranean, and thereby to contribute to supporting national economies and protecting the livelihoods of those involved in the fisheries sector.

The project’s **immediate objective** is to support and improve the capacity of national fishery departments in the sub-region to increase their scientific and technical information base for fisheries management and to develop coordinated and participative fisheries management plans in the Eastern Mediterranean sub-region.

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Comments on this document would be welcomed and should be sent to the Project headquarters:

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Preparation of this document

This study was implemented after the 3rd EastMed Coordination Committee (19-20 April, 2012, Bari, Italy), where the participants agreed to conduct the first clam fisheries resources survey in Egypt. The arrangements for the survey started with a preliminary mission in February 2013 to assess the fishing vessel and the fishing gear, train the fishermen in utilising the fishing gear, train the scientists in clam fisheries surveys, assess the logistical requirements for the survey, and make some trial hauls. Another mission was then organised from the 20th to the 26th of April 2013, in order to start the campaign for the clam fisheries resources survey. Apart from this in the 4th EastMed Coordination Committee (4-5 April, 2013, Rome, Italy), a request was made to determine the environmental impacts of the hydraulic dredge on the bottom. Following this request an extensive literature review was made on the subject which can be found as an annex to this document. The survey consisted of a preliminary 3 day hydraulic dredge survey followed by an extensive survey covering the bay from Rasheed to Burullus conducted with the assistance of the General Authority for Fish Resources Development in Egypt (GAFRD) and the National Institute of Oceanography and Fisheries (NIOF). The document was prepared by Mark Dimech (FAO), Atif Salah (GAFRD), Ahmed Abbas (NIOF), Mohamed Kamal (NIOF), Hamdi Omar (NIOF), Nermeen El Sersy (NIOF), Eman El Wazzan (NIOF), Paolo Tiozzo (FAO), Dario Pinello (FAO), Fabio Carocci (FAO), Alaa Elhaweet (AAST), Hatem Hanafy Mahmood (AAST) and Constantina Riga (FAO).

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FAO EastMed 2014. A study to investigate the potential exploitation of the venus clam *Chamelea gallina* in Egypt. Scientific and Institutional Cooperation to Support Responsible Fisheries in the Eastern Mediterranean. GCP/INT/041/EC – GRE – ITA/TD-20. Athens 2014: 83 pp.

ABSTRACT

In Egypt due to the Nile delta and the presence of large shallow waters (0-20 m), with areas composed of sand and mud, there could be a great potential for the exploitation of a variety of clams. Given the big gap in knowledge on clams in Egypt the FAO EastMed project has started a study to support Egypt in exploring the possibility to determine if the clam resources exists, and then assist Egypt in developing a potential fishery. The study was conducted between Rasheed and Burullus, where there is a large extend of 60 km of shallow water sandy bottoms. The depth was decided to be limited to 10 m depth contour and target the main potential stock present, that of the clam *Chamelea gallina*. In total 126 hauls were conducted covering a coastline of about 60 km from 3 - 10 m in depth. All the species sampled were counted and weighed and *Chamelea gallina* samples were also kept for further processing in the laboratory, where the collection of stock parameters, microbiological and heavy metal analysis were conducted. Overall the results show that the commercial clam *Chamelea gallina* has a potential for exploitation together with other potentially commercial species such as the changeable nassa *Nassarius mutabilis* and the bivalve *Anadara polii*. Most of the biomass is located on the Western side of the area investigated and close to the fishing port of Rasheed, making the area more easily reachable. The results obtained from the bacterial and heavy metal analysis show that the clams are in general within safe limits especially in the western and middle parts of the investigated area and when compared to other commercially exploited bivalve species in Egypt such as *Tapes decussatus*. In the investigated area when considering the MSY and the cost structure of small trawlers the recommendation is that as a start 10 hydraulic dredgers would be suitable to exploit the fisheries resources. Most of the potential production would probably be for local consumption in Egypt, since export is rather difficult due to the special regulations for the import of bivalve species. The main constraint for the commercialisation of the products will be the market, since these species are at present not commercialised in Egypt, market strategy should be devised in order to successfully introduce the product in the local markets. Once the market has been understood and the products are successfully introduced an EAF management plan could be drawn up.

1. Table of Contents

Executive Summary

In Egypt landings of clams are approximately 3000 tons (FAO GFCM), while in other Mediterranean countries with similar environmental conditions (e.g. shallow sandy bottoms) the production is more than ten times this value (e.g. Italy). According to the knowledge currently available most of this production is conducted by hand raking at depths from 0-1.5 m. This production is considerably high when one considers that it is only derived from very shallow water. In Egypt due to the Nile delta and the presence of large shallow waters (0-20 m), with areas composed of sand and mud, there could be a great potential for the exploitation of a variety of clams. Given the big gap in knowledge on clams in Egypt the FAO EastMed project has started a study to support Egypt in exploring the possibility to determine if the clam resources exists, and then assist Egypt in developing a potential fishery. The study was conducted between Rasheed and Burullus, where there is a large extend of 60 km of shallow water sandy bottoms. The depth was decided to be limited to 10 m depth contour and target the main potential stock present, that of the clam *Chamelea gallina*.

The main results show that, the biological communities in the investigated area are dominated by bivalve and gastropod molluscs. The commercial clam *Chamelea gallina* was found in the investigated area together with other potentially commercial species such as the changeable nassa (*N. mutabilis*), the ark clam *A. polii* and minor catches of the Egyptian sole, *S. aegyptiaca*. Together with the added production of the bycatch species, the exploitation of clam *C. gallina* could be considered as viable. Most of the biomass is located on the Western side of the area investigated and close to the fishing port of Rasheed, making the fishing grounds more easily reachable. Only for the gastropd *N. mutabilis*, the biomass is located on the Eastern part of the bay, and close to the fishing port of Burullus. In the investigated area when considering the estimated MSY and the cost structure of small trawlers from 12 - 16 m, the fishery could support between 15 - 20 hydraulic dredgers with an average L.OA. of 15 m. However when one considers the uncertainty in the estimation of MSY, if the fishery would be developed probably 10 vessels would be more suited as a first start.

Most of the potential production would probably be easier to commercialise on the local markets in Egypt. In theory the export of clams could be possible however several countries require special regulations for the import of bivalve species which can be met in some sites but not all. Results of bacterial analysis showed that, the quality of *C. gallina* is by far higher with much lower levels of microbiological contaminants than other commercially exploited species. Additionally, clams are in general within safe limits for human use when toxic risks of hazardous heavy metals are concern. However, the eastern part must be monitored for Pb contamination and clam exploitation should be avoided when necessary. The main constraint for the commercialisation of the products will be the market, since the most valuable species including *C. gallina* and *N. mutabilis* are at present not commercialised in Egypt, so a market chain analysis should be conducted together with a market strategy in order to successfully introduce the products in the local markets. One important aspect to note is that bivalves are already an established product in Egypt, so the challenge would be to introduce a new bivalve species in the market, as opposed to the introduction of a completely new group of seafood, such as the gastropods, which would be much more difficult.

A STUDY TO INVESTIGATE THE POTENTIAL EXPLOITATION OF THE VENUS CLAM *CHAMELEA GALLINA* IN EGYPT

FEBRUARY - JUNE 2013

1. Introduction

In Egypt the landings of clams are approximately 3000 tons (FAO GFCM), while in other Mediterranean countries with similar environmental conditions (e.g. shallow sandy bottoms) the production is more than ten times this value (e.g Italy). According to the knowledge gathered during our visits in Egypt, most of this production is conducted by fishing activities by hand raking at depths from 0-1.5 m. This production is considerably high when one considers that it is only derived from very shallow water. In Egypt due to the Nile delta and the presence of large shallow (0-20 m) waters, with areas composed of sand and mud, there could be a great potential for the exploitation of a variety of clams and more information is required to ascertain the actual potential as a basis for further developing the fishery.

However, some commercial bivalve fisheries are polluted with different kinds of contaminants caused by the discharges of industrial and municipal effluents containing chemical and biological contaminants such as heavy metals, hydrocarbons organochlorines, pesticides and pathogenic bacteria and viruses (Hamza and Gallup 1982, Abdel-Shafy *et al*. 1987, Shriadah 1992, Hussein *et al*. 2002). Therefore, there is safety concerns regarding the consumption of such bivalves, especially those contaminated with pathogens and their role in outbreak of diseases such as typhoid (Buchan 1910, Murray and Lee 2010).

The EastMed project initiated this activity in order to support Egypt in exploring the possibility to determine if the clam resource exists, and then assist Egypt in developing this fishery, support the establishment of sustainable management practices, contribute to maximize value adding of the product and its marketing. The activity was a joint effort between GAFRD, fishermen co-operatives, scientific institutions (e.g. NIOF) and FAO EastMed.

This report describes the first survey which was conducted in Egypt between Rasheed and Burullus, where there is a large extend of 60 km of shallow water sandy bottoms. The depth was decided to be limited to 10 m depth contour and target the main potential stock present, that of the clam *Chamelea gallina*. The main aim of the survey was to determine the spatial distribution of commercial species present, both in term of species composition, abundance (N/km^2) and biomass (kg/km^2). Microbiological and heavy metal analysis was also conducted in order to determine the suitability of the target bivalve for human consumption. Furthermore based on the results of the survey, the Maximum Sustainable Yield and the potential value of the fishery was estimated from the results of the survey, and proposals for future work have been given.

2. Materials and Methods

2.1 Sampling design

Sampling was conducted in order to evaluate which clam species are present in Egypt, to determine the biomass (kg/km^2) and density (N/km^2), at different depth strata, up to a maximum depth of 10 m, to collect some biological parameters on the most important species *Chamelea gallina* and to assess the microbiological and heavy metal content. The sampling design for the experiment followed a stratified random sampling design, with 3 predetermined depth strata. Fourteen transects lying at an equidistant from each other were laid, and in every depth stratum, three replicate samples were collected. The sampling design is shown in figure 10, and is composed of three levels, geographical area, depth, station (Fig. 1).

The depth strata were as follows: A 3 m (2.5 - 4.49 m)
B 6 m (4.5 - 7.49 m)
C 9 m (7.55 - 10 m)

Sampling was conducted using a hydraulic dredge with a mouth of 2.7 m, between April and June 2013. The duration for each replicate sample was approximately 5 minutes. The time of each tow, the average speed and the GPS positions of the start and end of the tow were taken, so that the distance towed and consequently the total towed surface could be calculated.

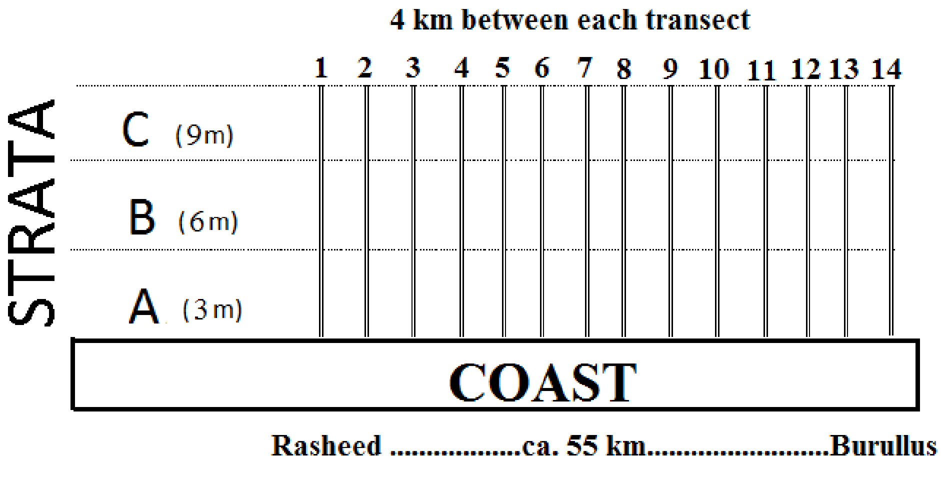

Fig. 1. Stratification scheme showing the depth in metres of each stratum, and the transects along the coast.

2.2 Sampling Area

Sampling was conducted in an area between Rasheed and Burullus (figure 2). The map shows the coastline between the two cities and the 5 and 10 m depth contour lines. The area consists of shallow water sandy and muddy bottoms of about 60 km in length. Following the sampling design 14 transects were arranged at 4 km intervals along the coastline. Samples were then collected along each transect at the pre determined depth stratum.

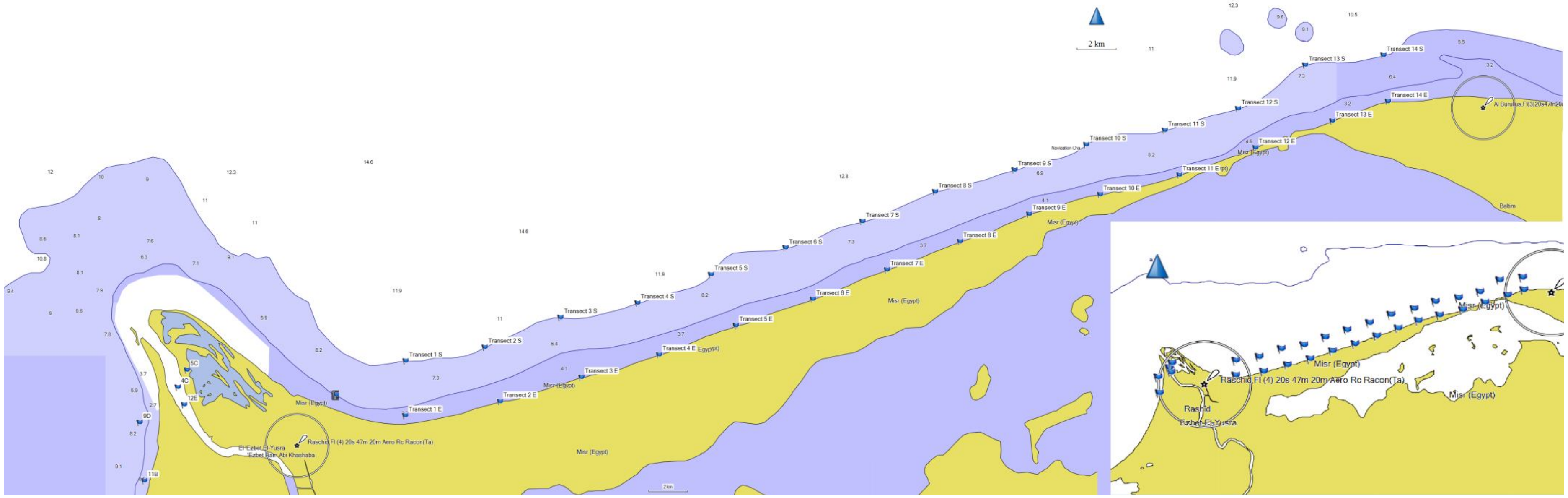

Fig. 2. Map showing the area in which the study was conducted and the location of the start and end co-ordinates of the transects.

2.3 Sample processing

Once the samples were brought onboard the entire sample was sorted by species counted and weighed. Any species other than bivalves, including all the invertebrates and fish were identified, counted and weighed. Samples of the stripped Venus clam, *Chamelea gallina* were transferred to NIOF Lab. for the collection of biological parameters, condition index, microbiological and heavy metal analysis. Briefly, samples were appropriately labelled and stored in an ice box (4-8 ^{o}C) equipped with plastic ice pads separated from the clams by pieces of soft Styrofoam to prevent freezing of clam tissues by direct contact with ice. Upon arrival to the laboratory, clam samples were immediately processed or stored overnight in fridge at 4^{o}C. In the laboratory the clam samples were checked for the identification. Clam soft tissue for heavy metal analysis was frozen at -20^{o} C until sent to the NIOF Central Laboratory for analysis.

Clams used for each analysis were initially measured and weighed before opening and the size ranges from each location will be recorded from pooling all the measurements together. Shell length (SL, anterior-posterior), shell height (SH, dorso-ventral), shell width (SW, thickness), and live weight (LW) were measured using a Vernier caliper and balance, respectively.

2.3.1. Condition Index

Clams ≥ 2 cm that represent market size clams were used for determination of the condition index (30 clams/location), Clams used for determination of condition index were randomly selected from the sample of each site. Clam were opened and soft body removed from shell and both shell and meat were separately weighed in aluminum pans for condition index measurement. Clam meat and shells were kept separately in the oven for 24 hours at 90^{o}C. Eighteen samples were processed and Condition Index was calculated according to the equation. When possible, sex was also determined macroscopically for some of the specimens. For a better determination of this index more samples should be taken in future surveys, in different seasons.

$$\frac{\text{Ash-free dry weight of meat (g) X 100}}{\text{Dry weight of shell (g)}}$$

2.3.2. Microbiological analysis

Samples of *Chamelea gallina* clam were collected from twelve different sites for microbiological analysis. From the samples stored microbiological analysis was conducted on *Chamelea gallina* for *Vibrio* sp., *Salmonella* sp., *Staphylococcus* sp., *and E.coli* sp.

The specific culture media for pathogen isolation are:

- Thiosulphate Citrate Bile Salt (TCBS) agar will be used for *Vibrio sp*. isolation.
- Mannitol salt agar medium will be used for *staphylococcus sp*. Detection.
- *Salmonella - Shigella* (SS) agar for *Salmonella sp.* Detection.
- V.R.B.A. with MUG will be used for *E.Coli* test.

According to clam size and flesh weight, 25 g flesh was collected from each sampling sites. Gaping shellfish and those with obvious signs of damage was discarded, clams were cleaned by washing under cold running water of potable quality. Clams were opened with a sterile sharp blade for collecting clam flesh**.**

Clam flesh and liquor were weighed to complete 25 g in sterile blender. Peptone solution, 0.1% (0.1% peptone/0.85% sodium chloride solution) was added, two parts by mass (25 g clam + 50ml peptone solution). Homogenize mixture in a rotary blender for sufficient time. The duration should not exceed 2.5 min. Stand for 30 s. Swirl briefly, then transfer 30 mL of the homogenate to a measured 70 mL of sterile 0.1% peptone solution and mix well. This gives the 10^{-1} dilution (Fig.3).

Preparing a 10^{-2} dilution was done by transferring 0.5 mL of 10^{-1} dilution to 4.5 mL of sterile sea water. Further dilutions (10^{-3} and $10^{-4)}$ should be prepared when needed. Inoculation of each sample was done in replicate Petri dishes for each corresponding selective medium for each tested indicator (Fig. 4.). Pour plate method was applied with selective medium for each corresponding bacterial sp. All plates were incubated at 37^{o}C for 24h and bacterial colonies were counted (Fig.5.).

Fig.3. The complete processed samples in screw caped sterile bottles.

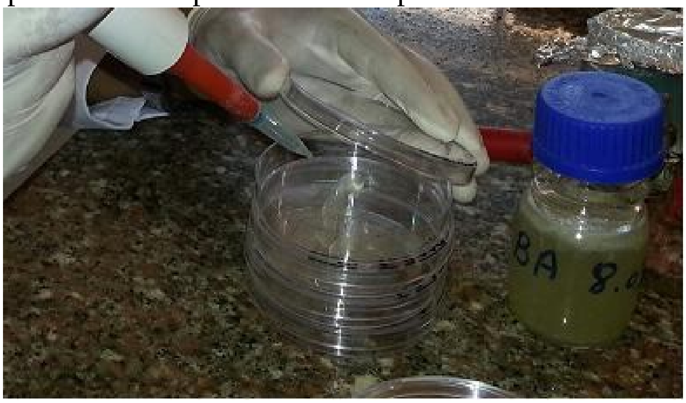

Fig.4. The inoculation technique for each collected sample.

Fig.5. Pour plate method was used for the inoculated petri-dishes.

2.3.3. Heavy metal analysis

The stripped Venus clam, *Chamelea gallina* soft tissues were analyzed for the levels of the eight heavy metals (Cu, Cr, Mn, Zn, Pb, Cd, Fe and Hg) and compared to authorities maximum permissible limits of different organizations of different countries.

2.3.3.1. Sampling sites:
Clam samples analyzed for heavy metals were selected from 12 transects representative of the study area along the Mediterranean coast between Rasheed and Burullus from 31.45874 N and 30.50054 E to 31.59596 N and 30.94383 E as shown in Table 1. Sample codes (Target Haul codes) in Table 4 will be shortened in the **Results** section by removing the first two letters "RB" from the left to fit in the tables and figures. For example, the first sample in Table 4 will be written as "A01.3" instead of "RBA01.3".

Table 1. Samples codes (Target Hauls Codes), geographical coordinates and depth of collection of the Striped Venus Clam *Chamelea gallina* for heavy metal analysis.

Target Hauls Code	PrHN°	GPS Coordinates				DEPTH (m)	
		START		END			
		LatN	LongE	LatN	LongE	START	END
RBA01.3	**3**	31.45874	30.50054	31.46004	30.5004	2.5	3
RBB01.1	**4**	31.46443	30.49735	31.46206	30.49884	6	5.2
RBA02.2	**11**	31.46659	30.54306	31.46746	30.54235	3	3
RBB02.2	**14**	31.47386	30.54023	31.47505	30.54325	5.2	5.6
RBA03.2	**20**	31.47787	30.59043	31.47795	30.59260	3.5	3.8
RBA03.3	**21**	31.48032	30.59477	31.48001	30.59580		3.9
RBA04.3	**30**	31.48686	30.63075	31.48693	30.62988	3.5	3.5
RBB04.3	**33**	31.49465	30.62794	31.49461	30.60320	5.4	5.3
RBC04.2	**35**	31.50511	30.62469	31.50566	30.62858	8.5	8
RBB05.1	**40**	31.51027	30.67956	31.50821	30.67992	6.3	
RBA06.1	**46**	31.50905	30.70628	31.51019	31.70818	3.2	3.3
RBA06.2	**47**	31.51151	30.71340	31.51224	30.71558	3.2	3.5
RBA06.3	**48**	31.51390	30.72055	31.51513	30.72255	3	3.4
RBB06.2	**50**	31.52013	30.76715	31.51854	30.70563	5.8	5.8
RBA08.1	**64**	31.53984	30.80530	31.53914	30.80721	3.5	3.2
RBB08.1	**67**	31.54062	30.79966	31.54445	30.80271	5.5	5.2
RBB08.2	**68**	31.54550	30.79247	31.54664	30.79865	6	5.5
RBB08.3	**69**	31.54501	30.78217	31.54621	30.78513	6.4	
RBB09.1	**76**	31.56298	30.84907	31.56477	30.85589	6.7	6
RBB09.2	**77**	31.55564	30.82896	31.55183	30.82973	6.4	5
RBB09.3	**78**	31.55484	30.82352	31.55260	30..82228	6.3	6
RBC10.3	**90**	31.57656	30.86324	31.57180	30.86166	8.8	8.5
RBB11.1	**94**	31.57673	30.89978	31.57768	30.90681	6.5	6.9
RBB12.1	**103**	31.58123	30.93228	31.58337	30.93468	5.9	6.2
RBB12.2	**104**	31.58313	30.93820	31.58193	30.93573	6.4	6.2
RBB12.3	**105**	31.58628	30.94037	31.58796	30.94400	6.5	6.7
RBC12.1	**106**	31.59367	30.94094	31.59596	30.94383	9	8.6

2.3.3.2. Clam processing:

The clams for biometric analysis that were assigned for heavy metal analysis were of different numbers according to the available number of clams from each station after taking condition index and microbiology samples. Therefore, When clams from certain station were not enough, the available clams from the three replicates of the same station were pooled and analyzed as one sample (e.g. RBA 6.1+ 6.2+ 6.3 and RBB 9.2 + 9.3). Clams for each sample were cleaned, shucked with a plastic or Teflon knife to avoid contamination. Clam soft tissues pooled from each sample were homogenized and weighed (average weight 34.72 g; min 6.54 in sample RBB 12.1; max 105.62 g in Sample RBA 02.2).

Since not all samples were enough to provide 15 g as was proposed in the methodology part of the proposal, similar aliquots of about 5 gm from each sample were dried at 105^{o} C until constant weight for analyzing the other seven metals on dry weight basis (1 g powder used) and for calculation of water content and dry/wet ratio for further calculation of concentration in on wet weight basis. Additionally, 5 g aliquot of the wet sample was kept aside in plastic bottle for wet tissue Hg analysis (except in samples with total tissues weight available less than 10 g in which the sample was divided between drying and Hg) .

