Morphometry and areal growth cohorts of common epifaunal species on a sand bottom of the Cilician shelf (Turkey), Mediterranean Sea

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Abstract

Biometry and growth cohorts of common epifauna collected monthly with a sledge for a two year period was studied on the Cilician shelf of the Mediterranean Sea. The dimorphisms in the length-width-weight relationships were observed for the epibentic fauna due presumably to the sexes whereas biometrically dimorphic relationship was not structured for the common flat fishes. Maximum number of growth cohorts changed between >C2 (*Buglossidium luteum*) and >C4 (*Arnoglossus laterna*) for the flatfishes. Nine cohorts coexisted for a hermit crab, a crustacean species. Three muricid (Mollusca) species were classified with maximum number of cohort up to >C2 and the nassariid gastropods as well. A Lesepsian bivalve, *Pinctada radiata* displayed two growth cohorts, and three cohorts based on disc thickness of a seastar (*Astropecten irregularis*).

Key words: Epifauna, biometry, growth cohorts, distribution, Cilician shelf, Eastern Mediterranean Sea.

INTRODUCTION

The population stock estimators, bioassay experimentalists, ecosystem modelers and ecologists have interested one of marine population dynamic parameters, growth and growth-related parameters (i.e. biometrical relationships, size frequencies, generation time, reproductive state, life span, maximum sizes of individuals, and number of annual cohorts and number of batch) of marine organisms. Those parameters which lead to a better understanding of their functional role in aquatic ecosystems are of important for not only marine biological theory but also life-history trade-offs for utilization, conservation and management of the stock in practical way (Binohlan and Pauly, 2000; Charnov, 1993, Moutopoulos and Stergio, 2002)

Many benthic invertebrates are keystone components for the Mediterranean ecosystems (Coll *et al.*, 2006). Marine invertebrates are a very diverse group which is also reflected in the various both biometrical and body part types more than those for the demersal fishes (basically, total, fork and caudal length, some others, Katsanevakis *et al.*, 2007). Body size-based growths of epifauna and infauna and some of pelagic invertebrates are estimated from measurements of a variety of their body parts of (Table 1). Width of certain segments, vestimentum width, head area of annelids, carapace width or length, chelas width, eyes width, total length, head length and specific indices of crustaceans, shell height, operculum length, body volume of gastropods, shell width or height of bivalves, upper jaw angles or mantle length of the squids, volume of ascidans and test diameters of echinoderms are the mostly used parts for assessment of the growth and growth-related parameters and cohort analyses (Table 1). Sexual dimorphisms in body size and some organs are generally observed for epibenthic animals (Zeldis, 1985; Branco *et al.*, 2002; Mutlu, 2004), which must be taken into

consideration for the growth issues. Different body parts play crucial function in growth as the specimens grow up; for instance, sub-adults or juveniles of *Strombus* (*Conomurex*) *persicus* grow in length of shell whereas the adults are stopped in growth of shell length after a certain length, and then continued in growth of shell length (Mutlu and Ergev, 2006) as in case of shell lip thickness for *Strombus gigas* (Stoner and Sandt, 1992). Therefore, integrating two measurements (length and width) surface area as an indication of the growth of epifauna could be functioned well in the modal analyses of cohorts in time.

Shimazaki and Shinomoto (2007) underlined that selection of optimal bin size relevant for specific size ranges of each species was of paramount to asses growth cohort. They described that these empirical methods for the bin size selection in a bar graph histogram in an order as follows : i) estimation of the number of sequences required for the histogram, and ii) estimation of the scaling exponents of the optimal bin size were corroborated by theoretical analysis derived for a generic stochastic rate process by dividing the observation period T into N bins of width Δ from the measurement (iii), and counting the frequency (k_i) of ith bin size (iv), and then constructing the mean and variance of the number of k_i (v) before repeating that computing the cost function changing the bin size Δ to search for minimum $C\Delta*$ (vi) which is the optimum bin size for the measurement (Figs. 2-4).

The choice of interval width (binwidth/bandwidth) is one of the central problems in density estimation within discriminated growth cohorts. There are several ways to select an appropriate binwidth for histograms; frequency polygons, or averaged shifted histograms and a bandwidth for kernel density estimators (KDEs). The kernel density estimators (KDEs) are superior at recovering interesting structure (Scott, 1979). It is possible to construct size-frequency histograms to separate batch classes, but this method can be subjective as it becomes increasingly

difficult to separate the older classes (Scott, 1985). Nevertheless, the fixed bandwidth KDEs are not effective to eliminate noisy bars in any low count interval of the distribution and miss distribution details in cohorts at which data concentrate (Salgado-Ugarte *et al.*, 1993, 1995), and the KDEs are recommended to analyze in detail data distributions instead of the traditional histograms or frequency polygons. Presented in the present paper are the optimal Gaussian binwidth for histograms and frequency polygons (Scott, 1992) and the optimal bandwidth for Gaussian KDE's (Silverman 1986).

The aim of the present investigation was to describe the biometry and size structures of common epibenthic fauna on a sand bottom on the most northeastern shelf of the Mediterranean Sea during 2-year monthly investigations. Additional goals included highlighting their areal growth cohorts and sexual dimorphisms in the size.

MATERIALS AND METHODS

The study was conducted on a shallow water section of Levantine (Mediterranean Sea) continental shelf off Erdemli, Mersin Bay, Turkey (Fig. 1A). Shallow water has been restricted to depth gradient up to 10 m. Bottom of the shallow zone was composed of pure sand sediment (>99%) and physically disturbed by currents, waves, climate and anthropogenic riverine sources. In the Mediterranean Sea, the zone has been classified as a part of "fine, well-sorted sand" (SFBC, Peres, 1982). Makra and Nicolaidou (2000) found two communities of the infralittoral zone, that of Muddy Sand in Sheltered Areas (SVMC) and that of SFBC under disturbance and/or eutrophication in the Eastern Mediterranean. The zone was temporally very dynamic and well-diversified in epifaunal species and abundance, due mainly and recently to an indo-pacific dominant species, *Conomurex persicus* which showed interannual and monthly variation in population (Mutlu and Ergev, 2006, 2008).