Samples (wet for Hg and whole dry powder for the other metals) were sent to NIOF central lab for further analysis and measurement. Water content was calculated and heavy metals concentrations were calculated on both dry weight and wet weight basis for comparisons with permissible limits for different references and guidelines.

2.3.3.3. Heavy metal analysis in the NIOF Central Lab.

Samples were stored in polyethylene bags at -20^{o} C until analysis. The extraction of Cu, Zn, Cr, Cd, Pb, Mn, and Fe as well as Hg was performed by using acid digestion bombs (with a Teflon cup) and concentrated nitric acid (IAEA, 1985).

The following heavy metals in parts per million (Cu, Cr, Mn, Zn, Pb, Cd, Fe and Hg) were measured using SHIMADZU Atomic Absorption Spectrophotometer AA-6800 equipped with GTA furnace and GVA cold vapour unit as well as flame unit(detection limits in Table 5) Glassware utilized were soaked on aqua- regia, rinsed with milli–Q water .The reagent utilized were of high purity, appropriate for heavy metals analysis. The standards were prepared from stock solutions (Merk) A calibration curve of each heavy metals was prepared prior to every batch of analysis.

The accuracy of measurements was tested using certified reference material ERM-CE278 (mussel tissue). Results (Table 5) were comparable to certified values and the standard deviations were low, showing feasibility of the used method. Detection limits are also included in Table 2. Co and Ni were not measured for technical reasons related to Central Lab.

Table 2. Concentrations (average ± standard deviation) of heavy metals mg/kg in the reference material ERM-CE278 (mussels tissue) as compared to certified values and the method detection limits.

Metal	ERM-CE278 (Mussel Tissue)		Detection limit (ppm)
	measured(mg/kg)	certified value(mg/kg)	
Cu	9.6 ± 0.35	9.45 ± 0.13	0.008
Cr	0.69 ± 0.14	0.78 ± 0.13	0.015
Mn	7.41 ± 0.43	7.69 ± 0.23	0.01
Zn	81.5 ± 0.71	83.1 ± 1.7	0.002
Pb	1.98 ± 0.14	2.00 ± 0.04	0.05
Cd	0.345 ± 0.003	0.348 ± 0.007	0.005
Fe			0.025
Hg	0.189 ± 0.03	0.196 ± 0.009	0.01 (ppb)

2.4 Data analysis

2.4.1. Biological Analysis

Morphometric relationships between flesh weight (FW) and shell weight (SW) and among total weight (TW), height (H), thickness (T) and width (W), were analysed according to the classic scaling (allometric) log linear model

$$\log_e Y = \log_e a + b * \log_e X$$

where SW and W are considered as the independent (*X*) variables

For each sample the swept area was calculated by first calculating the distance between the start and end of the GPS co-ordinates using the haversine formula to calculate the great-circle distance between two points – that is, the shortest distance over the earth’s surface. Then the swept area was estimated based on the distance travel and the width of the blade of the dredge. This was important so that the data could be standardized per km^2. The density indicator (DI in N/km^2) and biomass indicator (BI kg/km^2), for each species, per replicate sample was then calculated according to the swept area method (after Sparre and Venema, 1998).

The biomass and density index were then subsequently geo-referenced using the GPS position recorded at the midpoint between the start and end co-ordinates of the survey transects and mapped with the Geostatistical Analyst package of ESRI ArcGIS version 10.0 using the Egyptian coastline as a base line and a buffer area encompassing the survey area extents. Using the ordinary kriging interpolation method, a set of maps on the biomass and density indexes distribution of *Anadara polii*, *Chamelea gallina*, *Nassarius mutabilis*, *Neverita josephinia*, and *Solea aegyptiaca* were plotted in order to facilitate the interpretation of the results. During the interpolation, attempts were made to identify major trends and anisotropy in the sampled values (i.e., those resulting by the distance from the coast and the bottom depth). The results have to be considered only indicatives as the predicted standard errors are relatively high and by no means they represent the best possible interpolation results. Further analysis could results in better estimations of biomass and density index distribution

From the biological information collected on *C. gallina* sex ratio by size class was calculated. Due to the low number of sex information, data from the February trials was also used. Shell length frequency distributions (LFD) were also produced per station, which were then standardized per km^2. Based on the a and b parameters of the length frequency distribution, a weight frequency distribution was also produced, in order to improve the visualisation of the weight of the product by size class. The length frequency distribution was converted into an age distribution using the age slicing procedure (Sparre and Venema, 1998) using the software Length Frequency Distribution Analysis (LFDA; Kirkwood *et al*., 2001; Hoggarth *et al*., 2006).

Using the standardised length frequency distributions (LFDs) growth parameters according to the von Bertalanffy growth curve as the growth model was estimated using the Elefan method (Sparre and Venema, 1992) with the LFDA software (Kirkwood *et al*., 2001; Hoggarth *et al*., 2006). These parameters were then compared to growth parameters available from literature.

Total mortality rate was estimated using the length converted catch curve method and the von Bertalanffy growth curve as the growth model (Sparre and Venema, 1992). Total mortality rate (Z) is obtained by fitting a regression line through the right-hand side of a length-converted von Bertalanffy catch curve. The software LFDA (Kirkwood *et al*., 2001; Hoggarth *et al*., 2006) was used to estimate Z. Since there is no exploitation of the target species annual natural mortality rate (M) was equal to the total mortality rate (Sparre and Venema, 1992).

The maximum theoretical sustainable yield was estimated by applying the Gulland's formula equation related to the dynamic biomass (or "surplus") models (Sparre and Venema, 1992).

$$Y_{(MSY)} = X*M*B_\infty$$

where M and B_∞ denote the natural mortality and the "virgin" biomass and X is a multiplier which ranges between 0.2-0.5 according to the populations, but always chosen in order to reduce the risk of a collapse of the resource taking into account recruitment variability and the constraint that spawning biomass should be maintained at 20% of the pristine level (Clark, 1991). MSY was calculated for the commercial species using a multiplier of 0.5, in the equation.

2.4.2. Socio-Economic analysis

From the estimated value of MSY the potential catch was calculated based on the local market price of the products

In order to estimate the value of the catch that a vessel requires in order to have a reasonable daily salary for the fishing activity per fisherman, the income and cost structure of the fleet segment trawl 12 - 18 m was used as a reference (FAO EastMed 2014). The value of the catch that a vessel requires in order to have a reasonable daily salary for the fishing activity per fisherman was also estimated. Based on this information three scenarios were devised with a potential daily revenue by maintaining the status quo or the same daily revenue of a 12 - 18 m trawler, and an increase of 20 and 30 % of the daily revenue.

3. Results

3.1. Catch data

A total of 34 species including 11 crustaceans, 5 bivalves, 5 gastropods, 1 Sepiidae, 2 echinoderms, 1 polychate and 7 fish species were identified. Bivalves were the most common taxon, both in terms of number (DI) and in weight (BI), followed by gastropods (Tables 3 & 4). The most abundant species was the gastropod *Neverita josephinia*, followed by the bivalve *Anadara polii*, the changeable nassa *Nassarius mutabilis*, the swimming crab *Charybdis longicollis*, the starfish *Astropecten* sp., and finally the clam *Chamelea gallina*. With respect to the commercial potential of the species caught, *Chamelea gallina*, is commercially important in Europe, with a high value, while the dog whelk or changeable nassa *Nassarius mutabilis* is considered as a delicacy in Italy, also with a high value. Bivalves of the genus *Anadara* have a commercial value worldwide but did not have a great success in Mediterranean markets due to its red or bloody colour. The gastropod *Neverita josephinia* has also a limited commercial value in Italy. The commercial Egyptian sole, *Solea aegyptiaca* was a minority in the catch but with sufficient quantities to have a commercial value.

Table 3. List of taxa identified in the catch, showing the standardized Biomass Index (kg/km^2) per depth stratum A (3 m), B (6 m), and C (9 m), and the standard deviation.

		Biomass Index (kg/km^2)			**Standard deviation**		
Group	**Species**	**A**	**B**	**C**	**A**	**B**	**C**
Bivalvia	*Anadara polii*	5363	3746	1425	7467	5462	1649
	Chamelea gallina	668	571	164	810	676	454
	Donax trunculus	870	3		998		
	Mactra stultorum	3432	33	4	8562	22	1
	Paphia sp.	8					
Gastropoda	GASTROPOD 1	146	64	129		86	143
	Nassarius gibbosulus	118	70	34	141	85	48
	Nassarius mutabilis	253	706	976	276	620	1035
	Nassarius reticulatus	46	30	54	80	49	59
	Neverita josephina	9198	2639	580	11448	3624	745
Sepiidae	*Sepia officinalis*			132			109
Echinoderms	*Astropecten* sp.	624	277	127	857	233	127
	Echinocardium sp.			91			133
Crustacea	*Charybdis longicollis*	426	334	292	390	209	188
	CRAB1 sp.	7		12			9
	CRAB2 sp.			15			
	Ilia nucleus	197	501	215	302	515	287
	Metapenaeus japonicus	39	37	27		22	14
	Metapenaeus monocerus	22	11	13	0	5	7
	Portumnus pelagicus	53	233		35	274	
	Metapenaeus stebingi	41	53	31	39	52	44
	Squila mantis	378	33	78			111
	Diogenes pugilator	35	72	40	30	66	31
	Treachypenaeus sp.		26	7		32	3
Polychaeta	*Polychaeta* sp.	3	1	30		0	65
Fish	*Chelidonichthys lucerna*	33	36	30	11	7	35
	Goby sp.	39	23	44	33	23	39
	Solea aegyptiaca	339	195	139	289	166	115
	Terapon puta	65	80	45	61		39
	Tracurus mediteraneus			69			
	Raja sp.	30	91	72			92
	Ophichthidae sp.		60	14			

Table 4. List of taxa identified in the catch, showing the standardized Density Index (N/km^2) per depth stratum A (3 m), B (6 m), and C (9 m), and the standard deviation.

		Density Index (N/km^2)			**Standard deviation**		
Group	**Species**	**A**	**B**	**C**	**A**	**B**	**C**
Bivalvia	*Anadara polii*	81290	79057	44340	109935	160547	61342
	Chamelea gallina	109838	76503	22519	133227	93584	57624
	Donax trunculus	433235	6173		278298		
	Mactra stultorum	608125	17099	1602	1457757	10552	360
	Paphia sp.	3915					
Gastropoda	GASTROPOD 1	5842	3353	8464		2099	8339
	Nassarius gibbosulus	52513	32840	16548	53789	41603	15133
	Nassarius mutabilis	65292	191288	326785	67717	182493	321557
	Nassarius reticulatus	18441	10446	20253	31791	7826	16285
	Neverita josephina	2121369	525493	148984	2271240	622512	251401
Sepiidae	*Sepia officinalis*			878			821
Echinodermata	*Astropecten* sp.	125461	70683	36548	170579	53799	42056
	Echinocardium sp.			11281			14046
Crustacea	*Charybdis longicollis*	67979	44861	40638	56824	28766	26487
	CRAB1 sp.	1099		1734			1173
	CRAB2 sp.			1514			#DIV/0!
	Ilia nucleus	27032	69308	32255	39128	69695	44809
	Metapenaeus japonicus	7749	3158	1777		2961	595
	Metapenaeus monocerus	3873	2015	2076	2381	1089	1654
	Portumnus pelagicus	2858	4306		827	2011	
	Metapenaeus stebingi	6307	5346	3962	7196	4613	4646
	Squila mantis	6300	3019	1806			877
	Diogenes pugilator	17709	35839	20142	15044	32990	13784
	Treachypenaeus sp.		3140	1489		2856	637
Polychaeta	*Polychaeta* sp.	3179	1170	8969		836	12048
Fish	*Chelidonichthys lucerna*	2839	3256	2349	441	1339	910
	Goby sp.	4137	3632	3595	3060	3403	1456
	Solea aegyptiaca	6067	3351	2697	4309	2286	1947
	Terapon puta	2518	1592	1594	702		187
	Tracurus mediteraneus			1373			
	Raja sp.	1973	3019	1877			1228
	Ophichthidae sp.		4003	1373			

3.1.1 Spatial distribution of the most important species

Distribution maps of Biomass and Density indices of *Neverita josephinia*, *Anadara polii*, *Nassarius mutabilis*, *Chamelea gallina* and *Solea aegyptiaca* were plotted in order to have a spatial representation of biomass and abundance within the bay under study. Bubble plots were plotted which represent the biomass and density distribution per species. The values plotted were the relative biomass and density of the particular species. The interpolation method then provided information on the relative biomass and density among the species.

Chamelea gallina was mostly present on the Western part of the bay with a bank on the centre- east (Fig 6).

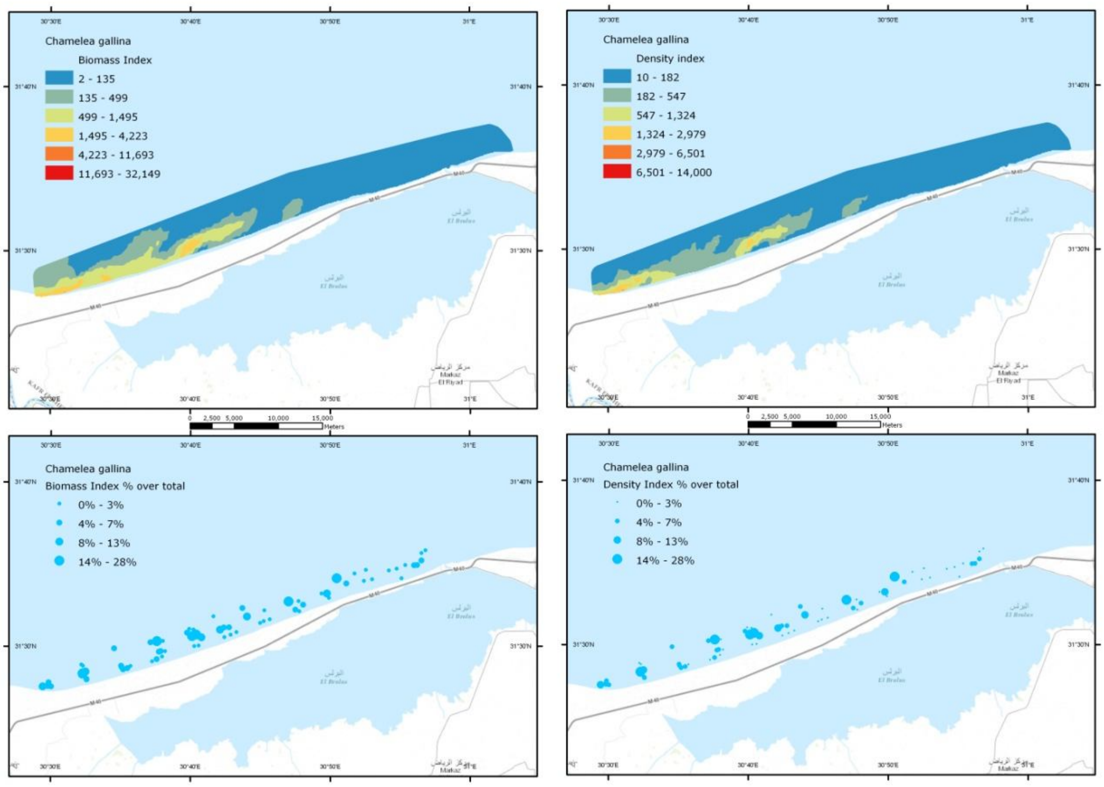

Fig. 6. Spatial distribution maps showing the Biomass and Density indices of *C. gallina* with the bubble and the interpolation plots.

The bivalve *Anadara polii* was mostly abundant on the centre east part of the bay (Fig 7), as well as the Egyptian sole (Fig. 8). The whelk *Nassarius mutabilis* was mostly common on the Western part of the bay and in the relatively deeper waters of the surveyed area (Fig. 9).The gastropod *Nevertia josephinia* was present throughout the bay, mostly restricted to the shallower waters (Fig. 10).

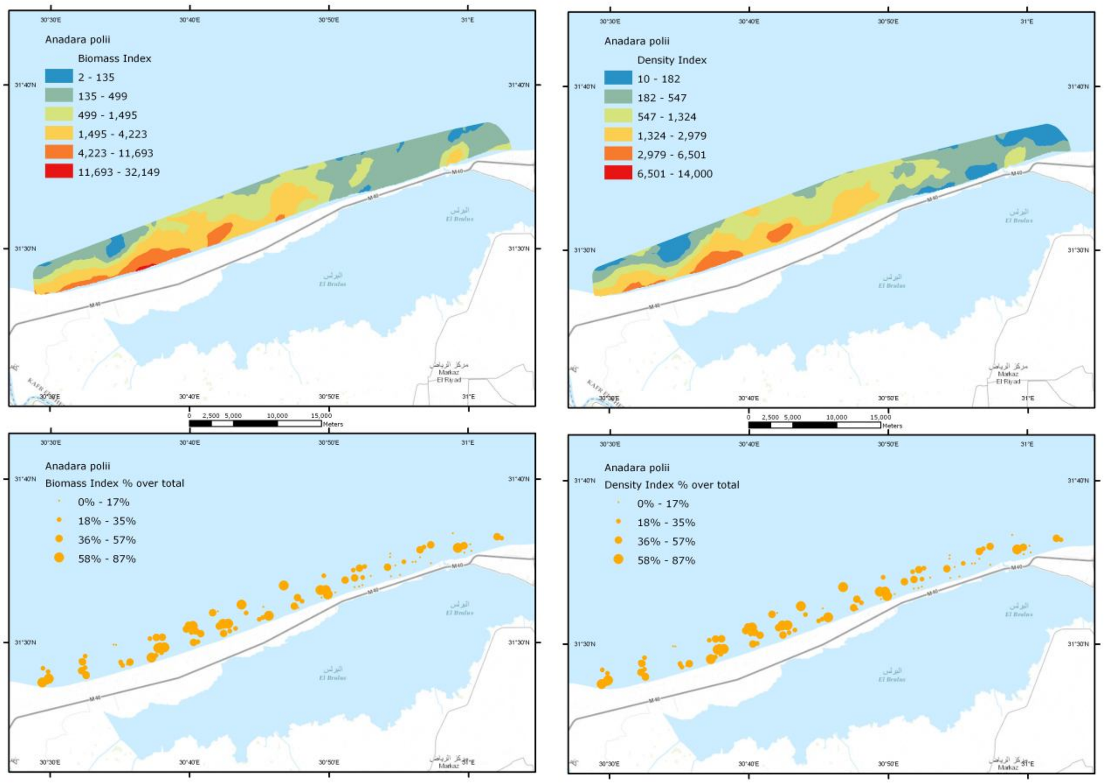

Fig. 7. Spatial distribution maps showing the Biomass and Density indices of *A. polii* with the bubble and the interpolation plots.

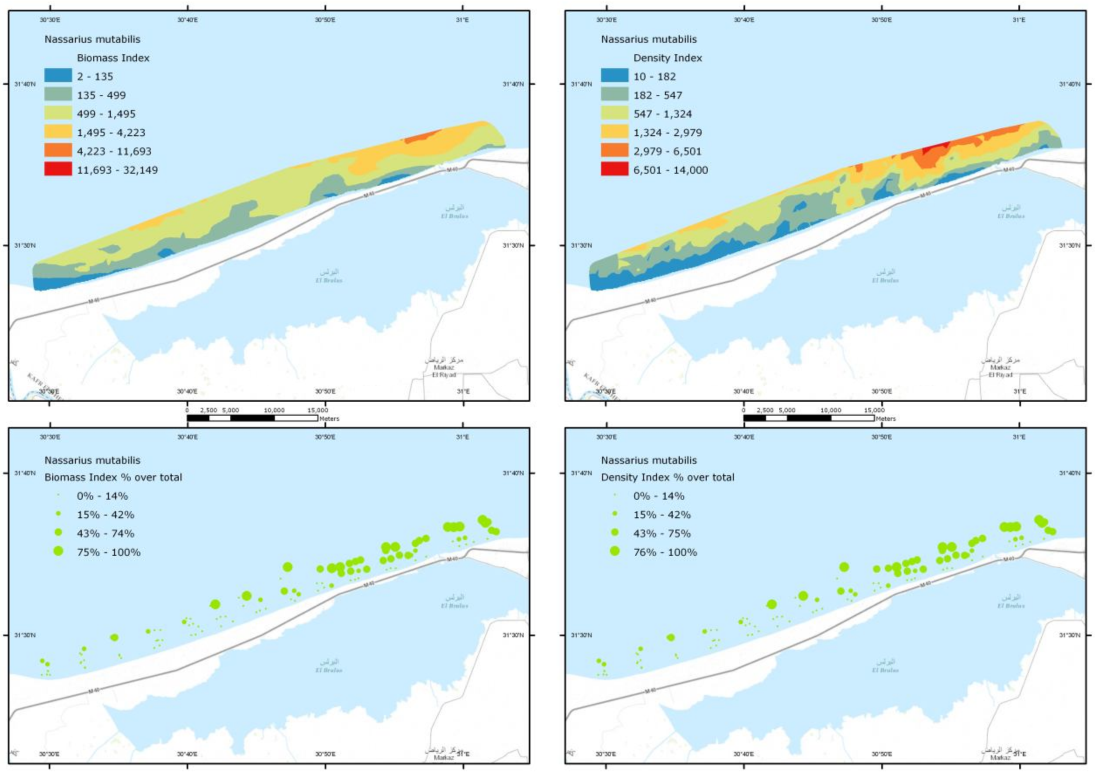

Fig. 8. Spatial distribution maps showing the Biomass and Density indices of *N. mutabilis* with the bubble and the interpolation plots.

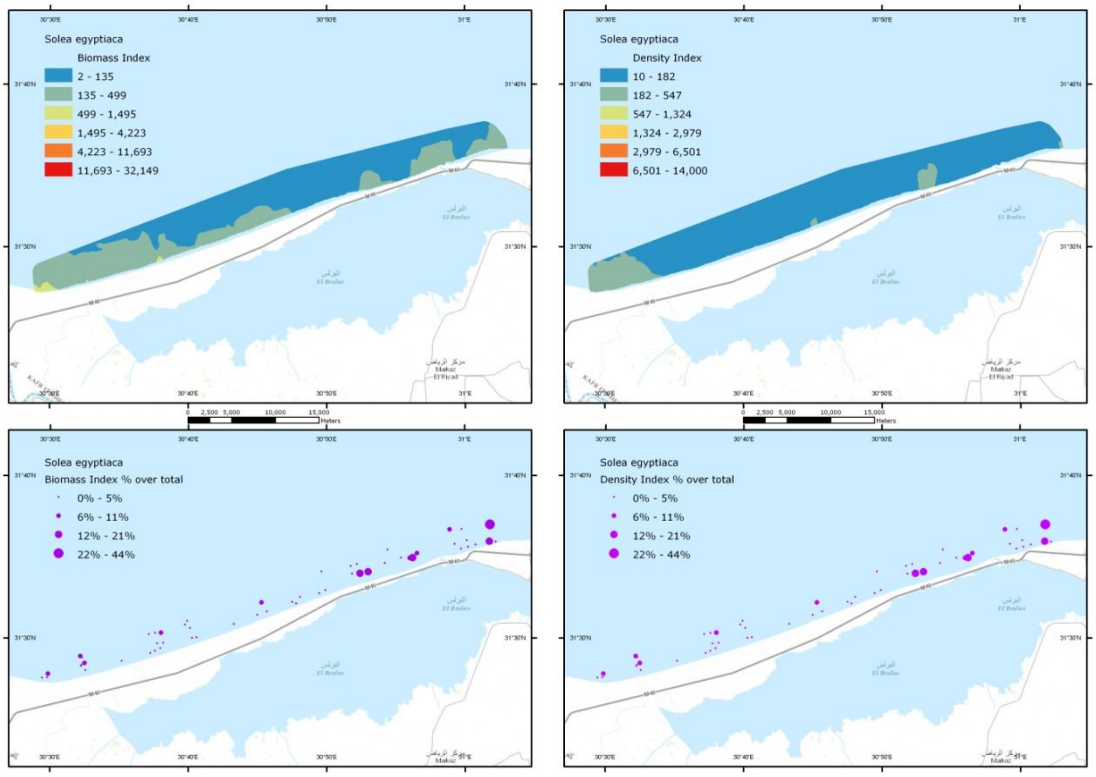

Fig. 9. Spatial distribution maps showing the Biomass and Density indices of *S. aegyptiaca* with the bubble and the interpolation plots.

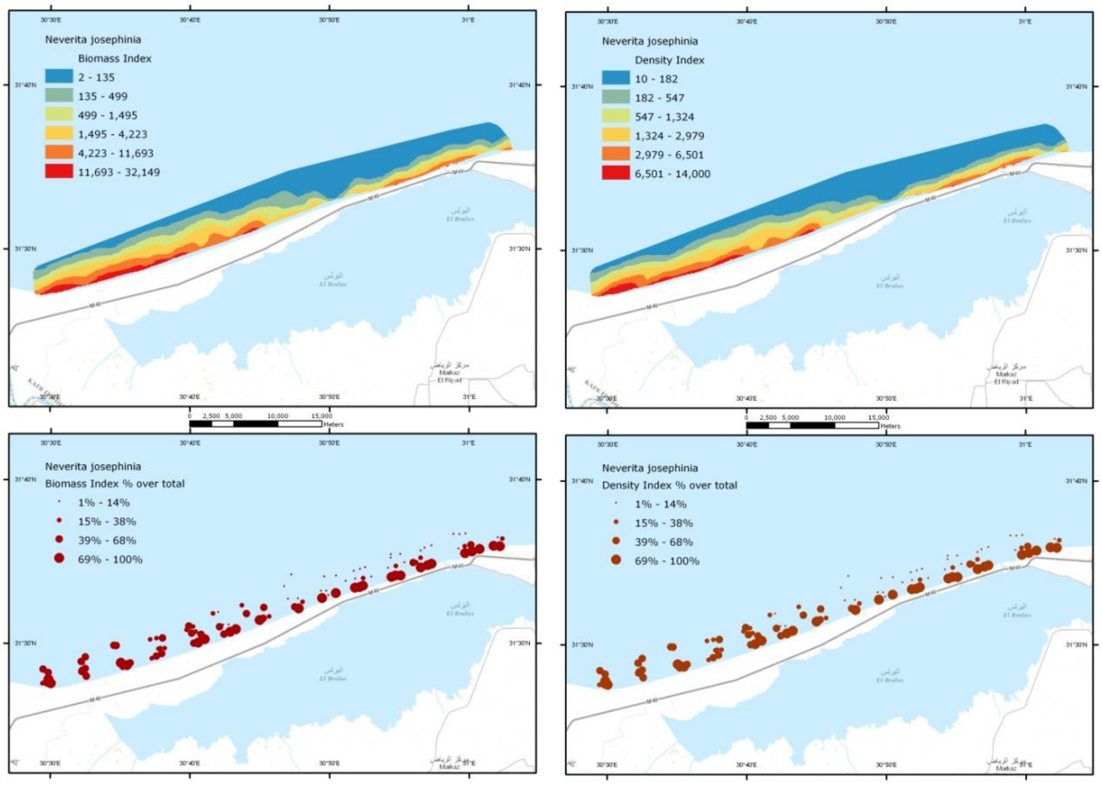

Fig. 10. Spatial distribution maps showing the Biomass and Density indices of *N. josephinia* with the bubble and the interpolation plots.

3.2. Biological characteristics of *C. gallina*

The bivalve *C. gallina* was found in 75 out of 126 stations sampled with a total of 2931 individuals and a total weight of 21.64 Kg. Out of these individuals, 1774 specimens were transported to the laboratory and total weight (TW), shell height (H), shell thickness (T) and shell width (W) were measured (table 5). For 269 specimens flesh weight (FW), shell weight (SW) and condition index were also determined. Sex was only determined for 86 specimens due to the difficulty in determining it macroscopically. In transects 10 - 14 several dead shells of *C. gallina* were encountered.

Table 5. Mean, minimum, maximum and number of specimens for which several morphometric characteristics, were collected.

Values	Average	STDev	Min	Max	N
Shell length (mm)	26.87	4.42	3.72	39.10	1774
Thickness (mm)	13.73	2.80	5.70	31.18	1774
Shell width (mm)	23.64	4.72	9.10	92.68	1774
Total weight (g)	7.05	4.13	1.56	21.25	1774
Flesh weight (g)	1.35	0.83	0.21	4.41	269
Shell weight (g)	5.30	3.12	1.12	14.75	269

3.2.1 Morphometric relationships

The logarithmic form used to compare the different morphological characteristics (table 6) shows that total weight vs shell length were significantly positive allometric (t-test; $P < 0.05$), while width vs carapace length showed a negative allometric growth (t-test; $P < 0.05$). Isometric growth was only encountered between thickness and shell length (t-test; $P < 0.05$). The relationship between flesh weight and shell weight was negatively allometric (t-test; $P < 0.05$) however the r value is relatively low which shows a poor correlation.

Table 6. Results of the morphometric relationships of *C. gallina*, showing also the resultant a and b parameters, the r coefficient, and the growth relationship.

LN Y	LN X	LN a	a	b	r^2	N	Growth
Total Weight	Shell length	-9.024	0.000121	3.3009	0.95	1629	+ve allometric
Width	Shell length	0.092	1.096803	0.9318	0.86	1787	-ve allometric
Tickness	Shell length	-0.854	0.425666	1.0543	0.81	1787	isometric
Flesh Weight	Shell weight	-1.171	0.309964	0.8651	0.73	396	-ve allometric

For the L-W relationship the ***a*** and ***b*** parameters indicated that the relationship was highly significant with a Spearman's rank order correlation coefficient (r_s) of 0.95 (t-test; $P < 0.01$) for both sexes combined. This procedure also assisted in identifying and removing outliers. The determined ***a*** and ***b*** parameters from the length-weight relationship are shown in table 7 with plotted logarithmic form of the L-W relationship in figure 11.

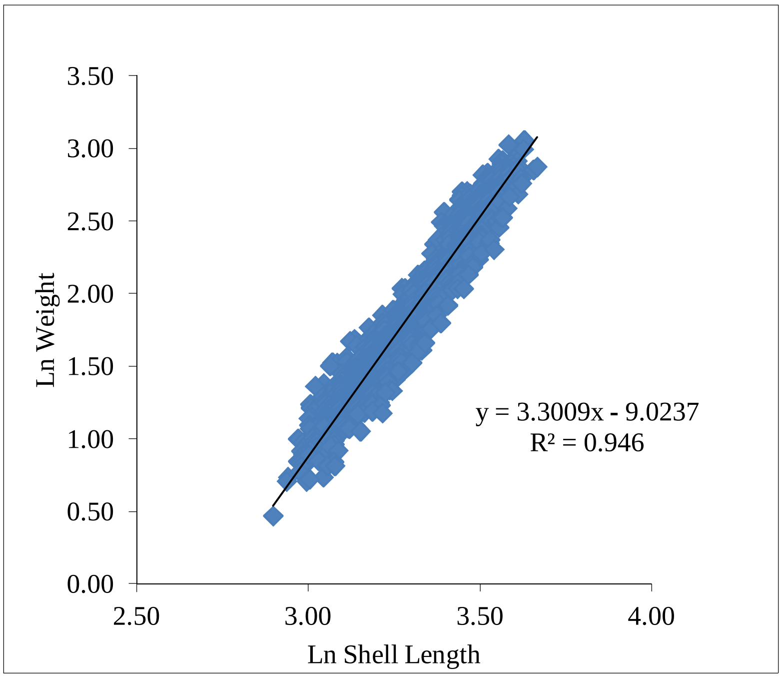

Fig. 11. The relationship between the natural logarithm of total weight (g) and shell length (mm) of the Clam *Chamelea gallina*.

3.2.2 Sex ratio by length class

The sex ratio by size class can be seen in figure 12. The total number of sex determinations was 236. Overall the sex ratio was 0.52 showing an almost equal number of males and females.

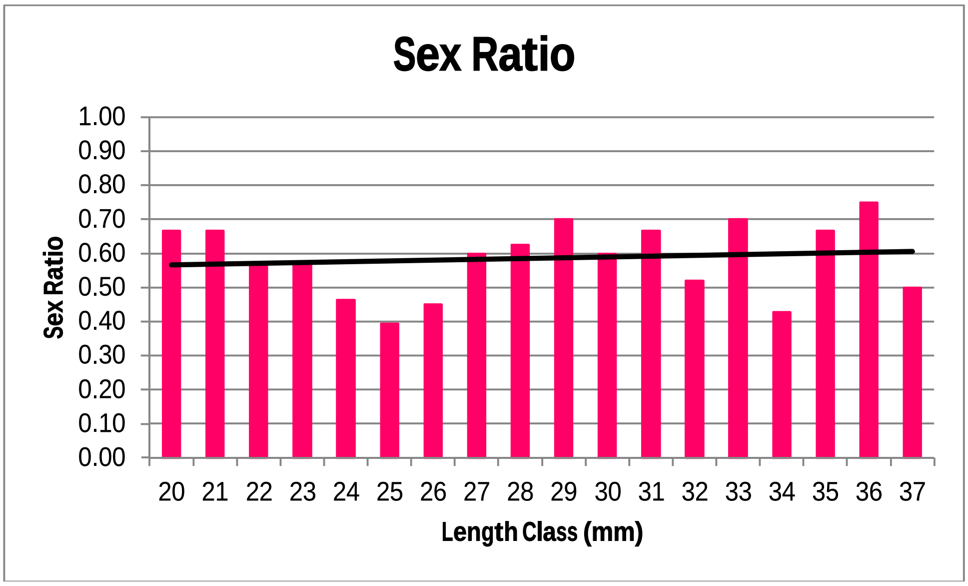

Fig. 12. Sex ratio by size for the clam *C. gallina*.

3.2.3 Condition index

The condition index (CI) has long been used for biological and commercial purposes (Venkataraman & Chari 1951, Baird 1958). These are closely related to the gametogenic and nutrient reserve storage-consumption cycles, and thus to meat quality (Gabbott 1975). In industrial settings, CI has been adopted in international trade as a standard criterion to select the best product. It is also recognized as a useful biomarker reflecting the ability of bivalves to withstand adverse natural and/or anthropogenic stress (Mann 1978, Bressan & Marin 1985, Fernandez-Castro & de Vido de Mattio 1987). Hence, the CI may be considered a measure of "fatness" and "marketability" of a commercially exploited species and, together with proximate biochemical composition, is probably the most practical and simple method of monitoring gametogenic activity (Okumus & Stirling 1998).

During the present study, a total of 270 specimens were examined for understanding the condition index. On each sampling occasion, 30 specimens of commercial size of *Chamelea gallina* were collected in order to calculate the condition index. The condition index was analyzed and calculated for each sample (A3.01, A4.01, B1.01, B2.01, B3.03, B4.02, B5.01, and C4.02).

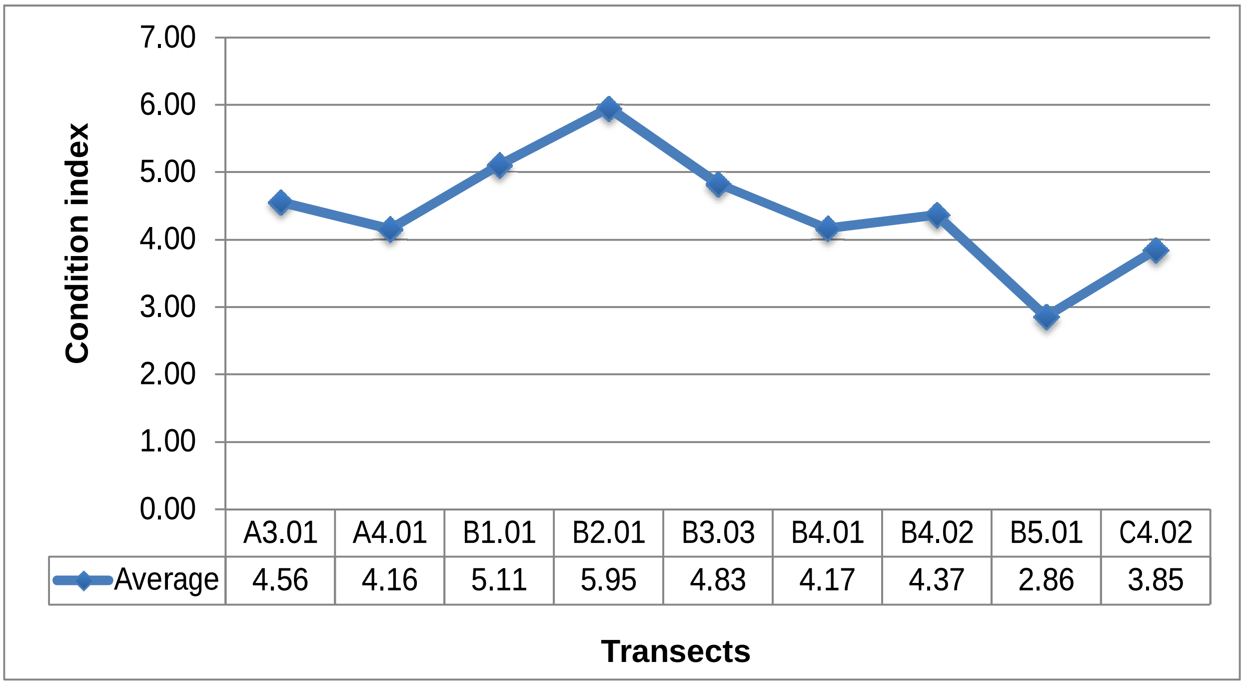

Fig. 13. Average condition index of *Chamelea gallina*

The present results showed that the condition index of *chamelea gallina* was the highest in B2.01 (5.95), and the lowest in B5.01 (2.86) as shown in Figure 13. While in transect (A4.01, A3.01) they were (4.16 and 4.56) respectively. On the other hand, the transects (B2.01, B1.01, B3.03, B4.02, B4.01 and B5.01) were recorded 5.95, 5.11, 4.83, 4.37, 4.17, and 2.86). Regarding the transect (C4.02), it represented (3.85).

In the present study, the condition index of *Chamelea gallina* showed the highest values reported in both stations (B2.01 and B1.01), and lowest value in (B5.01). Larger-sized groups showed smaller condition index throughout the study, while the small-sized groups showed higher condition index.

3.3. Assessment of the resources

In Egypt this was the first scientific record of the stock of *Chamelea gallina*. At present its distribution along the entire Egyptian coast is unknown, however its distribution in the bay under study, that is, between Rasheed and Burullus has been considerably covered by the present survey. The distribution can be seen in figure 15. In this respect the stock identity for the purposes of this study, will be the stock of *Chamelea gallina* between Rasheed and Burullus. One has to consider that if other populations of *C. gallina* exist in neighbouring bays this will surely have an impact on the population dynamics of this sub-population. The stock parameters which have been calculated in this report have taken this into consideration, which however due to the relatively unknown adjacent areas, the present analysis was undertaken assuming the sub-population sampled is the unit stock of *C. gallina.*

3.3.1 Growth

The Growth and age of the clam *Chamelea gallina* has been extensively studied using several aging methods including modal progression analysis of length-frequency distributions, shell surface growth rings and shell internal bands (shell cross-sections and acetate peel replicas). A good comparison of the methods used and results obtained is given by Gaspar *et al*., 2004 (Figure 14).

Using the data obtained from this study, an attempt was made to estimate growth parameters using the Elefan method with the LFDA software (Kirkwood *et al*., 2001; Hoggarth *et al*., 2006). The biological parameters obtained were the following:

$$\mathbf{L_\infty = 38.84 \quad K = 0.737 \quad to = -0.26}$$

However the results obtained show a K value which is quite high when compared to the results obtained by the studies described in Gaspar *et al*., 2004. The use of size–frequency distributions to estimate population growth rates is not very reliable when annual recruitment is extensive and the individual growth rate is variable, which is the case for *C. gallina* (Gaspar *et al*., 2004). In this respect the authors decided to use biological parameters published from literature which although originate from another area, more accurate methods to determine the von Bertallanfy growth parameters such as shell internal bands were used. The L_{max} in the present study was 39.1 so biological parameters with a similar L_{max} (40.0) were chosen and are listed below:

L_∞ = 38.95   K = 0.47   (Gaspar *et al*., 2004)

For the a and b parameters of the length weight relationship the ones obtained from this study were used:

a = 0.000120519   b = 3.3009

Location	Method	Age (years)											
		L_1 (mm)	L_2 (mm)	L_3 (mm)	L_4 (mm)	L_5 (mm)	L_6 (mm)	L_7 (mm)	L_8 (mm)	L_{max} (mm)	L_∞ (mm)	K	Author
Northern Marmara Sea, Turkey	Surface rings	16.15	22.44	26.53	29.20	30.93	–	–	–	34.5	34.17	0.43	Deval & Oray (1998)
Northern Marmara Sea, Turkey	Acetate peels	15.3	20.8	24.7	27.3	29.2	30.5	31.4	–	34.3	33.46	0.37	Deval (2001)
Middle Adriatic, Ancona, Italy	Length–frequency	17	25	–	–	–	–	–	–	50	–	–	Froglia (1975, 1989, 2000)
Middle Adriatic, Ancona, Italy	Acetate peels	17	25	30	34	38	39	42	45	49	–	–	Polenta (1993)
Western Adriatic, Ancona, Italy	Thin sections	–	–	–	–	–	–	–	–	–	41.6	0.48	Arneri *et al.* (1995)
Western Adriatic, Neretva Estuary	Thin sections	–	–	–	–	–	–	–	–	46	39.5	0.52	Arneri *et al.* (1997)
Middle Adriatic, Fano, Pesaro, Italy	Surface rings	15	24	30	33	35	–	–	–	46	–	–	Poggiani *et al.* (1973)
South Adriatic, Bari, Italy	Surface rings	15	23	31	35	38	42	–	–	47	–	–	Marano *et al.* (1982)
Marseille Gulf, Mediterranean, France	Length–frequency	13	23	–	–	–	–	–	–	23	–	–	Bodoy (1983)
Marseille Gulf, Mediterranean, France	Surface rings	21	32	–	–	–	–	–	–	32	–	–	Massé (1972)
Western Mediterranean, Ebro, Spain	Surface rings	18	24	28	31	–	–	–	–	41	–	–	Vives & Suau (1962)
Western Mediterranean, Valencia, Spain	Acetate peels	20	25	28	31	–	–	–	–	–	36.12	0.35	Ramón & Richardson (1992); Ramón (1993)
Western Mediterranean, Valencia, Spain	Length–frequency	–	–	–	–	–	–	–	–	–	40.05	0.40	Ramón (1993)
Bahía de Mazarrón, Mediterranean, Spain	Surface rings	17–21	22–26	–	–	–	–	–	–	–	–	–	Cano & Hernández (1987)
Atlantic, Huelva, Spain	Surface rings	11	23	29	–	–	–	–	–	–	–	–	Royo (1984)
Algarve coast (southern Portugal)	Surface rings	19.2	28.8	32.7	36.0	37.5	–	–	–	40	37.55	0.71	Present study
Algarve coast (southern Portugal)	Acetate peels	17.3	25.3	30.7	33.6		–	–	–	40	38.95	0.47	Present study
Algarve coast (southern Portugal)	Length–frequency	18.2	24.7	29.5	33.0	35.5	–	–	–	40	42.15	0.32	Present study

Fig. 14. Results and comparisons of the growth of *C. gallina*, including length at age, K and L_∞ values obtained with distinct ageing techniques in different geographical areas; data from Gaspar *et al*., 2004.

3.3.2 Mortality rate

Total mortality rate was estimated using the length converted catch curve method and the biological parameters from Gaspar *et al*., 2004. The software LFDA (Kirkwood *et al*., 2001; Hoggarth *et al*., 2006) was used to estimate Z.

Since at present there is no exploitation of the species Z is equal to M (natural mortality rate).

The value obtained for Z or in this case M is: **1.02**

3.3.3 Length Frequency analysis

The standardized length frequency distribution is shown in Figure 15.

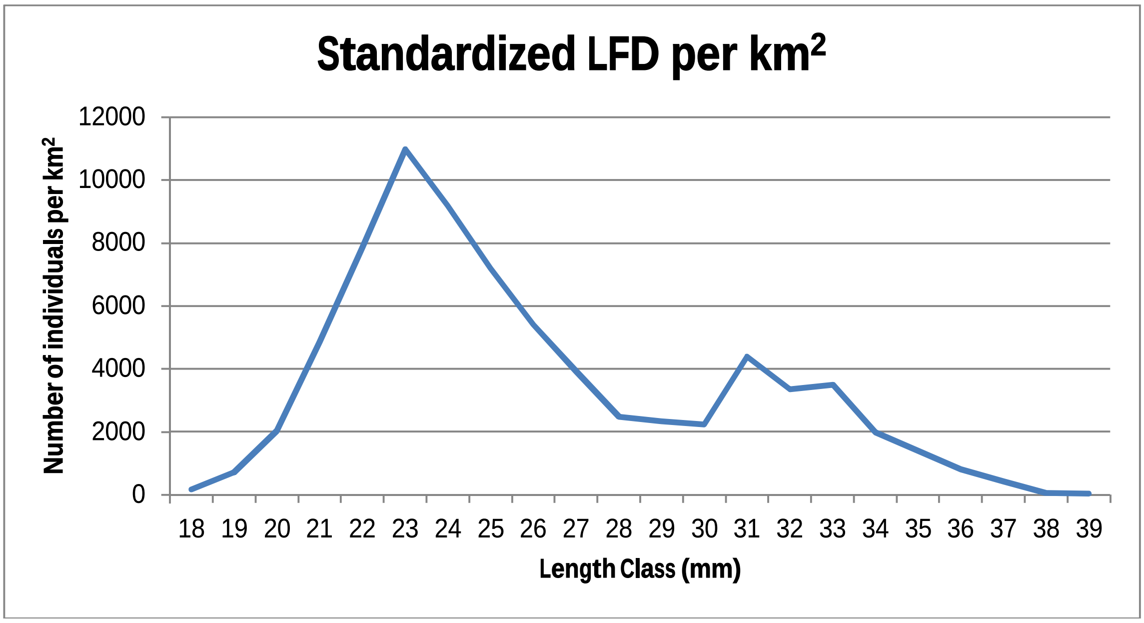

Fig. 15. Standardized length frequency distribution of *C. gallina*.

The length frequency distribution was converted into an age distribution using the age splicing procedure and the von Bertallanfy growth parameters. This yielded seven age groups and the age frequency distribution in figure 16. Most of the individuals are present in ages 1 and 2.

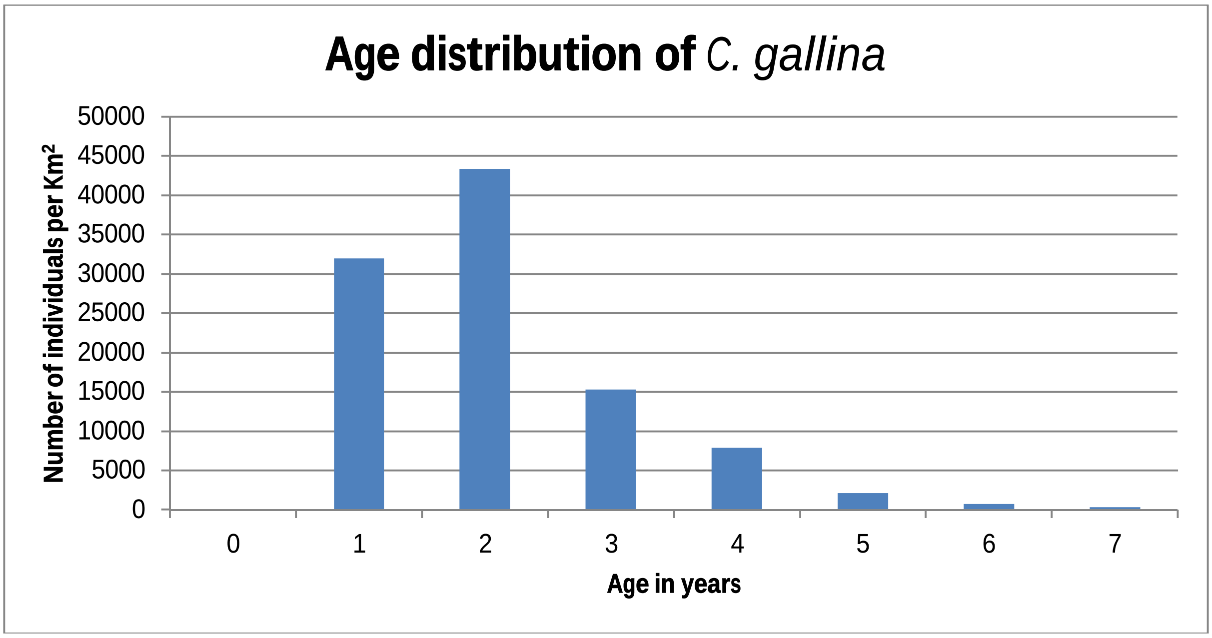

Fig. 16. Standardized age frequency distribution of *C. gallina*.