Samples of epifaunal individuals were collected monthly along the 5 and 10 m depth contours off Erdemli, Mersin (Fig. 1B) in a period (*T*) of June 2000 to November 2001, and then seasonally between February and April 2002 and between February and May 2000. Samples of soft bottom epifauna were collected using the epibenthic sledge of Hessler & Sanders (60 x 15 cm mouth opening, 0.5 x 0.5 cm mesh size: Holme and McIntyre, 1971) deployed by R/V Erdemli of Institute of Marine Sciences-Middle East Technical University (IMS-METU) in the study area (Fig. 1A). Sledges lasted about 15 min at 2 knots. Geographical coordinates were fixed from GPS to estimate distance trawled on the bottom. Each sample was washed in a sieve (0.5 mm square mesh), then preserved in the 9% formalin solution buffered with the borax. On board, samples with total number of individuals higher than about 500 inds (i.e. a gastropod *Conomurex persicus*) were sub-sampled with 3-5 jars each containing 70-90 randomly taken specimens, and the rest of these samples were only counted.

In the laboratory, samples with total number of individuals higher than about 100 inds (i.e. a host crab, *Diogenes pugilator*) were sub-sampled, and the rest of these samples were only counted. Total length (L, cm) and the widest width (Wi, cm) of the fish species identified were measured with a scale to the nearest millimeter. Shell lengths (as function of height) and width of the molluscan individuals, carapace length and widest width of the crustacean individuals, and the length (as a function of disc diameter) between the mouth and the tip of the longest arm

of each starfish and disc thickness (as function of width) of the echinoderms were measured using vernier calipers to the nearest 0.01 mm. Their individual weights (W, g) were measured with an electronic balance in a precise of 0.0001 g. Shells of mollusks and crusts of the crustaceans included to the individual weights. Individual weight of the host crab was measured after the individuals were taken out of the molluscan shells. Their individuals whose abdomen was broken apart from the carapace was weighed, but not involved into any analyses of the present study.

Of a total of 76 species found on a sand bottom of the study area (Mutlu and Ergev, 2008), common and constant species (Soyer's frequency index; 25%>F>50% and F>50%, respectively; Soyer, 1970) were chosen for the growth cohort analyses (Fig. 2, Table 2) due to inefficiency of KDEs in any low count and species with a total abundance of greater than 4 ind for the biometrical processing in the present work (Table 1).

With a method developed by Shimazaki and Shinomoto (2007), we determined the optimal bin size tested with a linear (equally spaced and logarithmic scale) and non-linear (geometric scale) spacing for a given set of each measurement of the length, width and weight, and some parameters (condition factor, surface area of the individuals) generated from the measurements. Surface areas of the individuals were calculated with different models (circular, triangular, trapezoidal and elliptical functions using the mathematical surface area equations) depending on the shapes of the organisms (Table 1). Only integral function was applied to trapezoidal species assumed (Table 1) using a function "trapz" of MatLab (ver. 7.0, The MathWorks, Inc.) to calculate nominal surface area of the individuals (Figs. 2-4).

Expecting a Gaussian distribution from any of measurements for ideal cohort analyses of a populated species, surface area of individuals was found to be a significant measurement (normality test, $p < 0.05$) for the growth cohort of all species which have different strategies in the growth. Before applying the modal analyses for the cohort discriminations, length-weight (powered fit; curve-linear), length-width (linear fit), and width-weight (powered fit) of each species were regressed and tested for the regression. Except for fish species, morphometrical dimorphisms were observed for most of crustacean, molluscan and echinoderm species, due presumably to sex of the species as the length-width-weight relationship (powered fit) were plotted in 3D. However, sexes of species were not determined during the laboratorial studies. Only sexes of large forms of crabs and a gastropod, *Conomurex persicus* were identified (Mutlu, 2004; Mutlu and Ergev, 2006). Each of the dimorphic classes (two clusters observed; Figs. 2-4) was distinguished manually applying a command of "inpolygon" onto 3D plot for each species. Sexes of species were experientially assessed from literature information in respect to their biometry. The relationships were bifurcated after a certain size for each species. To test the difference of the intercept and slopes among two sex-based clusters of the species, $\log_{10}$-transformed-length (and width) and $\log_{10}$-transformed weight were subjected to ANalyses Of COVARiance (ANOCOVA) using functions of "Aoctool" in statistical tool of MatLab (Table 2).

KDEs computed a probability density estimate of the sample in the vector of surface area of the species at length of bin sizes specified by the method of a bin size selection. The estimate is based on a normal kernel function, using a window parameter (binwidth) that is a function of the

growth cohort. Presented in the present paper are the optimal Gaussian binwidth for histograms and frequency polygons and the optimal bandwidth for Gaussian KDE's code scripted in MatLab.

Table 1. Body parts and measurements of marine benthic animals in relation to estimates of growth parameters, allometric/isometric growth in size, and size frequency and cohort analyses.