Apart from the length frequency and age frequency, a weight frequency distributed (Fig. 17) was plotted to show the importance of the large size classes in the distribution of the population biomass among the size classes.

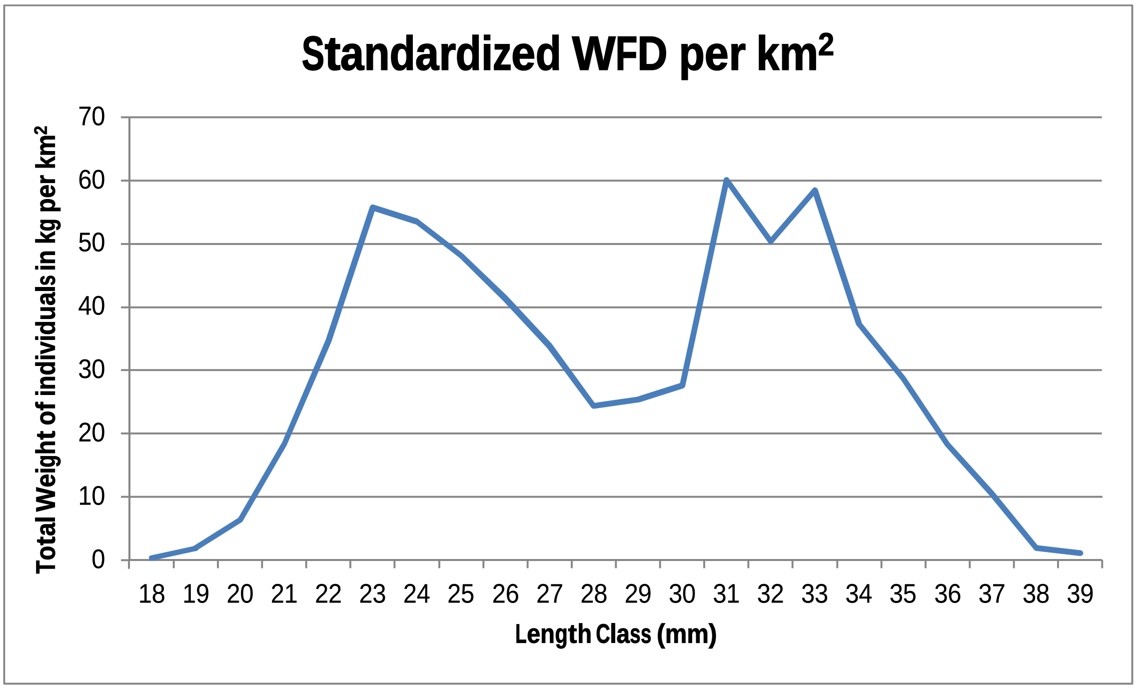

Fig. 17. Standardized weight frequency distribution of *C. gallina*.

3.3.4 Maximum Sustainable Yield (MSY)

The maximum theoretical sustainable yield was estimated by applying Gulland's formula (Sparre and Venema, 1992). MSY was calculated for the commercial species using a multiplier of 0.5, in the equation.

The main problem in the equation is to obtain a value of natural mortality (M). For *C. gallina* this was obtained by the length converted catch curve. For the other species since no length frequency data was available, M was obtained from literature when possible. For *S. aegyptiaca* the value of M was obtained from Mehanna 2007 which conducted a stock assessment of the species in the Egyptian Mediterranean waters.

No information was found for *Anadara polii*, however an independent estimate of M was obtained based on the suggestion by Gayanilo *et al.* (1997) that Myear-1 for bivalves can be reasonably estimated as roughly equal to K. In this respect K value was obtained from a close species from Turkish waters (Acari *et al.*, 2011), with a K value of 1.19 and hence the same M value.

For *Nassarius mutabilis* and *Neverita josephina*, no estimates of M could be obtained from literature, and hence a conservative M value of 0.5 was used.

The following table shows the results obtained for the species analysed.

Table 7. Estimation of MSY for the commercial species encountered.

Species	*C. gallina*	*N. josephina*	*A. polii*	*N. mutabilis*	*S. aegyptiaca*
Biomass index kg/km^2	756	4407	3644	669	236
Area of Bay (km^2)	180	180	180	180	180
Total Biomass (t)	136	793	656	120	43
M	1.02	0.5	1.19	0.5	0.75
Prop of pop. to exploit	0.5	0.5	0.5	0.5	0.5
MSY (t)	60	198	390	30	16

3.3.5 Estimated total value of the catch and potential vessels involved in the fishery.

Using the values of the estimated MSY and the price per kilo, the value in Egyptian pounds and US dollars of the possible production was calculated (table 8). The price per kilo of *C. gallina* was estimated as one third of the current first sale price of the commercial clam *Ruditapes decussatus*, hence about USD 3 per kilo. Based on the knowledge gathered during visits in Egypt that of *A. polii*, was estimated as USD 1 per kilo. The price of *S. aegyptiaca* is about USD 10 per kilo in Egypt (pers. observ.). For the two gastropod species since at the moment there is no equivalent market for such species in Egypt, a low value of USD 1 per kilo was used. Just as a comparison the first sale price of *N. mutabilis* in Italy is about USD 6 per kilo.

Table 8. Estimation of the commercial value of the MSY.

Species	*C. gallina*	*N. josephina*	*A. polii*	*N. mutabilis*	*S. aegyptiaca*	Total
MSY (t)	60	198	390	30	16	695
Price per Kg (EGP)	21	7	7	7	70	
Price per Kg (USD)	3	1	1	1	10	
Value per year (million EGP)	1.25	1.37	2.69	0.21	1.10	6.62
Value per year (million USD)	0.18	0.20	0.39	0.03	0.16	0.96

To estimate the value of the catch that a vessel requires in order to have a reasonable daily salary for the fishing activity per fisherman, the income and cost structure of the fleet segment trawl 12 - 18 m was used as a reference (FAO EastMed 2013). Based on this information four scenarios were devised with a potential daily revenue, by maintaining the same daily revenue and cost structure of a 12 - 18 m trawler (*status quo*), and an increase of 5%, 10% and 15% respectively of the daily revenue (table 9).

Table 9. Annual net profit per vessel and salary per crew of a potential fishing vessel for clams. The estimates were based on the daily activity of a trawl 12 - 18 m in length with 184 fishing days per year (FAO EastMed 2014)

	Status quo	Scenario 1 - Daily revenues per vessel (+10%)	Scenario 2 - Daily revenues per vessel (+15%)	Scenario 3 - Daily revenues per vessel (+20%)
Tot. no. of fishing days	2,717	2,470	2,363	2,265
No. of vessels	15	13	13	12
Value of landings ($)	353.3	389	406	424
Volume of landings (Kg)	256	281	294	307
Salary per crew per day ($)	13.3	15.1	16.0	16.9
Average annual net profit	19,890	26395	29647	32,899

The results show that for a 10%, 15% and 20% increase in revenue, 13 and 12 vessels could be utilised respectively in this fishery. However due to the uncertainty in estimating MSY and the total revenue 10 vessels would probably be a good first start, until more information of the dynamics of the stocks and market in obtained.

3.4. Microbiological Analysis

In order to explore the quality in terms of food safety of the bivalve *Chamelea gallina* from natural Egyptian fisheries, four types of pathogens (*Escherichia coli, Salmonella* sp. *Vibrio* sp. *Staphyllococcus* sp.) were tested. Samples were collected from twelve different sampling sites between Rasheed to Burullus in order to examine the health status and possible risk associated with consumption of this bivalve from natural Egyptian Mediterranean fisheries.

3.4.1 *Escherichia coli*

This pathogen was highly recorded at site (RBA2.03), with gradual decrease at sites (RBC4.02, RBB5.01, RBB3.02, RBB1.02, RBB1.03, RBA1.02, RBA5.02, RBA3.03, RBB7.01, RB7.02) respectively (Fig. 18). The presence of high concentrations (more that 100 CFU/100ml) of this pathogen may indicate sewage contamination of these sites.

Escherichia coli was completely absent at the other three sites (RBC5.01, RBC5.02, RBA8.03, RBB8.02).

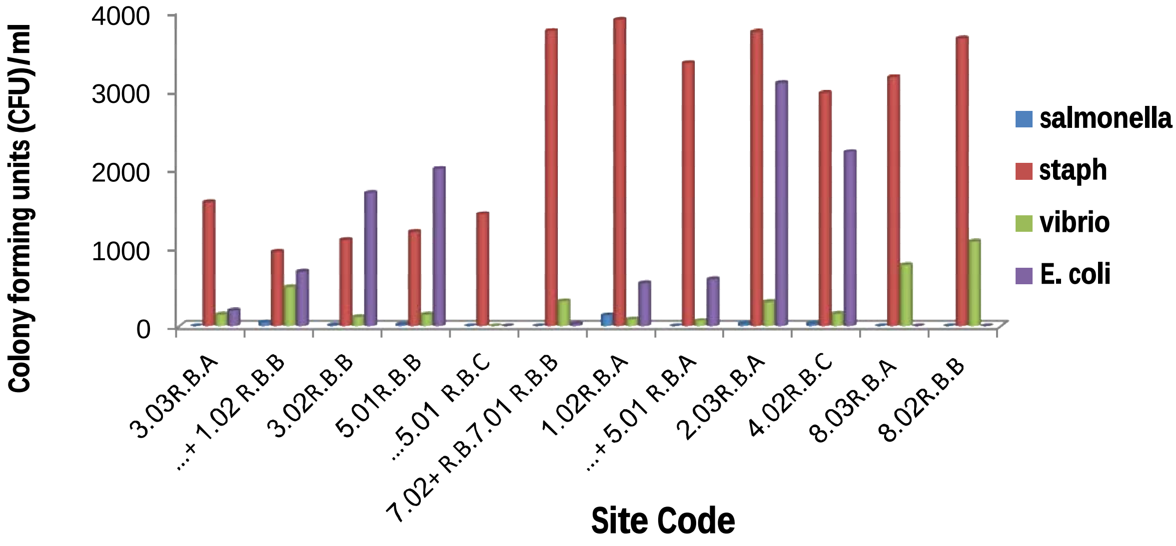

Fig. 18. This figure illustrates different pathogen counts (CFU/ml) from the bivalve *C. gallina* flesh, at twelve sites samples in Rasheed (Egypt).

3.4.2 *Salmonella* sp.

This food born pathogen was absent nearly from all site samples except two sites (RBA1.02 and RBB102, RBB1.03; Fig. 18. This may reflect human health safe consumption for *Chamelea gallina* of these sites regarding *Salmonella* sp.

3.4.2 *Vibrio* sp.

This human and clam marine pathogen was present in a high concentration at only one site (RBB8.02) and with gradual decrease concentrations at all other sites (Fig. 18). Moreover, site (RBC5.01, RBC5.02) was totally free from this pathogen.

3.4.3 *Staphylococcus* sp.

Food poisoning, disease-associated strains often promote infections by producing potent protein toxins, and expressing cell-surface proteins that bind and inactivate antibodies. This strain was recorded at all sites with minimum of 1000 CFU/ml to maximum of 3500 CFU/ml which is a slightly unsatisfactory range.

The acceptable range is 10^2 to $<10^3$ CFU/ml, unsatisfactory range is 10^3 to $< 10^4$ CFU/ml. (According to Microbiological quality guide for ready-to-eat foods. A guide to interpreting microbiological results, July 2009, NSW/FA/CP028/0906).

From the microbiological point of view, it can be concluded that, site (R.B.C5.01+R.B.C5.02) was the most safe and worth for *Chamelea gallina* fisheries regarding to the four tested pathogens. However more sampling sites should be investigated for exploring more clam fishery resources.

3.5. Heavy Metal analysis

The main objective of the heavy metal analysis was to investigate the heavy metal concentrations in the Stripped Venus Clam, *Chamelea gallina* to evaluate its safety for human consumption as potential bivalve resource for exploitation from Egyptian fisheries.

Concentrations of eight heavy metals; four hazardous metals [lead (Pb), cadmium (Cd), Mercury (Hg) and chromium (Cr)]; and four essential metals [copper (Cu), manganese (Mn), iron (Fe) and zinc (Zn)] were determined in tissues of the stripped Venus clam, *Chamelea gallina* collected along the Mediterranean coast of Egypt in 12 transects from Rosetta to Burullus.

The measured concentrations/sample, averages and ranges (min-max) of the examined metals are represented as mg/kg dry weight and mg/kg wet weight (Table 10 and Table 11, respectively) and compared to lowest and highest permissible limits prescribed by legislations set by authorities from different countries for mollusks or bivalves.

3.5.1. Safety of *Chamelea gallina* for human consumption

The guidelines set by different organizations for permissible limits for sea food safety of the metals measured in the present study are recorded in Tables 12 and 13 on dry weight and wet weight bases, respectively.

Heavy metals concentrations measured in the present study (Tables 10 and 11) were compared to lowest (most strict) and the highest maximum permissible limits prescribed by different world authorities (Tables 12 and 13). Sites with heavy metal concentrations that exceeded the lowest P.L. were marked by "**black bold face font"**. The concentrations that exceeded the highest permissible limits were marked with "**red bold font**" in Tables 10 and 11, and **red columns in Figures 28-30.**

3.5.1.1. Comparison with dry weight based permissible limits

When comparing the data of the present study to permissible limits on dry weight basis (Table 10), it was observed that.

Lead (Pb) concentration (av. 7.99 mg/kg d.w.) exceeded the lowest maximum permissible limits set for mollusks of 1.5 mg/kg d.w. prescribed by European communities (EC 2001) in all sites except 2 sites (B 02.2 and A 04.3) and the highest of 10 prescribed by Hong Kong Environmental Protection Department (HKEPD, 1997; Table 13) in 5 sites out of 26 sites most of which located towards the east of the studied area reflecting the heavy contamination with Pb concentrated towards Burullus (values in red bold font in Table 11 and red columns in Fig.19).

Cadmium concentrations exceeded the permissible limit set by USFDA (2007) guidelines of 4 mg/kg dry weight (Table 13) in only two sites (B05.1 and B 06.2; Table 12; Fig. 19). Cd exceeded the highest permissible limit of 5.5 mg/kg dry weight set by Marine Organism Pollution Assessment Standard (MOPAS) used in Guangdong Province, China. However, it exceeded the permissible limits of the European Community of 1 g/kg d.w. (Table 12) in 20 out of 24 sites (black bold font in Table 10) which reflects that the studied sites might be approved by American and other countries guidelines but not the European ones.

Table 10. Heavy metals concentrations on dry weight basis in the soft tissue of the Stripped Venus Clam, *Chamelea gallina* collected from different stations along the Mediterranean coasts from Rasheed to Burullus.

Sample Code	Heavy Metals Concentration (Dry Samples mg/kg)							
	Pb	Cd	Hg	Cr	Cu	Zn	Mn	Fe
A 01.3	**2.55**	**1.44**	0.04	**2.50**	12.19	55.34	56.88	1134.46
B 01.1	**3.95**	**2.01**	0.05	**2.85**	15.38	80.79	28.82	468.35
A 02.2	**3.40**	**1.17**	0.04	**3.50**	7.38	56.72	16.97	423.39
B 02.2	1.30	**3.08**	0.07	**37.30**	18.78	79.85	35.03	1424.19
A 03.2	**5.06**	**1.20**	0.06	**3.26**	13.47	55.45	25.63	966.48
A 03.3	**6.28**	0.60	0.03	**1.48**	10.06	45.18	18.35	379.35
A 04.3	0.59	0.99	0.08	**1.66**	6.63	36.32	15.54	655.13
B 04.3	**4.32**	**1.56**	0.05	**1.57**	5.80	35.59	11.43	383.13
C 04.2	**5.49**	**2.70**	0.02	**2.95**	13.06	66.79	27.92	1160.85
B 05.1	**3.47**	**4.32**	0.03	**3.17**	13.09	76.27	41.68	1213.91
A 06.1,2,3	**6.25**	**3.99**	N.D	**2.56**	8.53	57.68	24.86	863.61
B 06.2	**3.03**	**5.52**	0.09	**1.57**	9.90	64.42	25.82	774.07
A 08.3	**6.02**	**2.20**	0.03	**6.07**	12.46	86.84	29.70	1593.10
B 08.1	**9.00**	**3.27**	0.12	**3.92**	13.43	84.35	28.96	1240.88
B 08.02	**10.76**	**3.22**	0.06	**4.77**	16.90	79.35	49.41	2077.11
B 08.3	**4.34**	**3.19**	0.03	**4.01**	12.18	69.67	31.34	1075.36
B 09.1	**5.81**	0.76	0.10	**1.94**	7.85	41.43	18.60	606.30
B 09.2,3	**7.06**	**3.45**	0.04	**2.91**	12.62	82.27	17.22	875.33
C 10.3	**13.55**	**1.75**	0.07	**2.93**	12.15	69.22	13.41	366.73
B 11.1	**19.77**	**2.78**	0.06	**4.74**	17.37	107.17	30.20	1498.94
B 12.1	**35.60**	**2.88**	0.10	**5.18**	9.39	71.24	30.70	1430.57
B 12.2	**9.94**	**2.68**	0.08	**4.14**	20.39	69.46	32.36	1808.88
B 12.3	**9.95**	**1.52**	0.01	**4.23**	12.15	72.78	21.67	1031.11
C12.1	**14.35**	0.54	0.13	**3.07**	2.85	30.25	6.25	205.91
Average	**7.99**	**2.37**	0.06	**4.68**	11.83	65.60	26.62	986.00
Min	**0.59**	**0.54**	0.01	**1.48**	2.85	30.25	6.25	205.91
Max	**35.60**	**5.52**	0.13	**37.30**	20.39	107.17	56.88	2077.00
***Min to max P.L. set for mollusks**	**1.5 to 10**	**1 to 5.5**	**0.3 to 1**	**1 to 13**	**30 - 70**	**1000**	**NP**	**NP**

*** Max permissible limits (P.L.) range (min – max) set by organizations from different world countries and authorities; NP means no permissible levels found for these metals.**

Chromium showed the same trend of cadmium with only one site exceeded the permissible limits of USFDA (2007) of 13 mg/kg (37.30 mg/kg dry weight; Table 12) but most sites exceeded the 1 mg/g value set by FAO (1983).

Mercury as the most potent toxic metal was under all permissible limits of 0.3 to 1 mg/kg dry weight in all sites showing that the studied area is completely clean of Hg contamination.

Similar observations were recorded for copper (Cu) and zinc (Zn) which were less than the lowest prescribed permissible limits (Table 12) of 30 and 1000 mg/kg d.w., respectively (Table 10). This reflects that *C. gallina* fisheries are completely clean of the three metals.

There were no permissible limits for Mn and Fe to compare against so they will be compared to other studies regarding their recorded levels in *Chamelea gallina* as example of bivalves in Egypt rather than their risk to human health. The only record for permissible limits of Mn found in literature was 0.5 (WHO 1985) which was used by Anim *et al.* (2011). However, this limit is prescribed to drinking water. This guideline may not be convenient to use it for mollusks since the weakly intake of drinking water is different than the possible weekly consumption of bivalves which makes the risk to human health different if tolerable weekly intake was to be measured in both cases. For example, FAO/WHO (2004) prescribed tolerable weekly intake for Pb as 0.3 mg/kg body weight but the maximum permissible concentration in fish was 0.4 mg/kg wet weight.

3.5.1.2. Comparison with wet weight based permissible limits

When comparing the data of the present study to permissible limits on wet weight basis (Table 11), after results were corrected to clam water contents, it was observed that:

Pb concentration exceeded the lowest value for "maximum permissible limits" set for mollusks of 0.5 (mg/kg w.w) prescribed by FAO 1983 (Table 13) in 17 out of 26 sites (values in black bold face in Table 11). Only four sites all located on the eastern part towards of the studied area reflecting the heavy contamination with Pb concentrated towards Burullus (values in red bold font in Table 12 and red columns in Fig. 21).

Cd concentrations did not exceed the highest permissible limit of 2 mg/kg w.w. set by FAO/WHO (2011); CEP, (2002) and Australian New Zealand food standard code (Abbott 2003) guidelines (Table 13; Fig. 21). This reflects that all sites are approved clean of Cd according to the rules of these three organizations. However, Cd values of FAO 1983 of 0.5 in 8 sites (black bold face font in Table 11). But since the most recent update of FAO/WHO 2011 approved the 2 mg/kg limits. It should be used instead of FAO 1983 which means all sites rendered clean of Cd based on the above mentioned three organizations from Europe and Australia.

Cr concentration on wet weight basis showed the same trend the dry weight values with only one site (B02.2) with Cr concentration (9.04 mg/kg w.w.) that exceeded the permissible limits of FAO 1983 that prescribed 1 mg/g w.w. (Table 11; Fig. 21).

Hg (0.01 mg/kg w.w.), and Zn (12.08 mg/kg w.w.) were less than the lowest prescribed permissible limits (Table 13) of 0.5 and 30 mg/kg w.w., respectively (Table 11; Fig. 21, 22). This reflects that *C. gallina* fisheries are completely clean of the two metals.

Table 11. Heavy metals concentrations on wet weight basis in the soft tissue of the Stripped Venus Clam, *Chamelea gallina* collected from different stations along the Mediterranean coasts from Rasheed to Burullus.