Parameters	Species	Taxa	References
Head area	*Chaetopterus* cf. *variopedatus*	**Annelida**	Thompson and Schaffner 2001
Width of segment 3	*Scolelepis squamata*	Polychaete	Speybroeck et al. 2007
Width of segment 10	*Neresi diversicolor*		Desholm 2000
Antero-posterior length	*Branchipolynoe seepensis*		Britayev et al. 2007
Width of thoracic setiger 4, 5	*Streblospio shrubsolii*		Kevrekidis 2005
Width of thoracic setiger 4	*Streblospio beneticti*		Sarda and Martin 1993
Vestimentum width	*Riftia pachyptila*		Thiébaut et al. 2002
Length and width of segments 9–11	*Monopylephorus rubroniveus*	oligochaete	Gillett et al. 2005
Width of segment 10	*Tubificoides benedii*		Desholm 2000
Maximum shell height	*Cyclocardia borealis*	**Mollusca**	c.f. Hermsen et al. 2003
Maximum shell height	*Placopecten magellanicus*	Bivalvia	c.f. Hermsen et al. 2003
Maximum shell height	*Placopecten magellanicus*		c.f. Hermsen et al. 2003
Shell length, Shell height	*Pecten jacobaeus*		Katsanevakis et al. 2007
Shell width, Shell length	*Pinna nobilis*		Katsanevakis 2007
Maximum shell height	*Astarte* spp.		c.f. Hermsen et al. 2003
Shell length	*Anadara demiri*		Morello et al. 2004
	Mytilus edulis		Leichte and Witmanb 1997
			Khalaman 2005
			Salkeld 1995
Shell length (anterior-posterior)	*Corbicula fluminea*		Mouthon 2001
Greatest valve length	*Donax hanleyanus*		Cardoso and Veloso 2003
Total length as divisor	*Pomacea canaliculata*	Gastropoda	Estebenet and Martin 2003
Maximum length of operculum	*Calidris alpine*		Desholm 2000
Volume	*Limapontia depressa*		Wilson and Forrest 2004
Shell length	*Ljttorina littorea*		Scheibling and Raymond 1990
Shell length	*Notoacmaea testudinalzs*		Scheibling and Raymond 1990
Shell width	*Conomurex persicus*		Mutlu and Ergev 2006
Shell height	*Buccinum undatum*		c.f.Hermsen et al 2003
Shell length	*Tonicella rubra*	Chiton	Scheibling and Raymond 1990
Upper jaw angles, Mantle length	*Todarodes sagittatus*	Squids	Katsanevakis et al. 2007
Upper jaw angles, Mantle length	*Todaropsis eblanae*	Squids	Katsanevakis et al. 2007
Total length	*Corophium volutator*	**Crustacea**	Desholm 2000
Head length	*Corophium urdaibaiense*	Amphipoda	Perez et al. 2007
Body length	*Eurythenes gryllus*		Christiansen et al. 1990
Rostrum to the tip of the telson	*Leucothoe* spp		Thiel 2000
Cephalothoracic length	*Dardanus insignis*	Anomura	Branco et al. 2002
Carapace length	*Munida gregaria*		Zeldis 1985
Shield length	Paguridea		Robinson and Tully 2000
Cephalothorax length	*Pagurus acadianus*		c.f. Hermsen et al. 2003
Cephalothorax length	*Pagurus pubescens*		c.f. Hermsen et al. 2003
Carapace width	*Cancer irroratus*	Crab	c.f. Hermsen et al. 2003
Carapace length	*Hyas coarctatus*		c.f. Hermsen et al. 2003
Telson width, Carapace width	*Pachygrapsus marmoratus*		Katsanevakis et al. 2007
Carapace width	*Portunus pelagicus*		Potter and Lestang 2000
	Charybdis bimaculata		Narita et al. 2008
	Parasesarma affinis		Lee and Kwok 2002
	Perisesarma bidens		
	Cancer polyodon		Wolff 1992
Chela width	*Cancer polyodon*		Wolff 1992
LF index	*Callinectes sapidus*		Ju et al. 1999
Carapace width	large crabs		Robinson and Tully 2000
Carapace length	Galathidea	Galathidea	
Uropod length, eye width	Caridea	Caridea	
Base of eyestalk to tip of telson	*Crangon septemspinosa*	Shrimp	c.f. Hermsen et al. 2003
Base of eyestalk to tip of telson	*Dichelopandalus leptocerus*	Shrimp	c.f. Hermsen et al. 2003
Base of eyestalk to tip of telson	*Eualus pusiolus*	shrimp	c.f. Hermsen et al. 2003
Base of eyestalk to tip of telson	*Spirontocaris liljeborgii*	Shrimp	c.f. Hermsen et al. 2003
Cephalothorax length	*Pandalus montagui*		c.f. Hermsen et al. 2003
Propodus width, Carapace length	*Pestarella tyrrhena*	Shrimp, ghost crab	Katsanevakis et al. 2007
		Anthozoa	
Conic volume	*Styela rustica*	ascidian	Khalaman 2005
Length (oral- cloacal siphon)	*Microcosmus savignyi*s	Tunicate	Panagiotou et al. 2008
Coral length	*Balanophyllia europaea*	Scleractinia	Goffredo et al. 2004
		Echinodermata	Scheibling and Raymond 1990
Test diameter	*Strongylocentrotus droebachiensis*	Echinoidea	c.f. Hermsen et al. 2003
Disc diameter	*Ophiopholis aculeata*	Ophiuroidea	c.f. Hermsen et al. 2003
Center of mouth to tip of arm	*Asterias vulgaris*	Asteroidea	c.f. Hermsen et al. 2003

Table II: 3D-growths, W (g)=a x L (cm)$^{b}_{l}$ x Wi (cm)$^{b}_{wi}$ of epibentic animals and models to estimate surface area of the body part for the assessment of number of cohorts in the study area (p values show that best fit of 3D biometrical relationships were significantly regressed at p<0.05. n: number of individuals. Model shows that which mathematical models were used to calculate surface area of the epifaunal species: E: Ellipsoid, T: Trapezoidal, C: Circular models. Sex in question mark: Female and males were assessed from the literatures published. Bold; 3D-relationship is significantly different between possible sexes. + denotes sexual dimorphisms occurred with no explanation presented). Font colors corresponded to color of best-fit line in Fig. 2).

| Species	a	b$_l$	b$_{wi}$	Serr	r^2	F	p	n	Model	Sex?
Fish										
Arnoglossus laterna	0.016	2.574	0.319	0.011	0.93	1470.37	0.000	228	E	
Bothus podas	0.016	2.538	0.475	0.0065	0.94	2578.66	0.000	317	E	
Buglossidium luteum	0.026	2.191	0.436	0.0039	0.86	141.59	0.000	48	E	
Callionymus filamentosus	0.347	0.751	1.865	0.0081	0.99	127.21	0.008	5		
Chelidonichthys lucernus	0.018	2.696	0.218	0.0010	1.00	606.63	0.000	7		
Pegusa lascaris	0.013	2.673	0.233	0.0012	1.00	3399.51	0.000	9		
Solea cunata	0.023	2.067	1.004	0.0125	0.97	269.52	0.000	22		
Trachinus draco	0.013	2.780	-0.029	0.0016	0.99	282.33	0.000	9		
Crustacea										
Diogenes pugilator	0.009	3.082	-0.419	0.668	89.612	0.000	0.077	92	T	**F**
Diogenes pugilator	0.101	1.704	0.233	0.647	176.614	0.000	0.029	196	T	**M**
Mollusca										
Barbatia barbata	1.316	3.165	0.018	0.0128	0.96	48.86	0.002	7		
Bittium latreilli	0.234	1.170	0.996	0.0065	0.68	118.49	0.000	115	E	**F**
Bittium latreilli	0.427	0.896	1.275	0.0054	0.72	135.20	0.000	106	E	**M**
Chamelea gallina	0.603	2.135	-1.163	0.0112	0.91	33.69	0.000	10		+
Chamelea gallina	0.758	1.256	2.194	0.0027	0.95	36.08	0.003	7		+
Conomurex persicus	0.316	1.617	1.541	0.0047	0.79	4808.37	0.000	2609	T	
Murex brandaris	0.150	2.081	0.497	0.0211	0.95	304.90	0.000	33	E	**M**
Murex brandaris	0.104	2.694	0.221	0.0143	0.98	398.44	0.000	20	E	**F**
Murex trunculus	0.221	2.109	0.748	0.0125	0.97	2212.17	0.000	138	E	**M**
Murex trunculus	0.326	1.886	1.217	0.0154	0.98	1089.01	0.000	43	E	**F**
Nassarius circumcinctus	0.587	0.401	1.821	0.0165	0.64	39.42	0.000	48	E	**F**
Nassarius circumcinctus	0.508	0.522	1.287	0.0062	0.40	4.03	0.046	15	E	**M**
Nassarius gibbosulus	0.503	1.252	1.425	0.0058	0.88	214.69	0.000	59	E	**F**
Nassarius gibbosulus	0.664	1.668	1.395	0.0060	0.87	235.57	0.000	72	E	**M**
Nassarius mutabilis	0.461	1.127	1.188	0.0153	0.63	15.42	0.000	21	E	**F**
Nassarius mutabilis	0.509	0.656	2.074	0.0050	0.90	121.10	0.000	31	E	**M**
Neverita josephinia	0.436	1.330	1.493	0.0004	1.00	445.11	0.000	7		
Pinctada radiata	0.082	0.594	2.821	0.0166	0.88	54.60	0.000	18	T	**F**
Pinctada radiata	0.344	2.264	0.531	0.0088	0.97	200.18	0.000	17	T	**M**
Pteria hirundo	0.298	0.844	2.470	0.0188	0.84	18.27	0.002	10		
Sepia officinalis	0.069	3.438	-0.950	0.0136	0.95	56.38	0.000	9		
Turbonilla acutissima	0.233	0.811	0.605	0.0012	0.93	57.19	0.000	12		
Echinodermata										
Astropecten irregularis	0.057	2.286	-0.439	0.008	0.88	91.63	0.000	28	C	**F**
Astropecten irregularis	0.328	1.465	0.260	0.016	0.51	14.47	0.000	31	C	**M**
Astropecten jonstoni	0.019	3.049	-0.563	0.0040	0.84	2.65	0.399	4		+
Astropecten jonstoni	1.900	0.489	0.872	0.0017	0.95	20.13	0.047	5		+
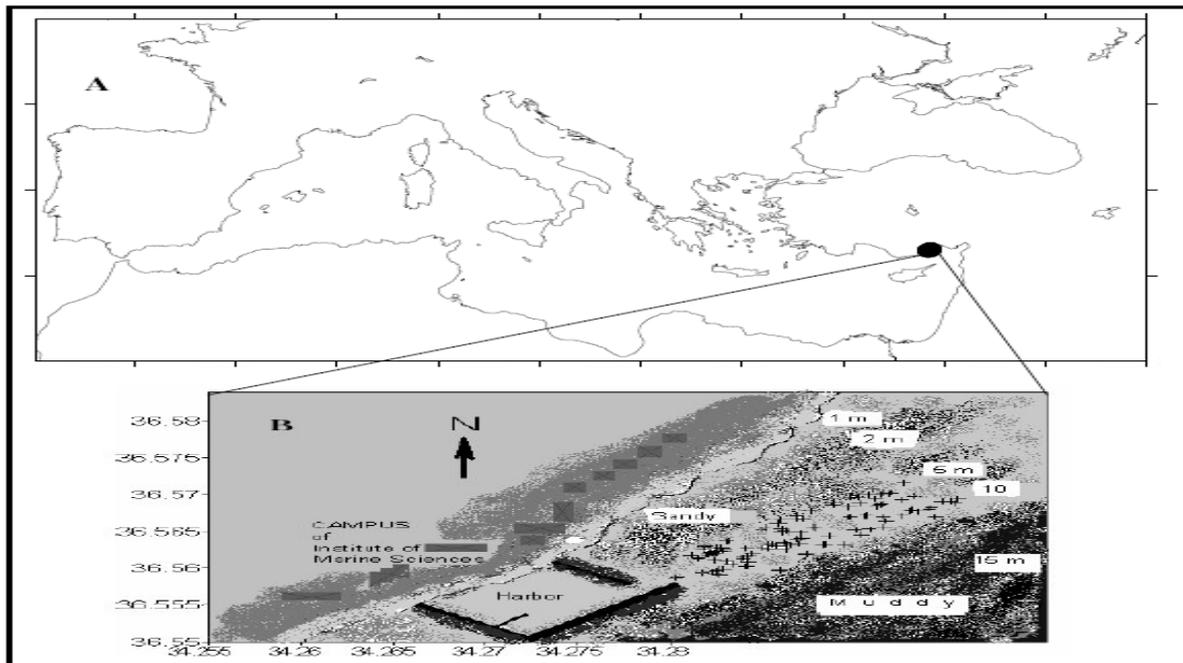
Figure 1. A. The study area; (B.) monthly sampling line stations (+) at 5 and 10 m depth contours at the shallow waters   between February 2000 and April 2002.