Site Code	**Heavy Metals Concentration (mg/kg wet weight)**							
	Pb	**Cd**	**Hg**	**Cr**	**Cu**	**Zn**	**Mn**	**Fe**
A 01.3	**0.75**	0.42	0.010	0.73	**3.57**	16.20	16.65	332.06
B 01.1	**0.86**	0.44	0.012	0.62	**3.35**	17.63	6.29	102.19
A 02.2	**0.63**	0.22	0.007	0.65	1.38	10.57	3.16	78.92
B 02.2	0.32	0.75	0.016	**9.04**	**4.55**	19.35	8.49	345.08
A 03.2	**1.08**	0.26	0.013	0.70	2.87	11.82	5.46	206.05
A 03.3	**1.58**	0.15	0.009	0.37	2.53	11.37	4.62	95.44
A 4.3	0.10	0.17	0.014	0.28	1.13	6.19	2.65	111.57
B 04.3	**0.98**	0.35	0.011	0.36	1.31	8.07	2.59	86.82
C 04.2	**1.12**	**0.55**	0.004	0.60	2.68	13.69	5.72	237.86
B 05.1	**0.60**	**0.75**	0.005	0.55	2.26	13.16	7.19	209.52
A 6.1,2,3	**0.92**	**0.59**	N.D	0.38	1.26	8.51	3.67	127.38
B 06.2	0.44	**0.79**	0.013	0.23	1.42	9.26	3.71	111.31
A 08.3	**0.94**	0.34	0.005	0.95	1.95	13.59	4.65	249.32
B 08.1	**1.34**	0.49	0.018	0.58	1.99	12.53	4.30	184.27
B 08.02	**1.53**	0.46	0.008	0.68	2.40	11.26	7.01	294.74
B 08.3	**0.88**	**0.65**	0.005	0.81	2.47	14.12	6.35	217.98
B 09.1	**0.76**	0.10	0.013	0.25	1.03	5.43	2.44	79.49
B 09.2,3	**1.23**	**0.60**	0.008	0.51	2.20	14.36	3.00	152.75
C 10.3	**1.77**	0.23	0.009	0.38	1.59	9.05	1.75	47.93
B 11.1	**2.55**	0.36	0.008	0.61	2.24	13.85	3.90	193.66
B 12.1	**6.86**	**0.55**	0.018	1.00	1.81	13.72	5.91	275.53
B 12.2	**2.32**	**0.63**	0.018	0.97	**4.76**	16.23	7.56	422.74
B 12.3	**1.94**	0.30	0.003	0.83	2.37	14.22	4.24	201.48
C12.1	**2.77**	0.10	0.025	0.59	0.55	5.84	1.21	39.78
Average	**1.43**	0.43	0.011	0.94	2.24	12.08	5.11	183.49
Min	0.10	0.10	0.003	0.23	0.55	5.43	1.21	39.78
Max	**6.86**	**0.79**	0.025	**9.04**	**4.76**	19.35	16.65	422.74
*** Min to max P.L. set for mollusks**	**0.5- 2**	**0.5-2**	0.5	**1**	**3.0-30**	**30-100**	**NP**	**NP**

*** Max permissible limits (P.L.) range (min – max) set by organizations from different world countries and authorities; NP means no permissible levels found for these metals.**

Cu (2.24 mg/kg w.w.) was lower than the higher permissible limit set for wet weight of 30 mg/kg w.w. (CEP, 2002) but few sites exceeded the FAO/WHO (2011) guidelines of 3.0 mg/kg w.w. (**bold font in Table 11**). The examined area is considered clean considering Cu contamination.

When values were above permissible limits for European Union, concentrations of all heavy metals in *Chamelea gallina* were below maximum permissible limit set by other countries (values in Red Font bold face in Table 10 and Table 11). Only Pb in few stations was higher than these values when values were corrected for water contents and represented as wet weight.

3.5.2. Spatial distribution of heavy metals in the studied area

Looking at the possible relation of the heavy metals concentration and collection site (Figs 19-22), it was observed that there was no significant relation between any of the measured heavy metals and collection site. However, some metals showed high concentration in certain sites with no similar increase in other metals.

For example, Cu showed highest value at the two ends of the collection range but the middle sites had moderate values that were not significantly different from highest values. Mn highest value was in the west and the rest were moderate (Figs. 20 and 22).

Cr showed only one high site (B 02.2) that exceeded the permissible limits would be considered as outlier from statistics point of view (Figs. 19 and 21). The only metal that showed significant difference among sites was Pb which showed higher values eastwards (Figs. 19 and 21).

In general, there is no certain trend of heavy metal concentration in the studied area and it is considered clean except for the eastern part which has higher Pb concentrations.

3.5.3. Comparison of the present study with other studies

Tables 14 and 15 shows comparison of heavy metals concentrations data of the present study with others from literature on both dry weight (d.w.) and wet weight (w.w.), respectively.

For *Chamelea gallina,* it was observed that Pb, Cd, and Cr concentrations (mg/kg d.w) measured in the present study were higher than those measured in *C. gallina* from Spain (Usero *et al.*, 2005). However, Hg, Cu and Zn concentrations in that study were higher than those observed in the present study (Table 15). Similarly, Çolakoğlu *et al.* (2010) recorded lower Pd, Cd, Cr and Fe but higher Cu concentrations measured as mg/kg w.w. in *C. gallina* collected from Turkey than those recorded in the present study (Table 15).

For other bivalves based on dry weight comparisons (Table 14), El Nemr *et al.* (2012) studied 9 stations from Rosetta to Port Said cities, Egypt using pooled samples of different bivalve species that represented biodiversity of each station. The study did not include *C. gallina* among the recorded bivalves. However, all the heavy metals measured were lower than those observed in the present study (Table 14).

El-Serehy *et al.* (2012) studied heavy metals in *Donax trunculus* along the Mediterranean coast of El-Gamil zone west of Port Said, Egypt (between lat. 31^{o} 10' – 31^{o} 20' N and long. 32^{o} 00' - 32^{o} 20') which is east of the area studied in the present study. However, all metals showed lower values than those measured in the present study (Table 14). Ahdy *et al.* (2007) showed lower Pb, Cd, Cu, Fe, Zn but higher Hg in two bivalve species, *Mactra* spp. and *Mytillus sp.* from Alexandria, Egypt (Table 14).

In the study of Spada *et al.* (2013), Pb, Cd and Cr levels in *Mytilus galloprovincialis* from Apulian Mediterranean coast of Italy were much lower than those measured in the present study. However, Hg ranges were higher and Cu ranges were more or less similar to the ranges measured in the present study. Wild mussels, *Perna viridis,* from the west coast of Malaysia (Yap *et al.*, 2008**)** had Cu, Fe and Zn levels within the ranges measured in the present study but closer to the upper limit and less Cd range (Table 14).

Comparing with data based on wet weight (mg/kg w.w.) from other studies (Table 16), it was observed that heavy metal concentrations in the carpet shell clam *Tapes decussatus* from six Egyptian fisheries measured by El-Wazzan *et al.* (2013) showed lower Pb concentration ranges than those in observed in *Chamelea gallina* of the present study (0.01 – 3.03 and 0.10 - 6.86 mg/kg w.w., respectively) and similar Cu ranges (0.46 - 4.94 and 0.55 - 4.76, respectively). In contrast, higher Cd concentrations were found in *Tapes decussatus* (0.01 - 2.24 mg/kg w.w.) than those found in the present study (0.10 - 0.79 mg/kg w.w.; Table 15). The concentrations of Pd, Cd and Hg in Cockles from Malaysia (Alina *et al.*, 2012) were higher than observed in the present study (Table 15).

Table 12. Comparison of concentrations of heavy metal in *C. gallina* (average, min and max.) with the guidelines of permissible limits of seafood for human safety by different countries based on dry weight permissible limits.

No	Legislation Organization and target organisms	Permissible Limits of Heavy Metals Concentration on dry weight basis (mg/kg d.w.)								Reference and organism studied; Country
		Pb	Cd	Hg	Cr	Cu	Zn	Mn	Fe	
1	FAO/WHO, 1984, 2011 Fish & mollusks	0.3**- 6	2*, 1**	0.5*	50	10 to 100	150	5.4**		
2	*Europe (European Communities, 2001); mollusks	1.5	1	0.5						Usero *et al.* 2005: mollusc *Chamelea gallina*; Spain
3	* (Abbott *et al.*, 2003); mollusks	2	2	0.5						Usero *et al.* 2005: mollusc *Chamelea gallina*; Spain
4	*(HKEPD, 1997); marine mollusks	6	2	0.5	1					Zhan qiang *et al.*, 2001; edible bivalve; China
5	*MOPAS; marine molluscks	10	5.5	0.3	5.5					Zhan qiang *et al.*, 2001; edible bivalve; China
6	*USFDA, 2007; molluscan shellfish	1.7	4	1	13					Yap *et al.* 2008: mussels, Malaysia
7	* FAO 1983	2-5.5	2	0.5	1	70	1000			Spada *et al.* 2013; mussel *Mytilus galloprovincialis*; Italy
Max permitted range set for mollusks		**1.5 to 10**	**1 to 5.5**	**0.3 to 1**	**1 to 13**	**30 to 70**	**100-1000**	**NP**	**NP**	**Different authorities and organizations**
Present study Average conc.		7.99	2.37	0.06	3.50	11.83	65.60	26.62	986	**values in bold face font are above max permissible limits for molluscs**
Present study min conc.		0.59	0.54	0.01	1.48	2.85	30.25	6.25	206	
Present study max conc.		**35.60**	**5.52**	0.13	9.04	20.39	107.17	56.88	2077	

*** values were set for mollusks and bivalves; ** values were set for fish; NP means no permissible levels found for these metals**

Table 13. Comparison of concentrations of heavy metal in *C. gallina* (average, min and max.) with the guidelines of permissible limits of seafood for human safety by different countries based on wet weight permissible limits.

No	Legislation Organization	Permissible Limits of Heavy Metals Concentration on Wet weight basis (mg/kg w.w.)								Reference # and organism studied; Country
		Pb	**Cd**	**Hg**	**Cr**	**Cu**	**Zn**	**Mn**	**Fe**	
1	*, ** FAO/WHO 2011; fish and bivalve	0.3**	2*	0.5**		3.0				
2	* EU 2006 (EC Reg.n. 1881/2006); **mollusks**	1.5	1	0.5						Spada *et al.* 2013; mussel Mytilus galloprovincialis; Italy
3	*, **FAO/WHO 2004; fish and shellfish	1.5*	0.05**	0.5*						Alina *et al.*, 2012: fish and shellfish
4	*Australia New Zealand Food Standards Code (Abbott *et al.*, 2003) **mollusks**	2	2	0.5						Usero *et al.* 2005: mollusc *Chamelea gallina*
5	*(CEP, 2002); **mollusks**		2			30	40-100			Yap *et al.* 2008: mussels, Malaysia
6	*Europe (European Communities, 2001); **mollusks**	1.5	1	0.5						Usero *et al.* 2005: mollusc *Chamelea gallina*
7	**(HKEPD, 1997); fish	6	2	0.5	1					Nor Hasyimah *et al.* 2011 fish; Malaysia
8	** MOPAS; fish	10	5.5	0.3	5.5					Nor Hasyimah *et al.* 2011 fish; Malaysia
9	**USFDA, 1990 ; 1993; Fish	1.7	3.7		12 to 13					Nor Hasyimah *et al.* 2011 fish; Malaysia; Yap *et al.* 2008: mussels, Malaysia
10	**Fourteenth Schedule (Regulation 38); Malaysian Food Regulation (1985)***	2***	1***	0.5***		30	100			Alina *et al.*, 2012: fish and shellfish; Yap *et al.* 2008: mussels, Malaysia
11	*FAO 1983; **mollusks**	0.5	0.5	0.5	1	30	30			Spada *et al.* 2013; mussel *Mytilus galloprovincialis*; Italy
	Max permitted range set for mollusks	**0.5 - 2**	**0.5 - 2**	**0.5**	**1**	**3.0 to 30**	**30 to 100**	**NP**	**NP**	**Different authorities and organizations**
	Present study Average conc.	1.43	0.43	0.01	0.94	2.24	12.08	5.11	183	**values in bold face font are above max permissible limits for mollusks**
	Present study min conc.	0.10	0.10	0.00	0.23	0.55	5.43	1.21	40	
	Present study max conc.	**6.86**	0.79	0.02	**9.04**	**4.76**	19.35	16.65	423	

*** values were set for molluscs and bivalves; ** values were set for fish; ***values are in mg/g; NP means no permissible levels found for these metals.**
Table 12 footnotes: References for dry weight heavy metals permissible limits mentioned in Table 13

1- FAO/WHO, 2011. CF/5 INF/1. ftp://ftp.fao.org/codex/meetings/CCCF/cccf5/cf05_INF.pdf
2 - Commission Regulation N° 466/2001 of 8 March 2001. Setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Communities, L77, 1-13.
3 - Australian New Zealand Food Standards Code (Abbott, P., Baines, J., Fox, P., Graf, L., Kelly, L., Stanley, G., Tomaska, L., 2003. Review of the regulations for contaminants and natural toxicants. Food Control 14, 383–389.
4 - Permissible limit set by the Hong Kong Environmental Protection Department (HKEPD, 1997)
5 - Marine Organism Pollution Assessment Standard, MOPAS as recommended by the Technical Group of Guangdong Provincial Coastal Zone Resource Comprehensive Survey.
6 - United States Food and Drug Administration of the United States (USFDA, 1990 ; 1993); National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish 2007.
7 - FAO, 1983. Food and Agriculture Organization Compilation of legal limits for hazardous substances in fish and fishery products", Fish Circ, 464, 5-100.

Table 13 footnotes: References for wet weight heavy metals permissible limits mentioned in Table 14

1- FAO/WHO, 2011. CF/5 INF/1. ftp://ftp.fao.org/codex/meetings/CCCF/cccf5/cf05_INF.pdf
2 - Commission Regulation N° 1881/2006 of 19 December 2006. Setting maximum levels for certain con-taminants in foodstuffs. Official Journal of the European Union, L364, 5-24.
4- Abbott, P., Baines, J., Fox, P., Graf, L., Kelly, L., Stanley, G., Tomaska, L., 2003. Review of the regulations for contaminants and natural toxicants. Food Control 14, 383–389.
5 - International Standards in mollusks/shellfish compiled by the Food and Agricultural Organization (FAO) of the United Nations (CEP, 2002)
6 - Commission Regulation N° 466/2001 of 8 March 2001. Setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Communities, L77, 1-13. http://www.fda.gov/downloads/Food/GuidanceRegulation/FederalStateFoodPrograms/UCM241512.pdf.
7 - Permissible limit set by the Hong Kong Environmental Protection Department (HKEPD, 1997) [cited in (Nor Hasyimah *et al.* 2011)].
8 - Marine Organism Pollution Assessment Standard, MOPAS as recommended by the Technical Group of Guangdong Provincial Coastal Zone Resource Comprehensive Survey.
9 - United States Food and Drug Administration of the United States (USFDA, 1990 ; 1993).
10 - Fourteenth Schedule (Regulation 38), Malaysian Food Regulation (1985) [cited in (Nor Hasyimah *et al.* 2011)].
11- FAO, 1983. Food and Agriculture Organization Compilation of legal limits for hazardous substances in fish and fishery products", Fish Circ, 464, 5-100.

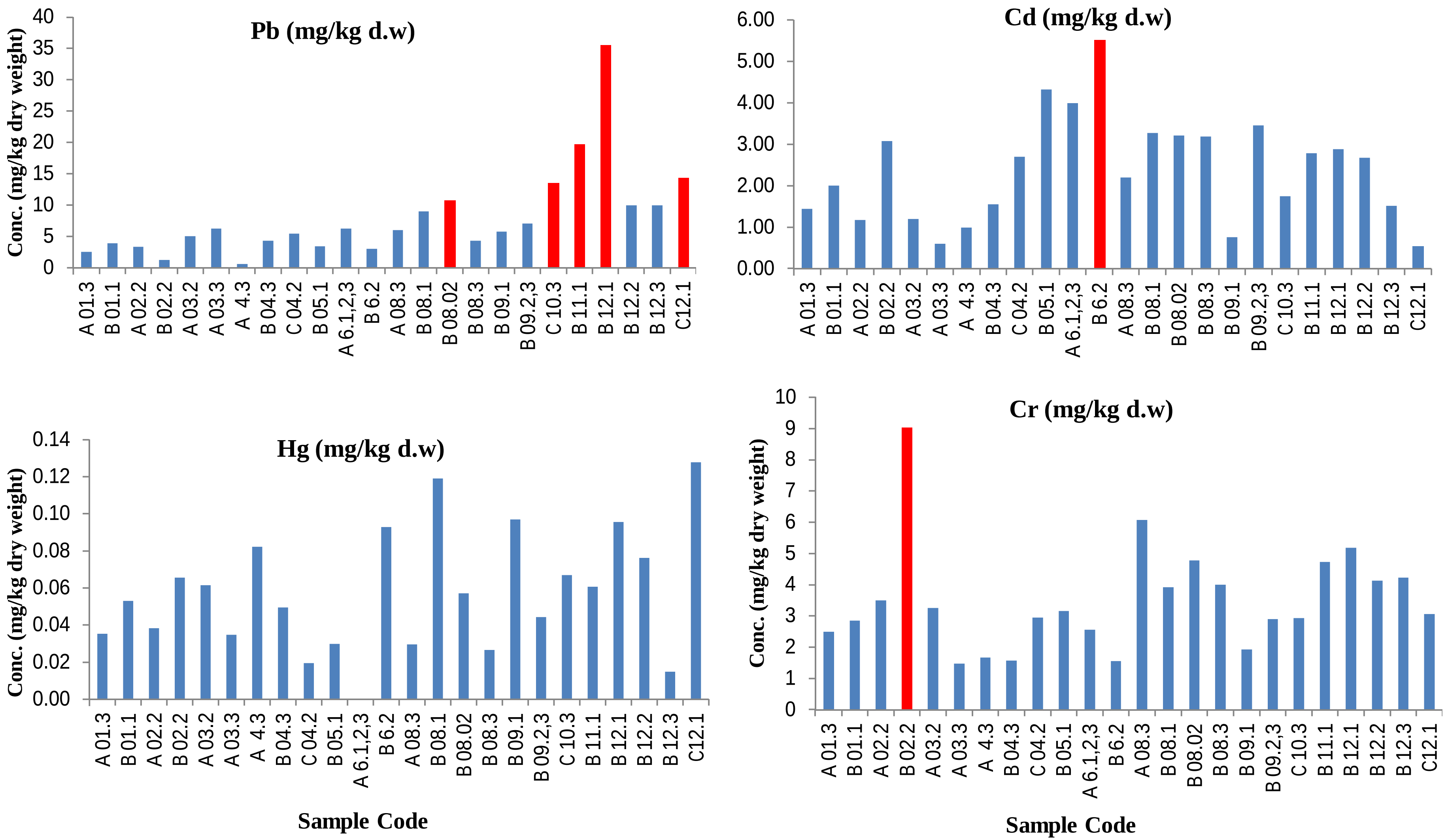

Fig. 19. Concentrations (mg/kg d.w.) of Pb, Cd, Hg and Cr in the stripped Venus clam, *Chamelea gallina*, collected from 12 transects along Egyptian Mediterranean coast from Rosetta to Burullus. Data points in red colour exceed the maximum permissible limits for the concerned metal set by all mollusk sanitation guidelines.

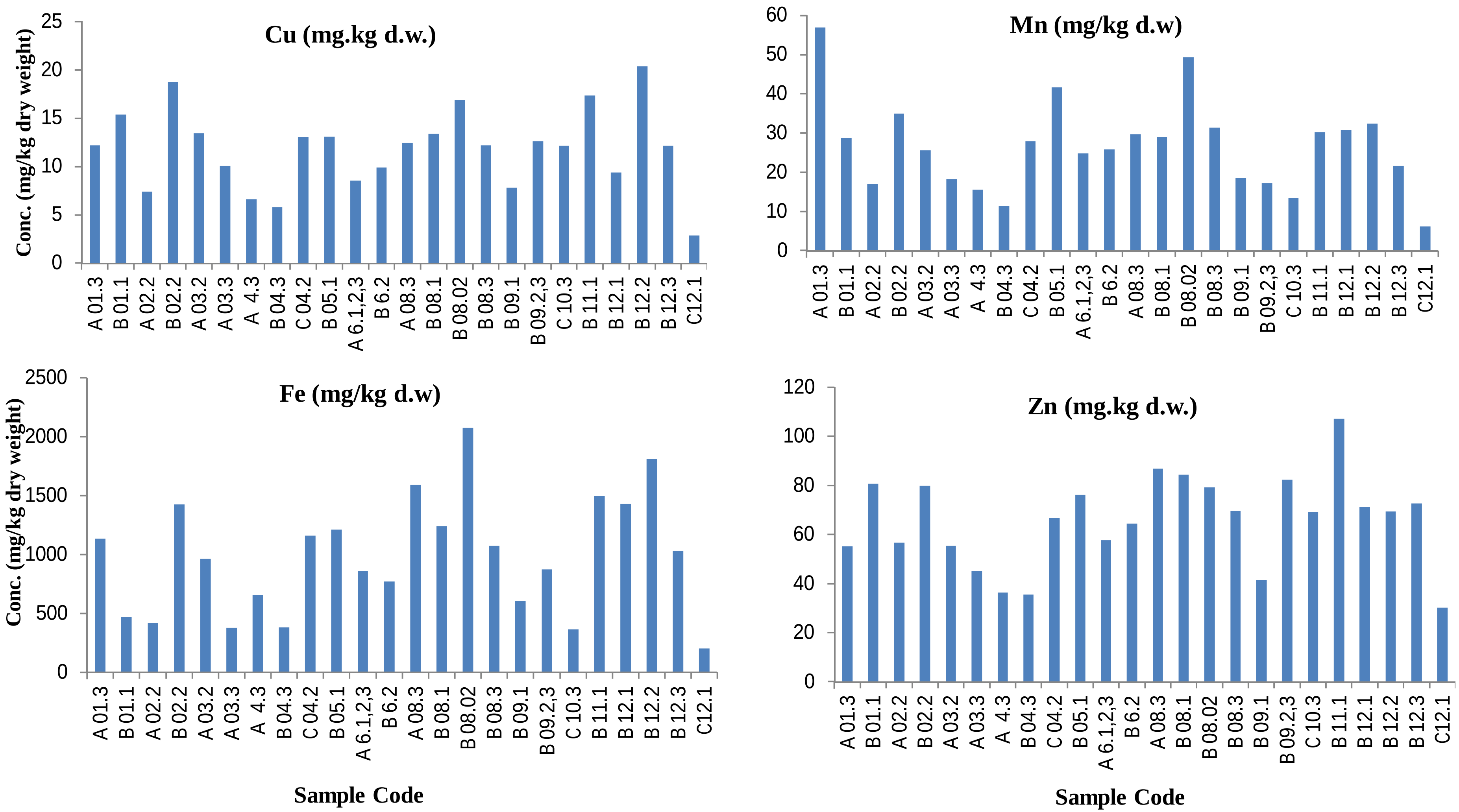

Fig. 20. Concentrations (mg/kg d.w.) of Cu, Mn, Fe and Zn in the stripped Venus clam, *Chamelea gallina*, collected from 12 transects along Egyptian Mediterranean coast from Rosetta to Burullus. Data points in red colour exceed the maximum permissible limits for the concerned metal set by all mollusk sanitation guidelines.

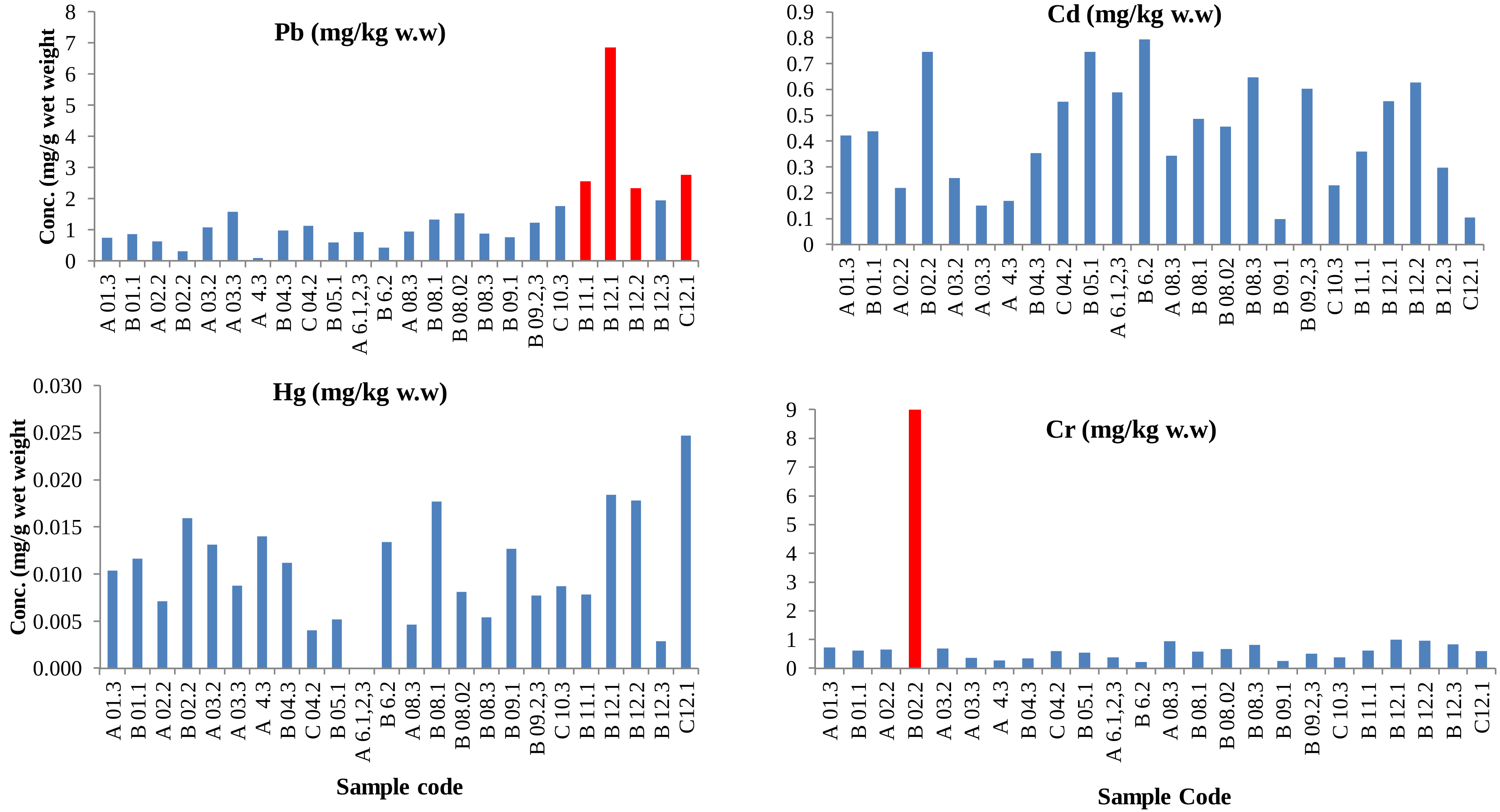

Fig. 21. Concentrations (mg/kg w.w.) of Pb, Cd, Hg and Cr in the stripped Venus clam, *Chamelea gallina*, collected from 12 transects along Egyptian Mediterranean coast from Rosetta to Burullus. Data points in red colour exceed the maximum permissible limits for the concerned metal set by all mollusk sanitation guidelines.