RESULTS AND DISCUSSION

Of the 76 species (Mutlu and Ergev, 2008), a total of 14 epifaunal species were commonly found during the study. Those were three flat fishes, two crustaceans, one echinoderm and eight molluscans of which one was bivalve. An indo-pacific gastropod, *Strombus* (*Conomurex*) *persicus* was found in the most tremendous number on a pure sand bottom of the study area (Mutlu and Ergev, 2006, 2008). Growth of the flat fishes was best explained in 2D (length-weight relationship) rather than 2D (width-weight) or 3D relationships (length-width-weight; Fig. 2, Table 2). Growth of weight to total length of the three fishes (*Arnoglossus laterna*, *Bothus podas* and *Buglossidium luteum*) was formulized with equations of $W=0.011 \ L^{2.94}$, $W=0.011 \ L^{3.04}$ and $W=0.017 \ L^{2.6}$, respectively. Similar allometric coefficients (b) were estimated for *A. laterna* and *B. luteum* found on the Turkish coast of Aegean Sea (Bayhan *et al.*, 2008a), and for *B. podas* on the Spanish-Atlantic coast (Mata *et al.*, 2008). *B. luteum* showed very low value of b as also suggested by Mata *et al.* (2008) to show a increasing trend for b values by length >7.5 cm, since this species reaches maturity at about 8.0 cm (Deniel, 1990) greater than maximum length observed in this present study (Fig. 2). Growth of weight to width showed the fish species negative allometry (2.1, 2.6 and 1.6, respectively). All relationships were significantly regressed for the fishes (Table 2). Overall, three-to-four areal growth cohorts were clearly estimated of the fishes using the KDEs (Fig. 2). Older age cohorts were presented for each species, which was not clearly extracted because of their low density available for the KDEs. Maximum age of *A. laterna* observed in some studies changed in a range of 4-5 (Djabali *et al.*, 1993; Bayhan *et al.*, 2008b) to 8 (Gibson and Ezzi, 1980; Deniel *et al.*, 1990; Ozutok and Avsar, 2002).

One of the most common and abundant crustacean species, a hermit crab, *Diogenes pugilator*, were sexually dimorphic species in a biometrical relationship of the length-width- weight (Fig.2; Table 2). Sexual dimorphism were reported that males reached larger sizes than females of another anomuran species, *Clibanarius vittatus* (Sant'Anna *et al.*, 2008) and *Pagurus brevidactylus* (Mantelatto *et al.*, 2005) similar to *D. pugilator*, with eight and seven-to-five cohorts coexisting at the same time, respectively. The dimorphism was very apparent in relationship of cephalothoracic length to the weight (**W=0.049 L$^{1.4027}$**, *W=0.2876 L$^{2.0704}$*, see color of best-fit for guessed sexes of this species and later species in Fig. 2) whereas the carapace width did not show any sign for sexual dimorphic structure to the weight, $W=1.0256 \ Wi^{2.342}$, which was not significantly different between sexes (ANOCOVA, p=0.605). Individual weight became bifurcated after a given carapace length of 1 cm of the hermit crab. Carapace width was significantly shorter (**0.10-to-0.8** cm) in their females than the males (*0.10-1.4* cm) while carapace length of both sexes varied between 0.25 and 3 cm (Fig. 2). Nine cohorts determined by the KDEs coexisted for both their sexes (Fig. 2). Dolbeth *et al*. (2006) recognized 9 cohorts of *D. pugilator* which recruited in June, February and October on in the south coast of Portugal. Length-weight, width-weight, and length-width relationship was significantly different between the sexes at p<0.05 (ANOCOVA). Another common crustacean, a crab, *Goneplax rhomboides* exhibited a slight dimorphic structure for weight dependency on carapace width and length-on-width relationship as well at p<0.05 (Table 2, Fig.3). The length-width-weight regression best explained statistically for their biometrical relationship growth (Table 2, ANOCOVA) at p<0.05. Three growth cohorts were resolved by means of KDEs.
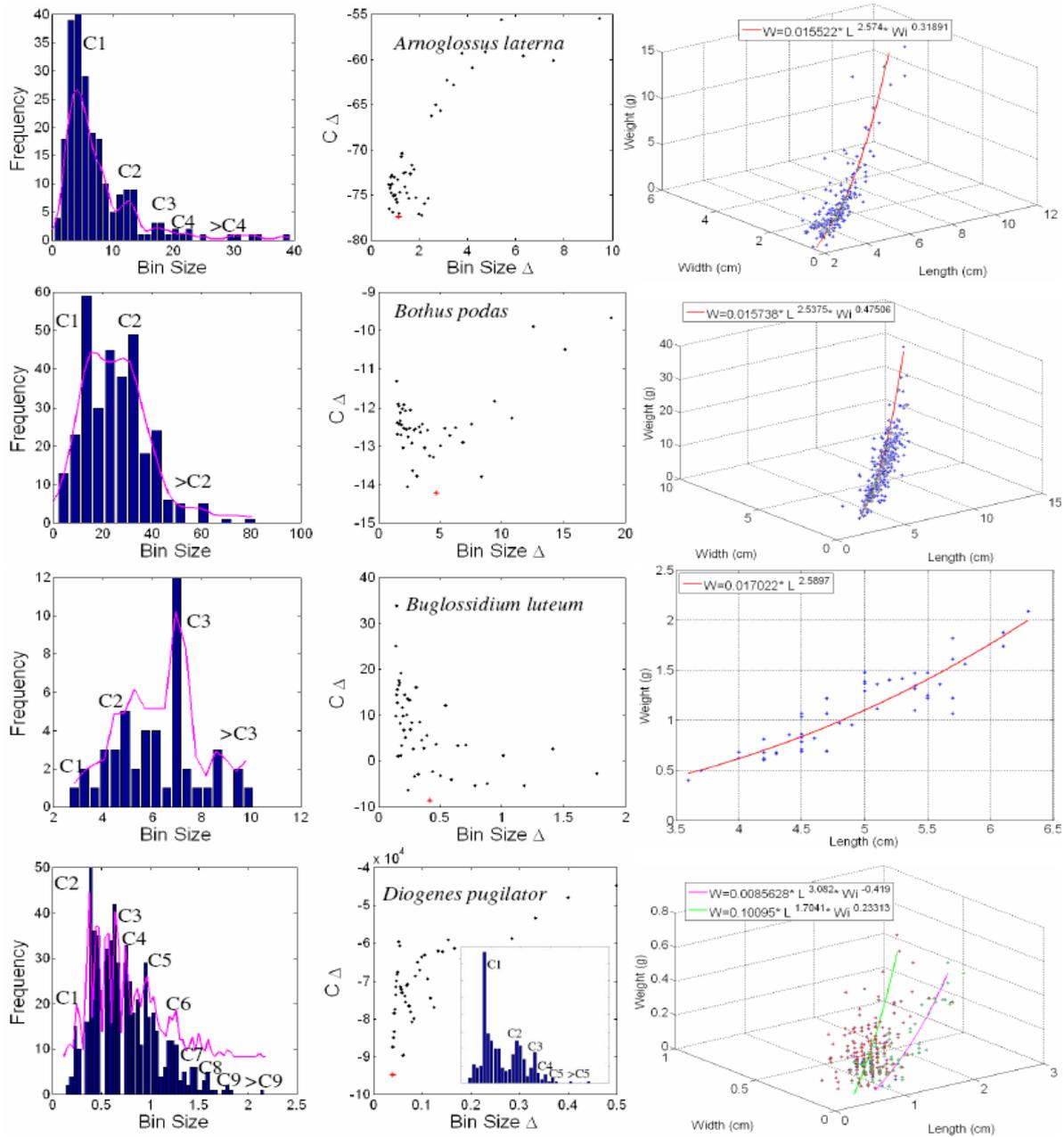
Figure 2. Areal size frequency and cohort resolved with KDEs, selection of optimum bin size (*) and 3D-biometrical relationship of the most common fish species and a hermit crab, in the Levantine Sea (Histogram within graph of bin size selection shows areal histogram of specimens fitted with green line for *Diogenes pugilator*).

Of three muricid molluscans, species of genus *Murex* were found to be sexually dimorphic in shell width even though the muricid *Hexaplex* (*Trunculariopsis*) *trunculus* lacks external sexual dimorphism (Vasconcelos *et al*., 2006). Sex-length interaction on weight was not significantly different at p<0.05 (ANOCOVA). Individual weight of *Hexaplex* (*Murex*) *brandaris* were significantly heavier in specimens of $W=1.01\ Wi^{2.892}$ (female, see color of best-fit for guessed sexes of this species in Fig. 3) than those of **$W=0.718\ Wi^{2.123}$** (male) at p<0.05 (ANOCOVA). Shell length varied in similar range of 1-to-7 cm, but shell width was significantly narrower (*max: 2.5 cm*) in their females than **the males (max: 4 cm).** The overall sex ratio of F: M was 1: 1.65 (Table 2). Only two growth cohorts

were observed a year for *Murex* (*Bolinus*) *brandaris* on the shelf. *Hexaplex* (*Murex*) *trunculus* was characterized biometrically with similarity to those of *Murex brandaris*, but shell length of their females was slightly larger than the males (Fig. 3). Vasconcelos *et al*. (2008) determined that females specimens of *M. trunculus* were significantly larger and heavier (57.84 mm and 18.11 g, respectively) than males (55.64 mm and 16.86 g, respectively) on a Portugal lagoon. Their maximum width were narrower (*max: 3.5 cm*) in their females than **the males (max: 5 cm,** Fig. 3). Individual weight of *Murex trunculus* were significantly clustered to be heavier in specimens of $W=1.363\ Wi^{2.99}$ (female) than those of **$W=0.903\ Wi^{2.37}$** (male) at p<0.05 (ANOCOVA). Length-width-weight relationship of *M.*

trunculus best described its biometry (Fig. 3, Table 2). However, another muricid species, *Strombus* (*Conomurex*) *persicus* did not displayed sexual dimorphisms in the shell morphometry. But sexually dimorphic radulae was shown in the strombiid species (Mutlu, 2004). Biometrical values of the male specimens were slightly smaller than those of the females. Only total weight (W) of the females was significantly heavier than that of the males (2.27, Parametric t-student test, n=138, p=0.025). The adults' growth diminished after a certain length and thereafter showed increase only in width. Therefore, a curvilinear multi-regression was an appropriate model to characterize length-width-weight relationship of *C. persicus* (Fig. 3). Accordingly, the multiple relationships were found to be statistically more significant than the two-variable relationship (Table 2). Weight of the specimens grow positive-allometrically with shell length ($W=0.101 \ L^{3.331}$), but negative allometrically with shell width ($W=1.54101 \ Wi^{2.5323}$). Population dynamics of the species were studied previously by Mutlu and Ergev (2006). Number of the cohorts was estimated by KDEs to be two for the species (Fig. 2). Individuals of C1 were subadults which recruited to stock form the sheltered area where the juveniles (<C1) were found intensively around the investigation region (Mutlu, 2004). Cohort C2 represented adult specimens. Growth cohorts by surface area of shell were more explicitly separated than those by the shell widths suggested in a study by Mutlu and Ergev (2006).