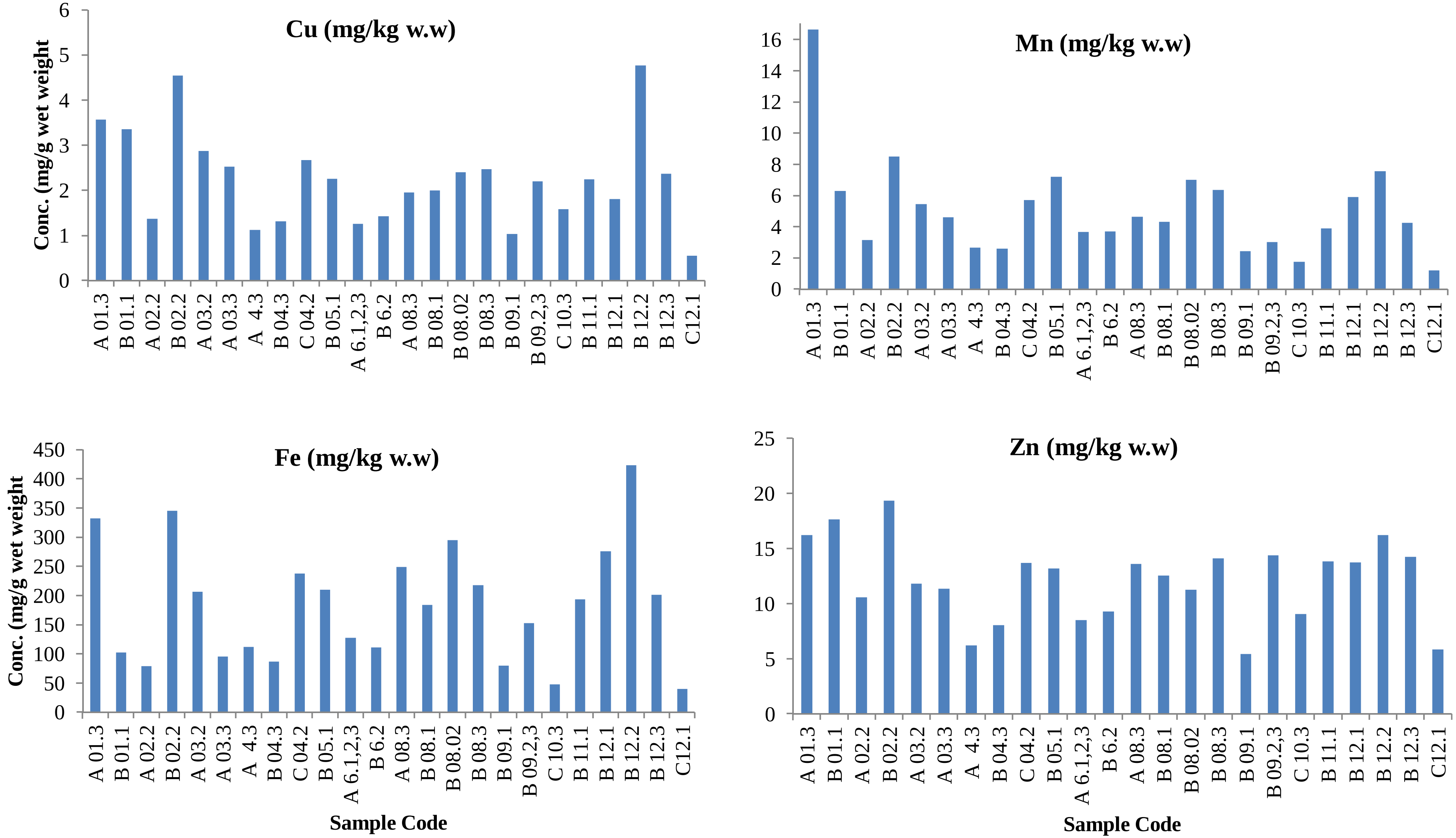

Fig. 22. Concentrations (mg/kg w.w.) of Cu, Mn, Fe and Zn in the stripped Venus clam, *Chamelea gallina*, collected from 12 transects along Egyptian Mediterranean coast from Rosetta to Burullus. Data points in red colour exceed the maximum permissible limits for the concerned metal set by all mollusk sanitation guidelines.

Table 14. Comparison of concentrations of heavy metal in *C. gallina* (average, min and max.) in the present study on dry weight basis with other bivalve studies from different countries.

Reference	**Country (area)**	**Organism**	**Heavy Metals Concentrations Ranges, means (mg/kg d.w.) in mollusks from different countries**							
			Pb	**Cd**	**Hg**	**Cr**	**Cu**	**Mn**	**Fe**	**Zn**
Present study (FAO – EastMed Project)	**Egypt (Rosettal to Burullus)**	**Stripped Venus Clam, *Chamelea gallina***	**7.99 (0.59 - 35.60)**	**2.37 (0.54 - 5.52)**	**0.06 (0.01 - 0.13)**	**4.68 (1.48 - 37.30)**	**11.84 (2.85-20.39)**	**26.62 (6.25 - 56.88)**	**986 (206 - 2077)**	**65.6 (30.25 - 107.17)**
Spada *et al.*, 2013	Italy	*Mytilus galloprovincialis*	(0.37 - 3. 25)	(0.38 - 1.84)	(0.1 - 0.81)	(0.96-9.46)	(4.66-19.22)			
El-Serehy *et al.*, 2012	Egypt (west Port Said)	*Donax trunculus*	(5.6 - 9.2)	(1.6 - 2.4)			(3.2 - 4.8)	(4.8 - 8.4)	(47.2 - 66.4)	(22 - 36.4)
Ahdy *et al.*, 2007	Egypt (Alexandria)	*Mactra spp.*	0.085 (0.03 - 0.17)	0.06 (0.03 - 0.29)	0.15 (0.011 - 0.33)	0.85 (0.7 - 17)	1.0 (0.5 - 2.1)		10.5 (7.7 - 18.7)	22 (18 - 35)
Ahdy *et al.*, 2007		*Mytilus spp.*	0.07 (0.06-1.08)	0.048 (0.031 - 0.18)	0.12 (0.061-0.270)	0.79 (0.6 - 1.1)	1.3 (0.7 - 25)		9.4 (7.2-16.1)	18 (17-20)
El Nemr *et al.*, 2012	Egypt (Alexandria to port Said)	Pool of different bivalves available	0.25 ± 0.15	0.09 ± 0.04		8.49 ± 5.19	3.82 ± 2.21			21.87 ± 21.38
Usero *et al.*, 2005	Spain	Stripped Venus Clam, *Chamelea gallina*	1.3	0.33	6.4	0.7	38			72
Usero *et al.*, 2005	Spain	*Donax trunculus*	3.6	0.19	0.12	1.2	175			107
Yap *et al.*, 2008	Malaysia	Wild mussels, *Perna viridis*		(0.51 - 2.90)			(12.61 - 15.01)		(385 – 1271)	(81.74 - 106.6)

Table 15. Comparison of concentrations of heavy metal in *C. gallina* (average, min and max.) in the present study on wet weight basis with other bivalve studies from different countries.

Reference	Country (area)	Organism	Heavy Metals Concentration Range, mean (mg/kg w.w.) in different mollusks and permissible limits used						
			Pb	Cd	Hg	Cr	Cu	Mn	Fe
Present study (FAO – EastMed Project)	**Egypt**	**Stripped Venus Clam, *Chamelea gallina***	**1.43 (0.10 - 6.86)**	**0.43 (0.10 - 0.79)**	**0.011 (0.003 - 0.025)**	**4.68 (1.48 - 37.3)**	**2.24 (0.55 - 4.76)**	**5.11 (1.21 - 16.65)**	**184 (39.78 - 423)**
El-Wazzan *et al.*, 2013	Egypt	Carpet shell clam, *Tapes decussatus*	(0.01 – 3.03)	(0.01 - 2.24)			(0.46 - 4.94)		
Çolakoğlu *et al.*, 2010	Turkey	Stripped Venus Clam, *Chamelea gallina*	(0.18 - 3.24)	(0.04 - 0.69)		(0.08 - 1.25)	(0.71 - 5.30)		(2.46 - 89.73)
Alina *et al.*, 2012	Malaysia	Cockles	0.19 - 0.28	25.1 - 47	3.6 - 6				

4. Discussion

4.1 Information on the resources

Based on our results, the biological communities in the investigated area, sampled with the hydraulic dredge are dominated by bivalve and gastropod molluscs both in terms of number (DI) and biomass (BI). The target and commercial clam *Chamelea gallina* was found in the investigated area together with other potentially commercial species such as the changeable nassa *Nassarius mutabilis* which is a type of whelk (edible sea snails) and the arc clam *Anadara polii*. Minor catches of the Egyptian sole, *Solea aegyptiaca* were also recorded. Together with the added production of the bycatch species, the exploitation of the clam *Chamelea gallina* could be considered as viable.

Most of the biomass is located on the Western side of the area investigated and close to the fishing port of Rasheed, making the area more easily reachable from this fishing port. Only for the commercial gastropd *Nassarius mutabilis*, the biomass is located on the Eastern part of the bay, and close to the fishing port of Burullus. In the westernmost part of the investigated area, high concentrations of dead shells of *C. gallina* were noticed, which could be an indication of high mortalities in some seasons. High mortalities can be a result of failure in recruitment and widespread mortality has been observed in several clam beds (Froglia, 1989, 2000).

The analysis of the length frequency data show that in terms of weight the majority of the clams are of a commercial size which is usually above 25 mm in length (EC Regulation 1626/1994). For the clam *Chamelea gallina* the use of size–frequency distributions to estimate population growth rates is not very reliable and hence techniques using acetate peel or external ring counting for a simple and rapid age estimation should be used (Gaspar *et al*., 2004). This is extremely important as the estimation of the Von Bertallanfy growth parameters has a critical impact on the estimation of mortality rates and the Maximum Sustainable Yield. Poor estimates of the VBGF will lead to high uncertainty and hence inadequate management advice. In this respect if *C. gallina* will be commercially exploited in Egypt, proper ageing should be conducted and included in any further research surveys. Nevertheless, an estimation of age structure was possible using the available information and the life span of the species has been estimated to a maximum of 7 years which is in accordance to several published studies (Gaspar *et al*., 2004).

The estimated biomass at sea and MSY for *C. gallina* is not particularly high, especially when one considers that the resources are not exploited. It is important to note that it is very difficult to assess production and sustainable yield of clams since the populations are sedentary and tend to spatially aggregate. This makes density dependent factors such as recruits competing for space, food supply, anoxic conditions etc., extremely limiting in population growth and fisheries production (Caddy, 1989). Consequently these features have shown that in many populations there are “boom and bust events” making hard any forecast and figure out reasonable management strategies or intervention. In this respect any estimations of MSY have to be taken with caution, especially those based on a one off survey like the one conducted in this study. Eventually if any fisheries will be established, annual monitoring of the fishery should be conducted in order to have better estimations of sustainable yields. In the Northern Adriatic sea there are some of the most developed *C. gallina* fisheries in the Mediterranean with routine monitoring programs. Experience from this area has pointed out the wide year-by-year and area-by-area variability in the abundance of both target and non target bivalve species, and the periodic occurrence of catastrophic mortality with the almost total disappearance of local beds and successive recovery (Froglia, 1989; Froglia *et al*., 1994).

With respect to the non-target species, apart from the retained commercial catch, most of them were considered as alive when discarded and probably the survival rate would be high when returned to sea. Several studies have shown high survival rates from similar fishing activities and *C. gallina* fisheries in particular (Morello *et al*., 2005, Morello *et al*., 2006), except for the bivalve *Mactra stultorum*. However for this particular species fishers argue that this bivalve is in direct competition with *C. gallina*, and reducing the quantities of *M. stultorum* in a fishing grounds increases the yield of *C. gallina* (Pers. comm.).

4.2 Exploitation and Commercialisation of the product

In the economic analysis we have estimated the annual revenue and salary per crew of a vessel fishing for clams. This was based on the cost structure of a small, about 15 m L.O.A. (Length Over All) trawler. A recent study in Egypt has shown that in economic terms small trawlers are rather inefficient and one possible way to improve the economic efficiency is to diversify the vessels into other fishing activities, such as fishing for clams, even if for a particular season (FAO EastMed 2013).

In this respect it is important to note that in general the cost structure for a clam fishing vessel is normally less due to less fuel consumption. Furthermore a hydraulic dredge vessel of about 15 m in length when compared with a trawler of the same dimension, spends less hours at sea, reducing in particular the travel time, which is the activity which consumes the greatest amount of fuel, therefore reducing significantly the fuel cost as well as all the running daily costs (operational and maintenance costs). The investment, and all the costs related to the investment, are significantly less. Without considering the fishing license, the capital investment for an hydraulic dredge is about one fourth to that of a trawler. The labour force involved in the hydraulic dredge is about 40-50% less than the trawler, therefore reducing all the personnel costs of the vessel. Furthermore the activity seems to be more appealing to the labour force when compared to the trawl fishery, since the work on board is more safe and relatively simple, with less working hours per day. Working on a hydraulic dredge also requires less skilled labours to run the fishing activity, making the clam fishery particularly attractive to workers coming from different economic sectors. Furthermore in the clam fishery the input (costs) and the output (revenues) of the activity are highly predictable, making easier the financial management of the activity.

In the investigated area when considering the MSY and the cost structure of small trawlers the fishery could support between 15 - 20 hydraulic dredge vessels with an average L.O.A. of 15 m. However when one considers the uncertainty in the estimation of MSY and taking into account the precautionary approach, if the fishery would be developed probably 10 vessels would be more suited as a start. Once the fishery would be developed, then based on new information on the status of the resources and the revenue of each vessel, new vessels could be introduced in the fisheries. This could be done in stepwise approach, in order not to jeopardise both the socio-economic security of any existing vessels, the status of the resources and the ecosystem which supports them.

Apart from the hydraulic dredge, another possibility for the exploitation of gastropods is to introduce basket traps (Fig. 23) for changeable nassa (*Nassarius mutabilis*). These could be also utilised by the small scale fleet, from the fishing port of Burullus, which is the port closest to the main aggregation of the species.

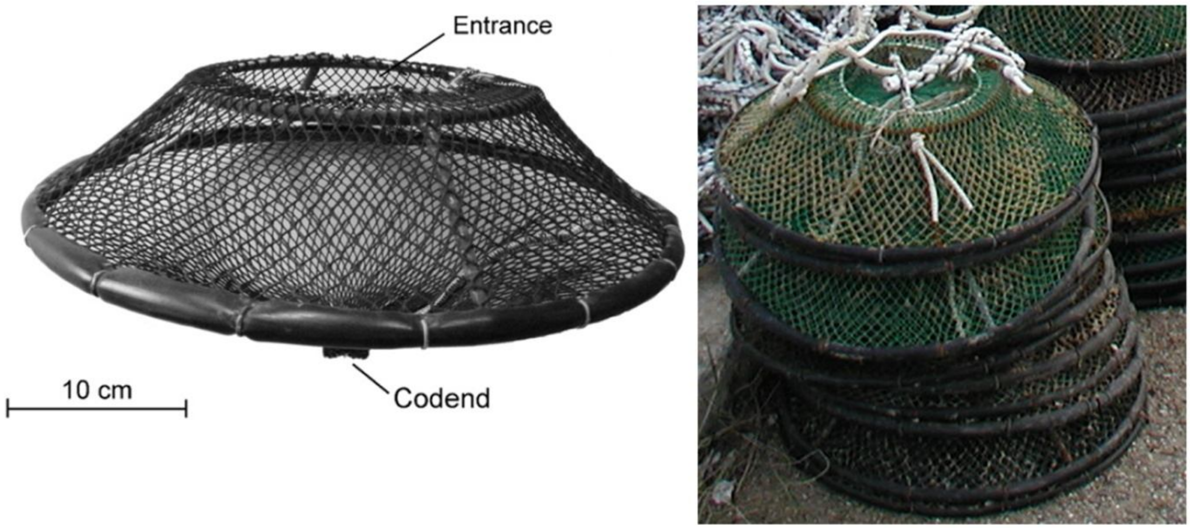

Fig 23. Left basket trap for *Nassarius mutabilis* (from Grati *et al*., 2010) and right stack of traps showing how traps can be easily stored.

Most of the potential production would probably be more suited for local consumption in Egypt. In theory the export of clams could be possible. However, several countries require special regulations for the import of bivalve species. Fort the biggest export market, that is, the European Union, the countries within the EU require that for any importation of bivalves the marine waters have to be classified based on the water quality parameters. Since bivalves are filter feeders they tend to bio-accumulate all sorts of contaminants, from bacterial and viral to heavy metals.

4.3 Microbial and Heavy metal contamination in *C. gallina*

Regarding microbiological contamination, when compared to other commercially exploited species in Egypt such as the bivalve Tapes decussatus, the quality of Chamelea gallina is by far higher with much lower levels of microbiological contamination. The reason may be that C. gallina lives in relatively open waters when compared to Tapes decussatus, since this species is found in lagoons and in relatively enclosed bodies like Timsah Lake, and hence tend to bio-accumulate more contaminants. In order to improve the quality of bivalves, purification may be performed prior to further sale.

Mollusks are able to accumulate heavy metals and impose health hazard to consumers. Heavy metals are classified into toxic and non-toxic groups. From human health risk point of view, the most toxic metals are As, Pb, Cd, Hg and Cr. Bioaccumulation of these metals in tissues leads to cellular damage and dysfunction of many organs and may lead to death. The most important of these are Pb, Cd and Hg as they are potent toxins. Therefore, there are strict legislations for maximum permissible limits (P.L.) have been set for human consumption by different authorities and organizations (e.g. FAO 1983; Malaysian Food and

Regulations, 1985; USFDA, 1993a,b, 2001, 2007; WHO 1985; EC 2001; EFSA, 2004; EU, 2006 and FAO/ WHO, 1984, 1989, 2004, 2011).

In contrast, Cu, Mn, Fe and Zn and Co are essential metals and play vital role in metabolic functions at low levels (Hogstrand and Haux, 2001). However, if they bio-accumulate to reach toxic levels, they pose health risk (Rietzler *et al.*, 2001).

Several studies monitored heavy metals in bivalves in Egypt as bioindicators of pollution and for assessing their suitability for human consumption (Abdel-Moati, 1991a, El-Sikaily *et al.*, 2004, Ahdy *et al.*, 2007, El Nemr *et al.*, 2012, El-Serehy *et al.*, 2012, El-Wazzan *et al.*, 2013).

Heavy metals have increased in the Egyptian marine environment in the past few decades due to disposal of large amounts of variety of contaminants from agricultural drainage, domestic wastes, shipping activities, sewage and nutrients (Hamza 1983, Hamza and Gallup 1982, Abdel-Moati 1991 b). The deterioration of water quality in Egyptian fisheries and their contamination with heavy metals raised the safety concern of using fish and shellfish from Egyptian fisheries for human consumption.

The danger of heavy metals arises from the fact that they are persistent in the marine environment and cannot be metabolized by the body. They accumulate at a rate faster than the body can eliminate them causing severe danger to health leading to DNA damage and cancer in some cases due to their high toxicity (Miller et a., 2000, Ekpo *et al.*, 2008).

Results shows that the examined fisheries are considered clean compared to other areas of the world as Malaysia (Alina *et al.*, 2012). *C. gallina* examined in the present study was clean especially for contamination with Hg and Cu compared to bivalve studies in Spain and Turkey (Usero *et al.*, 2005, Çolakoğlu *et al.*, 2010). However, contamination with Pb, Cd, Cr, and Fe in *C. gallina* exceeded those observed in some bivalves in Spain, Turkey and Italy (Usero *et al.*, 2005, Çolakoğlu *et al.*, 2010, Spada *et al.*, 2013, respectively).

Furthermore, heavy metals measured in the present study were higher than those measured in other Egyptian fisheries such as Alexandria (Ahdy *et al.*, 2007), Alexandria to west Port Said (El Nemr *et al.*, 2012) and west Port Said (El-Serehy *et al.*, 2012). In contrast, only Pb was higher in the present study than in the study of El-Wazzan *et al.* (2013) in which *Tapes decussatus* collected from Alexandria, Ismailia and Damietta was examined. In that study, Cd values were much higher than those observed in the present study and exceeded permissible limits set by FAO (1983) of 0.5 mg/kg w.w. only in Alexandria (El-Max) and Ismailia (Timsah Lake) but not Damietta. However, it exceeded the 2 mg/kg w.w. prescribed by other regulations (e.g. FAO/WHO 2011, CEP, 2002, Abbott *et al.*, 2003) for mollusks in only samples of El-Max site of Alexandria.

In general, although the concentrations of some heavy metals measured in the present study were higher than those of other studies, the differences were not exaggerated and the measured levels were still within the permissible limits of some countries. Even when values were above permissible limits for European Union, concentrations of all heavy metals in *Chamelea gallina* were below maximum permissible limit set by other countries. Only Pb was higher than these values (5 sites and 4 sites in the dry weight values and when values were corrected for water contents and represented as wet weight, respectively). Therefore, Rasheed which have the maximum biomass of *C. gallina* is completely clean and Burullus is considered heavily contaminated with Pb.

In agreement with the present study, studying levels of Cd, Cu, Ni, Pb and Zn in several bivalves collected along the Egyptian Mediterranean coast from Alexandria to Port Said, El Nemr *et al.* (2012) showed that these metals do not cause adverse effect for either low or high shellfish consumers. Cr. was the only metal that had risk of causing health problems for heavy shellfish consumers. These results show that open water fisheries in the present study and other studied are less contaminated with heavy metals than closed ones as lake Timsah and El-Max area of Alexandria studied by El-Wazzan *et al.* (2013).

All these results from Egyptian fisheries reflect that most Egyptian bivalve fisheries are considered relatively clean considering the FAO/WHO, USFDA and other regulations from different countries of the world (FAO/WHO 2011, CEP, 2002, Abbott *et al.,* 2003). However, in few cases they fail to be approved for the European regulations (EC 2001, EU 2006) which are the most strict legislations. For example, some sites in the present study for Pb and the study of El-Wazzan *et al.* (2013) for Pb and Cd.

This indicates that, *Chamelea gallina* collected from the studied areas should be safe for human use and might provide promising fisheries when toxic risk of the most hazardous heavy metals such Hg, Cu, Cr and Zn are concern. However, the eastern part of the studied area must be monitored for Pb contamination and sources. Then, collection of *C. gallina* should be avoided when necessary.

Taking in consideration the fact that bivalve from these fisheries are safe for human use, the main constraint for the commercialisation of the products will be the market, since these species are at present not commercialised in Egypt, so a market chain analysis should be conducted and a market strategy should be devised in order to successfully introduce the product in the local markets. One important aspect to note is that bivalves are already an established product in Egypt, so the challenge would be to introduce a new bivalve species, in the market, which is much less difficult than the introduction of a completely new group of seafood, such as the gastropods.

5. Conclusions and Recommendations

In the area investigated there is a potential for exploitation of bivalve and gastropod molluscs, using different fishing gears. The potential is limited to a few semi-industrialised vessels, which however would increase the production from the area. Furthermore due to the present overcapacity of the Egyptian fishing fleet, the excessive number of trawlers and the poor economic performance of the 12-18 m trawlers, part of this fleet segment could be converted to fish for clams. If this occurs apart from increasing the production, a reduction in fishing pressure on trawl resources would also be achieved.

Furthermore the survey investigated a relatively small area of about 10% of the Mediterranean coast of Egypt where such fisheries products could occur. This leaves the potential for further surveys along the entire Egyptian coast. On top of this, waters deeper than 10 m were not investigated, in which there could be the potential to exploit bivalve species which are more common in deeper waters, such as scallops and razor clams. This adds the potential for further exploration.

Chamelea gallina collected from the studied areas should be safe for human use and might provide promising fisheries except from the eastern part of the investigated area towards Burullus.

The main constraint in developing this fishery will be the market since at present most of the species encountered are not present on the Egyptian market, so a market analysis and marketing strategy should be performed in order to understand the best way on how to introduce the products on the local market.

Once the market has been understood and the products are successfully introduced in the market a management plan based on the context and methodology of the Ecosystem Approach to Fisheries (EAF), could be drawn up.

Following the results and discussion the following summary recommendations came out from this study:

1) to better understand the potential for marketing the species identified

2) if 1) is positive, to devise a strategy to introduce the product on the local market

3) if the product is successfully introduced on the local markets, to survey other areas along the Egyptian coast which could potentially have fisheries resources similar to the ones found in this study

4) to set up a management plan if the fishery is developed

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ANNEX I - Background information on bivalve fisheries in the Mediterranean with special reference to Egypt.

1.1 Bivalves and their fisheries

The edible bivalve molluscs, such as mussels (e.g. *Mytilus galloprovincialis*), oysters (e.g. *Ostrea* spp.), clams (e.g. *Donax* spp., *Tapes* spp. *Chamelea gallina*), cockles (e.g. *Acanthocardia* spp.) sustain important fisheries throughout the world, including the Mediterranean (Voultsiadou *et al.* 2010), where clams are the group with the highest landings. The word clam is a general term that covers all the bivalve molluscs that burrow in sediment, as opposed to ones that attach themselves to the substrate (for example oysters and mussels), or ones that can swim and are migratory, like scallops.

Clams usually live in shallow water (< 20 m) sandy bottoms which are exposed to nutrient inputs from rivers. In the Mediterranean such areas include the Po delta region of the Adriatic Sea, the Ebro Delta in Spain, the Gulf of Gabes in Tunisia, and other smaller areas such as the sea of Marmara, Northern Greece and the Iberian islands.

Bivalves are fished with a variety of techniques, including by hands (*Tapes* spp.), hammer and chisel (*Lithophaga lithophaga*), knife (*Mytilus* spp.), rake (*Donax* spp.), dredges (*Chamelea gallina*). There are several ways how to use bivalves, both for human consumption (e.g. raw and cooked), for bait, and as ornaments such as necklaces and ashtrays. Typically, the whole animal is extracted from the shell and marketed in several various ways, however for some species only the adductor muscle is used and the rest is discarded or used to make clam chowder.

Bivalves are predated by a variety of organisms including humans, starfishes, shellfish, fish, birds, and especially other molluscs (gastropods) in particular the families Naticidae (e.g. *Natica* sp. and *Neverita* sp.), Muricidae (e.g. *Rapana* sp.) and Nassaridae (e.g. *Nassarius* sp.). Bivalves are also the subject of other natural mortalities, since the organisms are relatively sedentary and closely linked with the substrate, in a limited space. Hence they are very susceptible to competition between organisms themselves, which for example tend to limit the deposition of the young (spat) on the substrate. Bivalves are also susceptible to parasites, siltation activities, both natural and anthropogenic (MacKenzie, 1983) and weather events (abiotic) such exceptional lack of dissolved oxygen on the bottom (anoxic conditions), sudden changes in salinity and temperature (Caddy, 1989). All these factors usually result in cyclical activities of bivalves with significant population fluctuations, including high productivity in certain seasons, followed by mass mortalities (Figure 24), the so-called "boom and bust events" (Caddy, 1989).

Fig. 24. Mass mortality of the bivalve *Anadara polii* in the region of Port Said Egypt

Bivalves represent an economic resource important throughout the world, not so much in the absolute tonnage (ca. 2 million tonnes or 2% of the total capture production; FAO 2012), but more because of the high unit value of the product and the vulnerable groups such as small-scale fisheries which are involved in bivalve fisheries. In the Mediterranean the total production of bivalve molluscs is around 65,000 tons (Figure 25; FAO 2011).

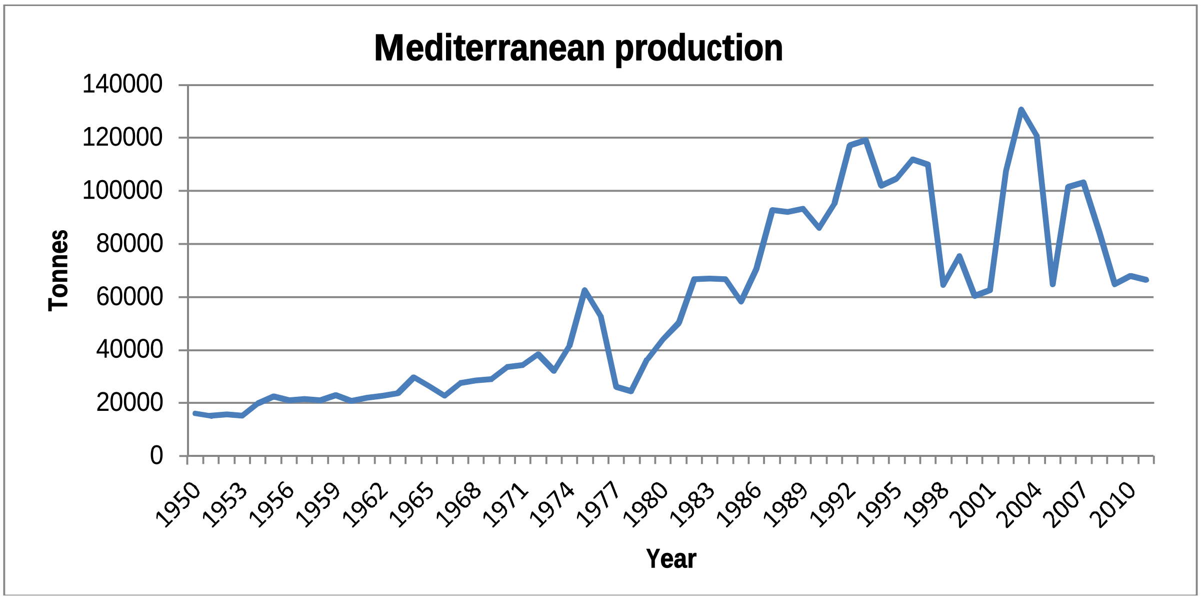

Fig. 25. Total Mediterranean production from 1950-2011 (source FAO).

The highest production is by Turkey 38,000 tons then by Italy with around 30,000 tons, and followed by Egypt with around 3,600 tons (Table 16). Most of the production comes from delta areas such as the Po delta in the Adriatic region, and the Nile delta in Egypt.

Table 16. Production in tonnes by country of bivalves in the Mediterranean (FAO, GFCM).

	2007	2008	2009	2010	2011
Algeria	43	17	6	96	22
Bulgaria	83	35	45	0	1
Croatia	133	80	92	108	167
Egypt	2500	2990	3231	3365	3615
France	160	96	76	145	101
Greece	1191	811	1230	313	0
Italy	32531	28168	21089	23306	23091
Montenegro	156	205	215	206	198
Romania	14	0	1	1	1
Slovenia	1	6	5	7	6
Spain	1183	1267	969	1258	558
Syrian Arab Republic	128	75	90	65	0
Tunisia	837	666	633	433	0
Turkey	64160	49970	37152	38584	38690
Grand Total	**103120**	**84386**	**64834**	**67887**	**66450**

1.2 Bivalve Fisheries in Egypt

In Egypt several bivalve species (Farag 1999) are common to consumers (Figure 26) and include the oyster *Pinctata radiata* (Al-Seridia) and *P. margaritifera* (Al-Sadaf; Farag 1999), the clams *Tridacana* spp. (Al-Boshr), the mussel *Mytilus* spp. and *Modiulus* spp. (Balah Al Bahr), the cockles *Cardium glaucum* (Al-bakalaweez; Farag 1999), different species of the family Veneridae such as *Ruditapes decussatus* (Al-Gandofly), *Venerupis pullastra (*Figure 27; Gabr HR., & Gab-Alla A 2008), and *Paphia textile* (pers. observ.; Figure 4) different species of the family Donacidae such as *Donax trunculus* (Om El-Kholool; Farag 1999) and the ark clam *Anadara* spp. (Farag 1999).

Fig. 26. Vendor of bivalves in the market of Port Said Egypt. *Ruditapes decussatus* can be seen in the right and lower right corner, submerged in water, while *Donax trunculus* can be seen in the upper left which are not submerged.

Fig. 27. Left and centre, *Paphia textile* being sold at the central fish market in Cairo. The species on the right is pullet carpet shell *Venerupis pullastra*

The most important commercial species by far is the clam *Ruditapes decussatus* which is widely distributed in high densities in the shallow inshore waters of Lake Timsah within the Suez canal (Gabr 1991, Kandeel 1992). In Egypt, these clams are greatly appreciated by seafood consumers and in the last decade, the importance of *R. decussatus* has been increasing in terms of landing volumes, economic value and relative importance among other marine resources. The first sale (ex-vessel) price for this species in 2013 was 60 EGP / kg (pers. observ.). At that price, this species is extremely expensive for the regular Egyptian consumer but has a high value for the upper class and tourists. One aquaculture facility exists for *Ruditapes decussatus,* located at the Damietta side of the mouth of Lake Manzala on the Mediterranean coast (Figure 28). The seeds for the aquaculture facility are fished from Lake Timsah from the Suez canal.

Fig. 28. The clam aquaculture farm with a freshly caught sample of *Ruditapes decussatus*.

The second most important species seems to be the bean clam *Donax trunculus* which is commonly found around the market and with a first sale price of about 15 EGP / kg (pers. observ.). A very common but not so commercially important species is *Anadara polii* with a first sale price of about 8 EGP / kg (pers. observ; Figure 29).

Fig. 29. Sales of *Anadara polii* along the highway from Rasheed to Alexandria.

Most of the species mentioned are caught in waters shallower than 1.5 m, mostly picked by hand, as well as by a rake which is pulled by the fishermen in a rocking motion (Figure 30), after which any clams caught end up in a collection basket at the end of the clam rake. Species which are fished in deeper waters such as the clam *Venus verrucosa* are caught by diving. Some large specimens of scallops are also occasionally caught by bottom otter trawlers fishing for shrimps (pers. observ).

Fig. 30. Fisherman fishing for *Donax trunculus* in Egypt in the bay between Port Said and Damietta. Right typical hand rake used for fishing clams.

Clams which are found in waters deeper than 2 meters such as the venus clam *Chamelea gallina*, the smooth clam *Callista chione*, the razor clams, *Ensis* spp. are not fished by a specific fishery, which however may be present in Egyptian waters in commercial quantities. In other countries in the Mediterranean clam banks are usually exploited through the use of a hydraulic dredge, by fishing vessels with an average gross tonnage of about 9-13t, 50 to 150 hp and 14 - 16 m length overall (Froglia, 1989).

An attempt was made in 2011-2012 to fish with a hydraulic dredge and commercialise the clam *Chamelea gallina*, by a local fisherman (pers. comm.). Although he managed to find commercial quantities, the clam could not be commercialised since it was not known in the local markets (pers. comm.).

1.3 The Fisheries of the Striped Venus Clam *Chamelea gallina*

The infaunal clam *Chamelea gallina* is a member of the Verenidae family which is represented by 37 species and 13 of them have an economic importance. *C. gallina* is one of the most important commercial species in the Mediterranean (Tunçer, 2002; Palmer *et al.*, 2004; Padella & Finco 2009). The venerid clam is a popular food item around the Mediterranean countries, with clams differing in market price according to their origin (Palmer *et al.*, 2004). It is a very common bivalve species in the Mediterranean inshore waters, where it inhabits the fine well-sorted sand biocoenosis (Pérès & Picard, 1964). *Chamelea gallina* is a gonochoristic species whose spawning period is long, running from April to October, and taking place at intervals during this period (Froglia 1975). Its growth is rather slow and it takes about 2 years to reach a landing size of 25 mm, by which time all individuals have reached sexual maturity (Froglia, 1975, 1989). Very little is known on species that prey upon *C. gallina*, amongst these are the starfish, *Astropecten* spp. (Thorson, 1966), the gastropod *Neverita josephinia* and the fish, *Gobius niger* and *Lithognathus mormyrus* (Froglia, 1989). A significant source of mortality can be ascribed to summer phytoplankton blooms and associated anoxic events, but exploitation by humans is by far the major cause of mortality amongst *C. gallina* populations (Morello *et al.*, 2005).

Chamelea gallina, is presently exploited in Italy especially along the Adriatic coast, along the Albanian coast (Southeast Adriatic), in the Sea of Marmara (Turkey), on the North Eastern coast of Greece, along the Spanish and Moroccan coasts of the Alboran Sea and along the Spanish coasts of Catalonia, mostly south of the Ebro delta (table 17).

Table 17. Production in tonnes by country of *Chamelea gallina* in the Mediterranean (FAO).

	2007	**2008**	**2009**	**2010**	**2011**
Greece	324	304	262	0	0
Italy	28802	24940	17328	19748	19668
Spain	78	111	55	53	24
Turkey	47215	36896	24574	26931	30176
Grand Total	**76419**	**62251**	**42219**	**46732**	**49868**

Historically the clam was fished using dredges, but in the late 1960s the hydraulic dredge was introduced with an immediate short/middle-term effect of an increase in landings in the early 1980s (Froglia, 1989). The clam is nowadays the target of large fleets of hydraulic dredgers operating in the sandy coastal bottoms (3–12 m), for example in the Adriatic sea a fleet of 700 Italian hydraulic dredgers target this species.

1.4 The Hydraulic dredge

The hydraulic dredge is a large steel cage which is dragged along the bottom by a clam boat (Figure 31). A large pump on the boat pumps sea water through a large hose to a manifold on the front of the dredge. The manifold jets the water into the sand, temporarily fluidizing it and allowing the dredge to pass through (Figure 32). Due to the carefully set spacing of the bars making up the body of the dredge most of the smaller clams and other organisms pass through, the larger clams being retained. The size of the grating of the dredger and the sieve, the maximum width of the dredger, the minimum size of the fishable clams and the maximum daily catch are regulated by law.

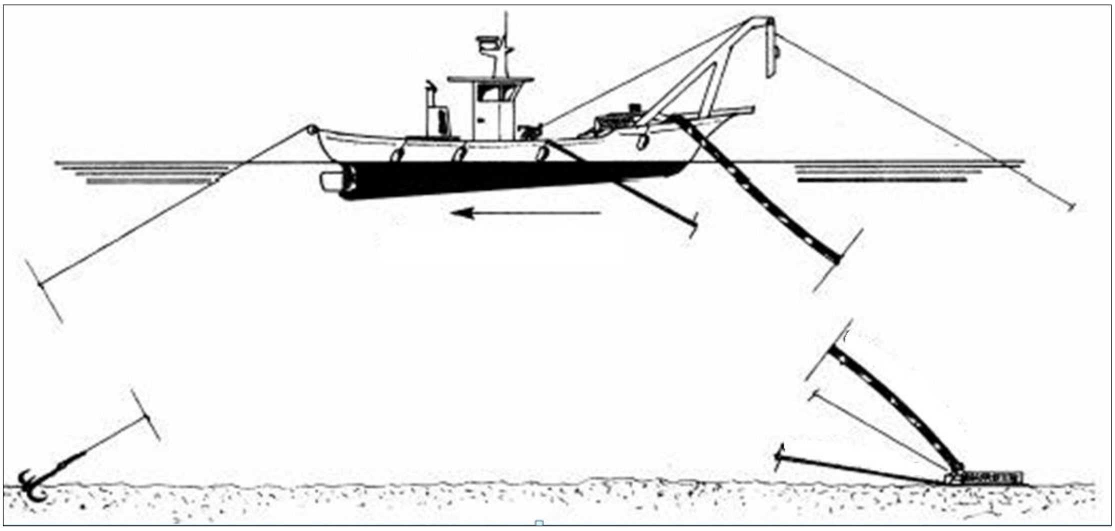

Fig. 31. Clam boat showing the fishing activity and the direction of the tow.

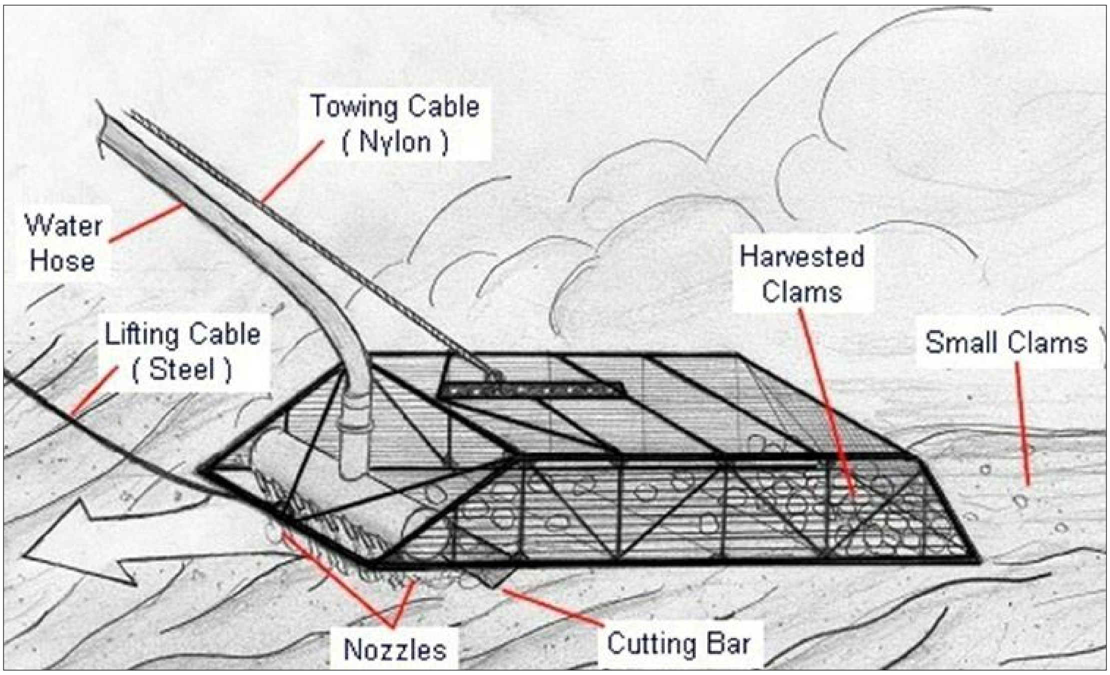

Fig. 32. Diagrammatic representation of a hydraulic dredge during fishing.

In the Mediterranean the fishery is carried out with vessels of 8-15 m in length with a tonnage not greater than 10 GT and an engine of about 150 hp. The fishing activity usually lasts for 6-8 hours and is carried out by two crew. In these six hours several hauls are made which take around 1 hour each. If operating conditions are good and the area chosen has proven successful, these steps are carried out for 9 to 10 times. While the captain is committed to operate the winch and the hydraulic pump and bilge, the sailor is committed to operate the screen and to wrap the catch in the bow. The only operation that is performed simultaneously by two crewmen, concerns the recovery of the dredge on board and emptying it. Screening is done to prepare the bags which are then stacked along the starboard corridor where they are then removed once they arrive in port.

1.5 Discards of the *Chamelea gallina* fishery

Discards comprise the incidental capture of non-target organisms that are returned to sea after a fishing operation (Hall, 1999) because undersized, unmarketable or surplus to quota (Ramsay *et al*., 1997; van Marlen, 2000). Biologically discarding constitutes a serious wastage of resources as well as a threat to the ecosystem as a whole, influencing ecosystem functioning (Ramsay *et al*., 1997; Jennings and Kaiser, 1998). The recent past has been characterised by a growing acknowledgement of the importance of managing fisheries at an ecosystem level thus including an environmental component in management actions. The quantification of discards, is an essential prerequisite if the fishery is managed within the context of the Ecosystem Approach to Fisheries.

Morello *et al*., 2005 studied the discards of the commercial fishery of *C. gallina* to provide a qualitative and quantitative assessment of the discards produced by the commercial hydraulic dredging fleet in two Maritime Districts of the Adriatic Sea, Ancona and S. Benedetto, with the aim of suggesting appropriate management actions.

Overall discards comprised just under 50% of total catch in both Maritime Districts, approximately 30% of which were undersized target species (< 25 mm) and 20% other benthic invertebrates, with a negligible quantity of fish. Such high proportions of discards appear to be common to many fisheries. In terms of discard and by-catch species composition a total of 58 taxa (43 molluscs, four polychaetes, four crustaceans, five echinoderms and two fish) were found in the dredge. By-catch species such as most fish (e.g. *Arnoglossus laterna, Solea vulgaris, Trigla lucerna*), cephalopods (*Sepia officinalis*) and most edible crustaceans (e.g. *Squilla mantis, Melicertus kerathurus*) are generally retained and landed for home consumption.

Proportions of landed target species were very similar, but discards in Ancona were dominated by small *C. gallina*, whilst in S. Benedetto discarded invertebrates prevailed. This was explained by the difference in status of the stock between areas. The *C. gallina* stock in the S. Benedetto Maritime District has been heavily exploited in the past 20 years and a larger number of vessels operated in a considerably reduced area. The result has been a marked decrease in stock over the past decade, with smaller size of *C. gallina* being landed. The overall scarcity of adult individuals has led to the exploitation of undersized product by the fishermen, despite *C. gallina* having a minimum landing size of 25mm (EC Regulation 1626/1994). The result is an inefficient fishery with low catch per unit effort. Large quantities of invertebrate discards are generated in order to be able to land an economically profitable amount of target species. In contrast, discards in the Ancona Maritime District were dominated by undersized target species reflecting good recruitment in the area. One of the zones within the Ancona district exhibited also the most ecologically efficient area, in that overall discards constituted less than 25% of total catch and these were dominated by invertebrates other than the target species. This Zone was subjected to very intense exploitation between January and March 2001, and was reported to have yielded a significantly overall higher catch per unit effort than any of the other areas in the District between July 2000 and 2001 (Marrs *et al.*, 2002).

Survival of discard organisms from the direct effects of fishing depends on a number of interacting factors. These include substratum type; duration, speed and depth of tow; size and composition of the total catch; and on-board exposure to air, temperature changes, light intensity changes and handling (Gaspar and Monteiro, 1999; Bergmann and Moore, 2001). The extent of damage is species-dependent, being a function of size, morphology, fragility, life cycle and vertical distribution within the sediment (Franceschini *et al.*, 1999; Bergman and van Santbrink, 2000). The catch on a hydraulic dredge is usually rapidly sorted on board and specimens that are undersized or of no commercial interest are returned to the sea. Generally starfishes (Kasier & Spencer 1994), sea urchins (Hauton *et al.*, 2003), hermit crabs and molluscs were highly resistant to the effects of capture (>60% survived in all cases). Fishes (Palma *et al.*, 2003), and swimming crabs (Kasier & Spencer 1994) suffered higher mortality after capture. Generally, the majority of the animals that passed through the meshes of the cod end survive.