Two (*N. gibbosulus* and *N. mutabilis*) of three *Nassarius* species yielded only two cohorts extracted with KDEs based on ellipsoidal projected area of the species. However, older cohort (>C2) of *N. circumcinctus* was observed (Figs. 3-4). Population dynamics on *Nassarius* spp were limitedly studied wit exception of few species (*N. dorsatus*, McKillup and McKillup, 1997) of the genus, *Nassarius reticulatus* whose females attained larger size than males (Barroso et al 2005; Chatzinikolaou and Richardson, 2008). Barroso *et al.* (2005) found number of the cohorts up to 7 for another species of the genus, *Nassarius reticulatus*. Length-weight regression of two sexes of *N. gibbosulus* was characterized by allometric growths, their shell widths were regressed with the weights by two significant different equations ($W=1.594Wi^{2.484}$ male, $W=0.85 \ Wi^{2.158}$ female) at p<0.05. This dimorphic growth was best characterized with mutli-variable regression for their biometry (Fig. 3, Table 2). However, such dimorphisms were not more clearly observed for other two species of genus *Nassarius* as compared with *N. gibbosulus* even though the multiple relationships were found to be statistically more significant than the two-variable relationship (Table 2). Shell length was larger in *specimens* than **specimens** of *Nassarius mutablis*, and in **specimens** than *specimens* of *N. circumcinetus*, respectively (Fig. 4).An elongated formic species of a gastropod, *Bittium latreilli* had a similar shell length-weight regression equations between sexes ($W=0.123 \ L^{1.666}$, $W=0.106 \ L^{1.874}$). Weights of the *females* ($W=1.065Wi^{2.054}$) were significantly heavier than the **males (W=0.533 Wi$^{1.8}$)** at p<0.05 for the same shell width. These differences were significantly observed in the multiple relationships (Fig. 4, Table 2). Two apparent areal growth cohorts were determined besides possible existence of older cohorts (Fig. 4). *Pinctada radiata* is protandric hermaphrodite, which

means that most are first male, then female with sex inversion occurring in shells 32-57 mm (Zaouali and Zaouali, 1994). Most commonly found bivalve, *Pinctada radiata* displayed insignificant difference in length (height, cm)-weight (g) relationships between sexes ($W=0.17 \ L^{2.918}$, $W=0.15 \ L^{2.926}$) (p=0.359 ANOCOVA). The relationship was given as W (g) = 0.0002606 (DVM, mm)$^{2.90707}$ from Qatari waters (Mohammed and Yassien, 2003), and W (g) = 0.321 (L, cm)$^{2.776}$ form Mediterranean Sea (Yassien *et al.*, 2000). Weight of the species significantly changed as dependency ofthe valve width. ($W=4.321 \ Wi^{2.17}$, $W=0.085 \ Wi^{3.41}$). Valve width of *the males* ranged from 0.25 to 2.5 cm while that of **the females** was 2.5 to 7 cm (Fig. 4). *P. radiata* was observed with two distinct growth cohorts a year (Fig. 4). Mohammed and Yassien (2003) determined four age groups of *P. radiata* from shell length (height)-frequency in Qatari waters.

One echinoid species, *Astropecten irregularis* was not sexually dimorphic in growth of disc weight to arm length as function of disc diameter as ($W=0.202 \ L^{1.724}$ female, $W=0.134 \ L^{1.916}$ male). By larger size of seastar than 12.5 mm, female gonad length was significantly larger than male gonad, which explained 91% of the variability of ovary length, but only 18% of the variability of testis length by disc radius of the seastar (Hendler and Franz, 1982). Relation of weight to the disc thickness (width) was characterized biometrically with equations of $W=3.6 \ L^{1.156}$ for female individual and $W=9.957 \ L^{2.046}$ for male individuals. Three cohorts were estimated from data of surface area, but disc thickness was useful better for the cohort analyses (Fig. 4). Three modal arm size classes of the starfish inhabiting the coastal waters of North Wales were determined: 6–8 mm, <20 mm to 37 mm, and 40–45 mm (Freeman *et al.*, 2001).

CONCLUSION

Benthic epifuana had complex strategies in the biometrical growth in the different ways of body parts due presumably to sexual dimorphisms. Dimorphic relationships were apparently seen in their at least 3D plotted as a function of length-width-weight of the species. Optimal bin size class selection was one of the important issues to show specific accurate cohorts of each species. Nevertheless, discrimination of the cohorts for each species was best explained by the kernel density estimators in a noisy frequency of cohort histogram. So the KDEs had a disadvantageous to separate the older classes. In the present study, those methods were well applied to range limits of the cohorts in areal (surface area) growth modeled in different surfacial projected shapes for each species. Identification of the sexes was not however performed in this study, which needs further studies to verify and justify all applications.
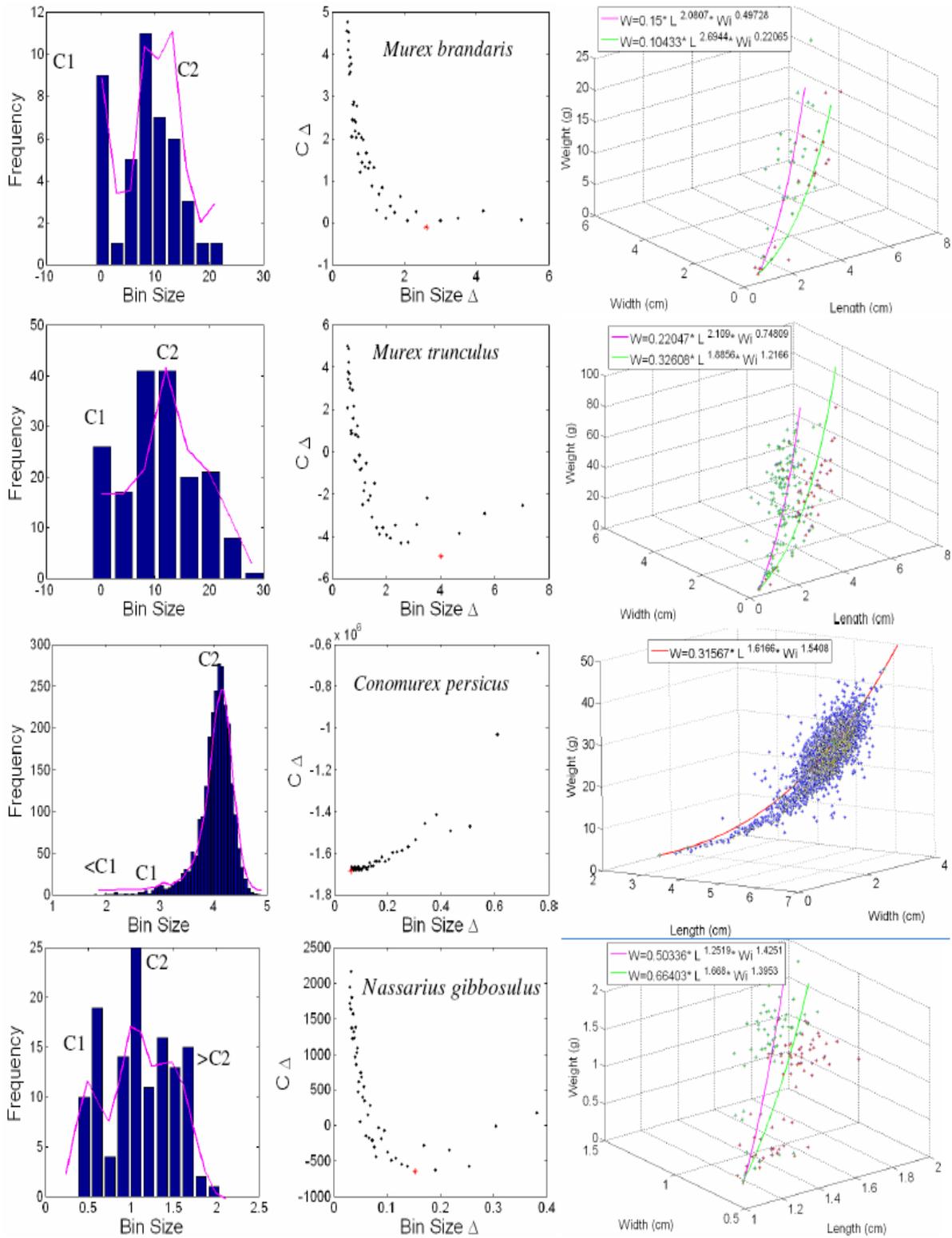
Figure 3. Areal size frequency and cohort resolved with KDEs, selection of optimum bin size (∗) and 3D-biometrical relationship of three muricid gastropods, and a nassarid gastropod in the Levantine Sea.
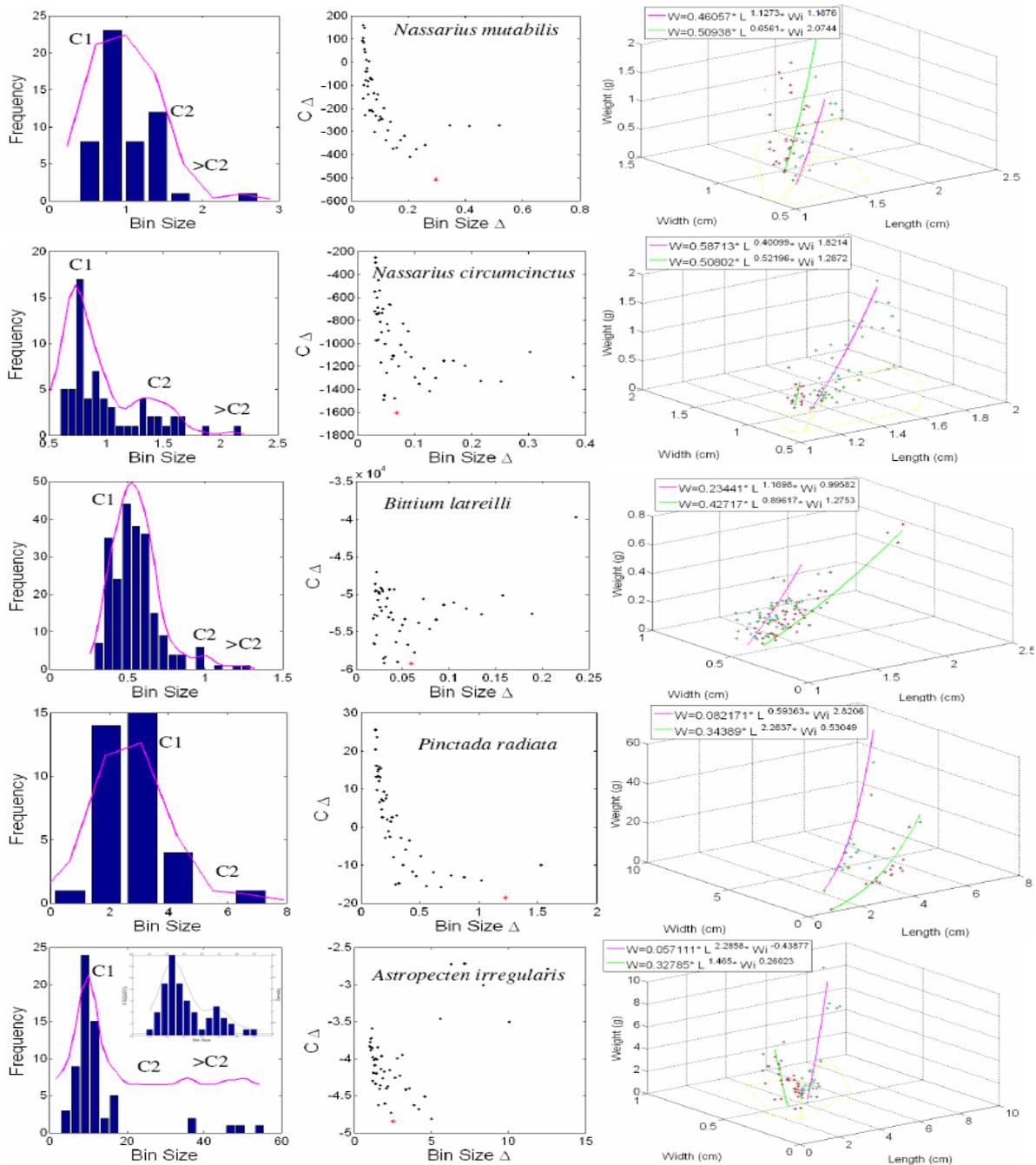
Figure 4. Areal size frequency and cohort resolved with KDEs, selection of optimum bin size (*) and 3D-biometrical relationship of most common three gastropods, a bivalve, and one seastar in the Levantine Sea (Histogram within areal growth histogram denotes size frequency based on disk thickness of *Astropecten irregularis*).

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