In the case of the *C. gallina* fishery Morello *et al.*, 2005 concluded that in order to reduce discarding and the impact of the fishery on the exploited benthic community, emphasis should be placed on both technical measures and the establishment of ecosystem-compatible fishing practices. Thus, an increase in the spacing between dredge bars from the present legal distance of 12 mm would significantly decrease the mobilisation of undersized target species. In view of a “recruitment” management strategy the rotational system of exploitation should be managed on a fishing ground by fishing ground basis.

1.6 Impacts of the *Chamelea gallina* hydraulic dredge on the benthic communities

Bottom trawling can have dramatic effects on the structure and functioning of marine ecosystems (Hall, 1999; Kaiser and De Groot, 2000). Shellfish dredging and hydraulic dredging have been reported amongst the bottom fishing activities, for causing the greatest disturbance to the seabed (Eleftheriou 2000; Kaiser *et al.* 2002). Hydraulic dredges not only scrape the surface of the substratum but also dig into it, resuspending significant amounts of sediment. It has been found that hydraulic dredging contributes to destabilisation and partial modification of sediment conditions, resulting in an overall decrease in habitat complexity with direct implications for the benthic community (Kaiser *et al.* 2002; Morello *et al.*, 2006). Shifts in benthic community structure in favour of a few dominant opportunistic species have been observed (Pranovi and Giovanardi 1994; Dayton *et al.* 1995). Short-term effects of inshore fisheries such as hydraulic dredging are widely reported in the literature (Tuck *et al.*, 2000; Morello *et al.*, 2006). Communities living in high-energy environments and constantly subjected to natural environmental stress will be less susceptible to fishing disturbance (Kaiser *et al.* 1996; Jennings and Reynolds 2000).

This may be the case for the macrobenthic community inhabiting the shallow sandy bottoms of the area in which *Chamelea Gallina* lives. Frequent small-scale disturbances, such as dredging operations, may be masked by large-scale environmental perturbations, such as storms, and prevailing hydrodynamic processes may be among the key factors determining the extent to which an area will be resilient to fishing disturbance.

Morello *et al.*, 2006 studied the impact of different levels of fishing intensity on the changes in the benthic community within the *Chamelea gallina* fishing ground in the Adriatic Sea. The results of Morello *et al.*, 2006 revealed relatively short recovery times for the macrobenthic community in response to different intensities of fishing activity. In all cases, such response occurred within 6 months (in the case of September 2000 samples within two months). The nature of the environment in which the studies were carried out is an important factor. Communities living in high-energy environments and constantly subjected to natural environmental stress will be less susceptible to fishing disturbance (Jennings and Reynolds 2000; Zajac and Whitlatch 2003). The study area comprises a shallow dynamic habitat subject to natural disturbance events, such as storms, which could have been responsible for an altered benthic community especially in seasons with strong winds. Average wave height data for the days immediately preceding sampling indicated no differences between the three sampling periods in terms of hydrodynamism. However fishing impacts were detected between the three fishing intensities considered and are thus an indication that fishing activities did play an important part in altering the benthic community.

The results obtained from Morello *et al.*, 2006 indicate that temporal and spatial variability of the sandy community considered is affected in different ways by different intensities of fishing disturbance. Differences within the shallower community (4–6 m depth stratum) were detected above a threshold level of fishing intensity, with differences being significant only between ‘moderate’ and ‘high’ fishing intensity. Contrarily, no differences were evident between ‘moderate fishing intensity’ and ‘no fishing’ indicating an overall condition of moderate disturbance within the benthic community. The benthic community in question has been subjected to years of commercial exploitation with hydraulic dredges and will have an inherent resilience to natural physical disturbance (MacDonald *et al*. 1996; Kaiser 1998). In addition, major changes in community structure probably occur when a fishery is new and when an area is first subjected to fishing pressure (Jennings and Kaiser 1998; Tuck *et al*. 1998; Hall-Spencer 1999). In Morello *et al.*, 2006 the results showed that in all cases, but especially for the 4–6 m depth stratum, an overall situation of moderate disturbance was detected (Kaiser and Spencer 1996; Kaiser *et al*. 2002). This situation did not improve with decreasing fishing disturbance within the 4–6 m depth stratum but some improvement, was evident within the 7–10 m depth stratum for relatively low fishing intensity.

An overall increase in the number of species with decreasing fishing intensity was found. In particular, the fragile bivalve species, *Mactra stultorum*, was positively correlated with ‘no fishing’ within the 4–6 m depth stratum. Owing to its thin shell and large size, *M. stultorum* is particularly vulnerable to damage by both the dredge and the sieving operations carried out to sort the catch, with over 60% of individuals caught having crushed shells (Morello *et al.*, 2006). Crushed individuals do not survive when returned to sea. The 6-month fishing closure, from April to September 2001 within the study area, allowed newly recruited (and the few remaining adults) of *M. stultorum* to grow undisturbed, a situation that was impeded, by fishing.

The hermit crab *Diogenes pugilator* was not particularly vulnerable to hydraulic dredging because of the protection offered by the gastropod shell that it inhabits. Despite this, disturbance by the gear, collection and subsequent sieving of the catch may lead to the loss of its protection and dramatically increases its vulnerability. On the other hand, *D. pugilator* may benefit from hydraulic dredging in two ways: increased food resources and increased 'home' availability. Numerous individuals of *D. pugilator* have been observed aggregating to feed on hydraulic dredge discards (Hauton *et al*. 2002) and similar findings have been reported by Ramsay *et al*. 1996. for the hermit crab *Pagurus bernhardus*. That *D. pugilator* abundance and biomass were highly correlated with the 'moderate fishing intensity' samples in particular, may be explained by the fact that no fishing at all will not offer the species any advantage with respect to other unfished areas and high fishing intensity may be too deleterious. The same was hypothesised for the scavenging starfish *Asterias rubens* (Ramsay *et al*. 2000). Within the 7–10 m depth stratum, the abundance of the bivalve *Alba alba* was highly correlated with the 'high fishing intensity' samples emphasising its high catchability and vulnerability with respect to the dredge. The same was true, upon consideration of biomass data, for starfish of the genus *Astropecten* sp.. These results reiterate the importance of *A. alba* highlighted by a short-term impact study (Morello *et al*. 2005), suggesting that, within this area, it may be an indicator species with respect to the effects of hydraulic dredging on the benthic community.

This study has highlighted important aspects of medium-term effects of hydraulic dredging within the clam fishery in the Adriatic Sea. Most importantly, the results have emphasised the fact that, despite intensive fishing that has been going on for decades and a benthic community that is typical of a moderately disturbed environment, above a medium fishing intensity, the effects of fishing on community structure were still discernible over and above natural variation and this was particularly true for the shallower assemblages. Furthermore, the results described here indicate a relatively rapid recovery of the system (within 6 months).

While the impact of hydraulic dredges on the bottom at first glance seems severe, the mechanical restrictions that the gear imposes, hose length, pumping pressure, and the management measures such as closed seasons and limited number of vessels, limit the impact of the dredge on this habitat. The sandy bottom environments in these areas are normally exposed to far greater perturbations during winter storms and take such disturbances regularly. This means that such habitats are used to and have adapted to such perturbations.

1.7 Behavioural effects of the hydraulic dredging on the target species *C. gallina*

Apart from the direct impacts of fishing on the status of the resources, other factors can contribute to the decline of the stocks of clams, for example along the western coast of the Adriatic failure in recruitment and widespread mortality has been observed in several clam beds (Froglia, 1989, 2000). As a consequence, it is important to monitoring abundances of the clam population, evaluating its dynamics, and investigating the causes of repeated outbreaks of mass mortalities (Froglia, 2000).

The use of biomarkers to describe the state of bivalve populations and evaluate the effects of hydraulic dredging as a whole on the biological response of the target species and/or the by-catch, has been addressed in the Northern Adriatic Sea by Da Ros L., *et al.*, 2003. The study focussed on the effects of repeated disturbance caused by commercial hydraulic dredging on the target species. The hypothesis was that dredging had a detrimental effect on undersized animals, subjecting the exploited clam populations to stress. If commercial hydraulic dredging had significantly negative effects, it might be considered at least a partial cause of increased mortality and a factor contributing towards abnormal susceptibility to normal fluctuations in environmental parameters.

The study focused on evaluating biological effects on the target species *Chamelea gallina* as a result of repeated exploitation of clam beds by hydraulic dredging. A biomarker approach was adopted and two physiological indices were applied: adenylate energy charge (AEC) (biochemical level) and re-burrowing behaviour (organism level). As a number of studies have found significant relationships between AEC levels and specific behaviour in bivalves, namely shell closure in mussels and recessing ability in scallops (Maguire *et al.*, 2002). Da Ros L., *et al.*, 2003 examined the AEC level in the foot, which is also the main organ involved in re-burrowing of *C. gallina.* Initially, a preliminary field investigation of the stress caused by different fishing methods was carried out. This was followed by an experimental study, undertaken in the laboratory, for better understanding of the biological response of the animals. The ultimate aim was to evaluate the negative effects of repeated mechanical stress imposed on undersized animals, because the smallest specimens are more likely to be taken up by the hydraulic dredge and then thrown back into the sea more than once before reaching commercial size, due to the high fishing pressure on the clam population.

Field results showed that clams which were exposed to dredging at high water pressure (inlet pressure value 2.5 bar) and mechanically sieved for sorting (high pressure; HP) exhibited significantly lower levels of AEC compared with clams which were dredged at low water pressure (inlet pressure value 1 bar) and without mechanical sorting (low pressure; LP). A similar trend was shown by re-burrowing behaviour; HP-treated clams re-burrowed less. Laboratory results were less clear: a very low level of AEC was measured in both control and treated clams. These poor conditions in foot muscle did not indicate worsening at organism level, as no dead or dying clams were recorded throughout the experiment. However, repeated mechanical stress reduced the percentage of re-burrowing clams, which suggested that harvesting may affect re-burrowing behaviour.

The ecological relevance of burrowing behaviour in clams becomes apparent when we consider their need to avoid predation (Doerding, 1982; Pearson *et al.*, 1981). It gives an indication of the indirect mortality resulting from increased exposure to predators (Phelps, 1989). These considerations are important in highlighting how long *C. gallina* can be left on the seabed after any kind of sediment perturbation, and show that it is a very responsive organism for evaluating mechanical stress. Juvenile individuals are in general more vulnerable and more sensitive to environmental variations (His *et al.*, 2000), than adults. When returned to the sea after passing through the mechanical sieve on board, these juveniles can no longer quickly reburrow and are thus more vulnerable to predation by crabs and gastropods, as suggested by Hall-Spencer *et al.* 1999 and Da Ros L., *et al.*, 2003.

1.8 Susceptibility of bivalves to pathogenic and heavy metal pollution in Egypt

Contamination of bivalve shellfish (e.g. oysters, clams, mussels and cockles) is a major food safety concern (Bella & Tam 2000). Bivalves respond to changes in concentrations of contaminants in water, and they bioaccumulate contaminants from the water column over time (De Kock & Kramer 1994, Gunther *et al.* 1999). Consequently some commercial bivalve fisheries are polluted with different kinds of contaminants caused by the discharges of industrial and municipal effluents containing chemical and biological contaminants such as heavy metals, hydrocarbons organochlorines, pesticides and pathogenic bacteria and viruses (Hamza and Gallup 1982, Abdel-Shafy *et al.* 1987, Shriadah 1992, Hussein *et al.* 2002). Therefore, there is safety concerns regarding the consumption of such bivalves, especially those contaminated with pathogens and their role in outbreak of diseases such as typhoid (Buchan 1910; Murray and Lee 2010).

Pathogenic bacteria (*Vibrios, Aeromonas, Staphylococcus* spp., Enteric *Salmonella*) are considered as potential hazard to humans, and marine organisms due to the possibility of causing severe diseases such as cholera and other gastrointestinal diseases which cause vomiting, abdominal pain, diarrhea and subsequent fluid and electrolyte loss to humans. Vibriosis and hemorrphagic septicemia, are diseases affecting a wide variety of freshwater and marine fish (Popoff 1984; Palumbo *et al*. 1989) in addition to human and swine. Moreover, Bovine salmonellosis is caused by *Salmonella typhimurium* (Popoff and Minor 1997), which is readily transmitted through the faeces of people or animals. Disease-associated mass mortalities of clams were responsible for declining clam populations and harvest from commercial clam beds in many areas (Altug *et al*. 2008).

Recent studies in Egypt showed that, the carpet shell clams, *Ruditapes deccussatus,* from three main Egyptian fisheries (Alexandria, Damietta and Ismailia) were found to be contaminated with pathogenic bacteria and heavy metals (El-Sersy *et al*., 2012, El-Wazzan *et al*. 2013) in addition to parasites that affected their reproductive potential by causing castration (Hashem *et al*. 2012). This might affect clam quality and suitability for human consumption. Therefore, to enhance public health protection, assessment and classification of clam fisheries into approved or non approved harvesting areas are needed to dictate whether harvesting can be permitted from such fisheries and, if so, what method and level of treatment may need to be applied to the bivalves prior to further sale. The areas should be periodically monitored for microbiological quality, toxin producing plankton, biotoxins and chemical contaminants.

The risk associated with contaminated shellfish can only be reduced in two ways; by relaying (transplantation) in clean water and by depuration (Richards 1988). The practice of relaying involves moving contaminated shellfish from polluted areas to clean areas and allowing the animals sufficient time to purge themselves of pathogens or chemicals. Shellfish are collected and re-planted over existing natural beds for at least one spawning season.

Depuration is the term applied to the purification, under controlled conditions, of shellfish harvested from moderately contaminated areas. The process generally involves holding the shellfish in tanks of flowing seawater for periods of 48 to 72 hours, the seawater being sterilised by ultraviolet light. Shellfish harvested from moderately contaminated areas can normally purge themselves of bacterial contaminants, but this process has not been successful in purging shellfish of heavy metals (Arnold 1991). Although the scientific literature suggests that metal depuration is possible, the mechanics of this process have not been adequately addressed (Han *et al.* 1993). Metal depuration rates vary widely, showing diverse ranges for the same metal within different bivalve species and for different metals within the same species (Richards 1988).

Ruditapes decussatus and *Venerupis pullastra* are clams widely distributed in high densities in the shallow inshore waters of Lake Timsah, Egypt (Gabr 1991; Kandeel 1992). Heavy metals, among other contaminants, are present in high concentrations in industrial effluents discharged into Lake Timsah (Mourad 1996). Recently, exports of *R. decussatus* were halted owing to contamination with heavy metals and bacteria. Moreover, the clam industry has suffered a decline in sales in the local market as a result of heightened publicity being given to clam-related illnesses. In this respect studies have been conducted in Egypt to assess the pathogenic and heavy metal pollution of commercial bivalves, mostly of *Ruditapes decussatus* and *Venerupis pullastra* due to their high economic importance.

El-Sersy *et al*., 2012 studied the current status of the carpet shell clam, *Ruditapes deccusataus*, and its health in Egyptian natural fisheries and the possible risk associated with their consumption. Potential clam pathogens (*Vibrio* and *Aeromonas*) and human pathogens (*E. coli*, *Staphyllococcus* and *Salmonella*) were monthly counted in clams from Alexandria, Ismailia and Damietta. Severe contamination with vibrios was observed in Ismailia from April to June with counts within the range 1125 -1750 CFU/ml. *Aeromona* and *Staphylococcus* were not detected during winter and spring, but the highest count in summer was within WHO permissible limits. Faecal indicators and potentially harmful human pathogens (*Salmonella* spp. and *E. coli*) were recorded in all sites with highest *Salmonella* spp. count in Alexandria in all months and in Damietta and Ismailia in July. Results showed that these sites are not suitable for clam aquaculture or natural harvest of clams for human consumption unless government regulations are enacted, (e.g., depuration before use for human consumption) to protect public health.

El-Wazzan *et al.* (2013) studied the contamination by four heavy metals, Pb, Cu, Cd and Zn (ppm) in the carpet shell clam, *Tapes deccussatus* from six sites in three main Egyptian natural fisheries over a six months period representing the winter and spring seasons (December 2010 – May 2011). The six stations were selected from locations exposed to different levels of industrial and municipal discharge [Ismailia (2 from Timsah Lake), Alexandria (2 from Eastern Harbour, El-Anfoushy) and Damietta (one from clam farm in Ezbet El-Borg)] Results showed that clams were more heavily polluted in the spring than in winter months. Pb, Cu and Cd exceeded the permissible limits of FAO (1999) in most of the studied stations in the spring even the assumed clean ones. Zn did not exceed the permissible limit in any of the stations in both seasons. Damietta showed the least contamination by Cu, Cd, and Zn but showed high contamination with Pb. Clams from two stations in Timsah Lake, Ismailia and from Ezbet El-borg, Damietta were contaminated with Pb in both seasons. However, only three of the six stations, one in Timsah Lake, Ismailia and two in Alexandria in El-Max and eastern harbour were heavily contaminated with metals reflecting spatial variations according to the sources of pollution. The data were in contrast to the sediments and water data for the same sites that showed that clam fisheries are not highly contaminated with heavy metals. However, bivalves have great ability of bioaccumulation of contaminants from the surrounding environment. Therefore, the studied sites were suggested to be not suitable for use as grow out sites for clam aquaculture in Egypt.

Gabr HR *et al.*, 2008 studied the effect of transplantation on levels of heavy metals (Fe, Mn, Zn, Cu, Ni, Co, Cd, Pb) in *Ruditapes decussatus* and *Venerupis pullastra*. The clams were removed from their polluted site and transplanted to a relatively clean area for a period of 120 days. Although the salinity at the transplantation site was higher than at the polluted site, it was stable and did not appear to have any adverse effect on clam growth. Heavy metals were analysed in the water, sediment and clam tissues from both the polluted and the transplantation sites. Although in both species transplantation evidently reduced heavy metal levels, these still exceeded the maximum permissible levels laid down by the WHO (1982).

In summary all of the studies conducted in Egypt show that the present pollution levels of the clam *Tapes decussatus* are high and in this respect one needs to assess the risk to public health of any clam species that can be exploited in Egypt, including the clam *Chamelea gallina*.

1.9 Governance and management of the *Chamelea gallina* fishery

In different countries different management measures exist for the fisheries of bivalves in general, however in the best managed fisheries, especially for the clam *Chamelea gallina* most of them are managed through Territorial User Rights (TURFs). As the term clearly suggests, TURFs involve a certain territory and certain rights of use relating to fishing within that territory. TURFs may be defined as community held rights of use (or tenure) and exclusion over the fishery resources within a specific area and for a period of time. Accompanying these rights might be certain responsibilities for maintenance and proper management of the resource base, as well as restrictions on the exercise of the rights of use and exclusion.

An example of this type of management for the clam *C. gallina* will be illustrated by one of the most successful examples in the North Adriatic Sea. Clam fishing for *C. gallina* is nowadays done by means of hydraulic dredges which was introduced relatively recently in the 1970`s since previously the clams used to be fished by hand rake and diving only.

The current clam management system is the outcome of a long process that started from the early 90`s (Padella *et al.*, 2009). With the introduction of the hydraulic dredge, fishing capacity increased dramatically, the harvests decreased and the resource became overexploited. Simultaneous failure in recruitment and widespread mortality in several clam beds along the western coast of the Adriatic have been suggested as concurrent factors (Froglia, 1989, 2000). New measures were immediately established by the national government; input and output measures were introduced and a specific licensing scheme was developed. A National Management Committee was introduced whose task was to co-ordinate the management measures governing this fleet segment.

Towards the end of the 90`s, the failure of the strategy that had been adopted by the government was evident. Fishing effort was considered too high and the income of the fishers declined dramatically. The management authority was considered responsible for the failure and fishers asked for financial support and new regulations. Since then a new management approach was initiated. The new management system aimed at:

a) shifting of responsibility from the central administration to ship owners or co-operatives,
b) replenishment of the clam stock and establishment of a sustainable ratio between effort and resource.

The National Management Committee was dismissed and Management and conservation of bivalve molluscs has been partitioned among Local Management Co-ordination Committees which, within a regulation framework could exert a restricted decision-making role. The powers granted to these committees were provided for by a central regulation, which entitled them to determine daily catch quota, number of fishing days in a week, seasonal closures, maximum landings, area rotation, allowed gears, periods, landing sites, restocking areas, and other local regulations. Basically, they were granted all the powers previously held by the Ministry, which were added to those already in their control. Furthermore, an "inter-consortia" Committee were established at national level. Its aim was to improve the co-ordination of the catch and of the commercial flows among its members.

The Ministry however still retained the basic regulations (Prioli 2005), which the local management committees had to respect. These included

a) Authorized vessels equipped with a hydraulic dredge system.
b) No new licenses could be issued,
c) Minimum size (25mm, Reg. 1639/68),
d) Maximum daily catches (600 kg),
e) Limits of fishing activities within the area where vessel is registered,
f) Minimal fishing depth of 3 m
g) Technical characteristic of the vessel: maximum length 10 m, maximum of 150 hp of propulsion engine, maximum boat displacement 10 t, no auxiliary engines for the pumps, simple propeller, not ducted
h) Technical characteristic of the fishing gear and selection gear including that the hydraulic dredge is a rectangular steel cage capable of penetrating into the bottom with an adjustable blade and a number of jets running the full width of its lower leading edge. It must have the following characteristics horizontal front, hard box where the product is collected, jets where high pressure water comes out from hydraulic pipes. A maximum dredge mouth width of 3 m, maximum pressure from the jets 1,8 atmospheres, maximum dredge weight 600 kg, The lower part of the cage must have a mesh or bar spacing to ensure the gear selectivity. Bar spacing cannot be smaller than 12 mm, with less than 1 mm tolerance. Minimum mesh sizes of the selective gear called must be at least 12 mm for bars with at least 21 mm diameter for perforated plates with round holes.
i) The trawling method is established by the consortium. Where there is no constituted consortium, or for unregistered vessels, the trawling must be carried out by hauling the anchor.
j) Two months of closed season are compulsory: they are fixed in the period 1st April - 31st October, throughout the year the closure is obligatory also on weekends and holidays. In the period between April 1st and September 30th one working day chosen by the Consortium can be added.
k) Further obligations concerning statistical data collection are provided for this fishery method. The license holder has to fill a form within the 5th of each month. The form is to be sent to the Consortium. The Consortium will put together the statistics of all the vessels registered and will send a summary form to the Ministry within the 15th of the following months.
l) The Consortium has to draw up an annual management plan of seed stocking and other management measures.

As can be seen from the table below, this permitted an increase in prices, while reducing the level of exploitation and the sector is now having excellent results (table 18).

Table 18. Main indicators for clam fishery with hydraulic dredges (1996 - 2002; IREPA-MIPAF).

Economic indicator	1996	2002	% Change
Incomes/vessel (000 euro)	42	96	129
Gross profit/vessel (000 euro)	14	39	179
Added value/vessel (000 euro)	30	77	157
Incomes (mill. euro)	34	64	88
Gross profit (mill. euro)	12	26	117
Added value (mill. euro)	25	52	108
Licence value (000 euro)	130	500	285

In summary over the period 1996-2002 there was considerable growth of saleable gross production, a constant decrease in fishing activity and a reduction of exploitation costs due to a more rational management of resources. The successful management of the fleet was based on a progressive decentralisation of the decision level, ending up with a co-management regime where Territorial Use Rights for Fisheries (TURFs) were introduced. A number of interesting issues can be derived from this experience. They can be summarised as follows:

- the sedentary character of the target resource, which is distributed in specific areas easily identified in every fishing district, make things much easier;
- homogeneity of the fishery segment is another important aspect, allowing the introduction of rules largely accepted by all fishermen,
- when TURFs were assigned fishermen are ready to take advantage of them,
- the existence of a co-management approach plays an important role; a command and control approach would have never been appropriate.

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