Regional Studies in Marine Science 33 (2020) 100905

Contents lists available at ScienceDirect

Regional Studies in Marine Science

journal homepage: www.elsevier.com/locate/rsma

Diversity and distribution of the intertidal Mollusca of the State of Kuwait, Arabian Gulf

Manal Al-Kandari [a], P. Graham Oliver [b,*], Weizhong Chen [a], Valerily Skryabin [a], Mera Raghu [a], Abdulrahman Yousif [a], Salah Al-Jazzaf [a], Ali Taqi [a], Ali AlHamad [a]

[a] *Ecosystem-Based Management of Marine Resources, Environment and Life Sciences Research Center, Kuwait Institute for Scientific Research, Kuwait*
[b] *National Museum of Wales, Cathays Park, Cardiff CF10 3NP, Wales, UK*

ARTICLE INFO

Article history:
Received 27 January 2019
Received in revised form 23 September 2019
Accepted 19 October 2019
Available online 24 October 2019

Keywords:
Biodiversity
Mollusca
Gastropoda
Bivalvia
Intertidal habitat
Kuwait
Arabian Gulf

ABSTRACT

A total of 271 species of Mollusca from 5 classes, 26 orders, and 87 families were identified in the intertidal macrofauna survey along Kuwaiti coastal areas. A total of 36 sites along Kuwait's mainland and island areas were sampled quantitatively and qualitatively during late autumn and winter season from December 2013 to December 2015. Of the 271 species, 211 were collected alive; the Gastropoda (104 species) ranked first, followed by the Bivalvia with 100; three species were recorded for the Polyplacophora, and two each for the Scaphopoda, and Cephalopoda. As many as 61 species, notably the micro-molluscs, are probably new records for Kuwait and many of may also be new to science.

The most frequently occurring species included *Brachidontes pharaonis*, *Ergalatax junionae*, *Planaxis savignyi*, *Leiosolenus tripartitus* and *Pinctada radiata*. Mollusca diversity was higher in rocky-sandy areas than intertidal mudflats. The highest species richness was found in the area of south Kuwait Bay and coastal area around Failaka Island.

Comparisons with previous surveys dating back to 1984 indicated that the dominant species composition was relatively unchanged. There are indications of the adverse affects of industrial impacts on the intertidal fauna, including eutrophication and increased turbidity. However, differences in methodology made any quantitative assessment impossible.

Wider comparisons with the molluscan faunas of the Arabian Gulf and Arabian region suggest that the fauna of Kuwait has some unique elements not found elsewhere. Taxonomic problems surrounding some of the dominant elements such as the number of species of oysters (Ostreiidae) and mud snails (Cerithiidae) were recognised. The lack of taxonomic congruence between studies and the incomplete taxonomy of the molluscs in general made such comparisons inconclusive but did highlight the need for a revised identification guide to the Mollusca of the Arabian Gulf and Arabian Sea.

1. Introduction

1.1. Aims

There is a distinct lack of basic information on the species composition, abundance, distribution and conservation status of molluscs along the coastal mainland and islands of Kuwait, the last survey being in 1985. Since then Kuwait has experienced the First Gulf War when considerable environmental pollution was created and over the intervening years many coastal habitats have become threatened by coastal development and uncontrolled exploitation of natural resources.

In 2013, the first project to quantify the intertidal fauna of Kuwait was initiated with the aim of providing a baseline against which comparisons with past and future surveys could be made. Part of the project was also to create a biodiversity inventory, which would provide a stable taxonomic checklist for future biological investigations. This project was completed in 2016 and a detailed unpublished report made by Al-Kandari et al. (2017) to the sponsoring agencies of the Kuwait Petroleum Company and Kuwait Institute for Scientific Research. From this survey it was noted that the Mollusca were numerous and were perhaps the only major invertebrate phylum where there was some previous data on their diversity and distribution. This allows some comparison with previous studies in Kuwait and within the Arabian region as a whole. This paper focuses on the molluscan data from this survey (Oliver, 2015, 2016) and attempts to define the following:-

- An inventory of the intertidal species
- Distribution and abundance within Kuwait

* Corresponding author.
E-mail address: graham.oliver@museumwales.ac.uk (P.G. Oliver).

https://doi.org/10.1016/j.rsma.2019.100905

- Comparisons with previous studies in Kuwait and Arabian Gulf.
- Taxonomic issues associated with this inventory

1.2. Past malacological studies in Kuwait

In this section it will be apparent that the available data on the Mollusca of Kuwait is sparse and has not been collected by comparable methods and has not used a consistent taxonomy. There are no quantitative data comparable with the present survey, the only similar study (Al-Bakri et al., 1985) had such poor taxonomic resolution that it is difficult to assess the data and no voucher specimens were retained; all other data are qualitative and involving both living molluscs and dead shells. As such these previous surveys serve primarily as checklists and any inferred changes in the Kuwait fauna are largely conjecture and anecdotal. However, this is all that is available and such information is referred to here but it should be stated that this survey is the only one that has used a consistent quantitative methodology along with general collecting.

Investigations of the intertidal Mollusca of Kuwait are few although the knowledge of the fauna of the Arabian Gulf and Arabian Sea is now quite extensive. Virtually nothing was recorded on the Mollusca from the eastern Arabian region until a long series of papers by James Cosmo Melvill and co-authors, that spanned the turn of the 19th and 20th centuries. Over a period of approximately 20 years 1618 species were identified from the Arabian (Persian) Gulf, Gulf of Oman and eastern Arabian Sea east to Bombay (Mumbai). (Melvill, 1928). Following Melvill's last paper (1928), there was a hiatus in molluscan research in the Arabian Gulf until the late 1950s, but even then, Kuwait did not figure largely with these studies (Biggs, 1958, 1973; Biggs and Grantier, 1960; Smythe, 1972, 1979; Tadjalli-Pour, 1974).

It is not until 1984 that the first checklist of the marine molluscs of Kuwait appeared (Glayzer et al., 1984). They listed 230 gastropods, 5 chitons, 5 scaphopods, 144 bivalves and 1 cephalopod for a total of 385 species with 66 others not identified, thus suggesting a total of 451. This list is based on extensive collecting by dedicated amateurs over a lengthy period from as early as 1972 through to 1982. Both live and dead shells of collected specimens were listed inferring that both intertidal and subtidal species may be included. It was also noted that many of the smaller species were extracted from shell sand such that their original habitat was unknown.

In 1985 the first environmental assessment of the intertidal of Kuwait was published by the Kuwait Institute for Scientific Research (Al-Bakri et al., 1985). This report listed 45 gastropods, 69 bivalves, 1 scaphopod, 1 chiton and 1 cephalopod (117 total). In 1986 a field guide to the intertidal fauna of Kuwait was published (Jones, 1986). This guide did not attempt to be comprehensive, listing only the more common species. It included 41 gastropods, 1 chiton, 1 scaphopod, 48 bivalves and 1 cephalopod, for a total of 92 species. In 1995 an identification manual to the eastern Arabian fauna was published (Dance et al., 1995) but this volume did not specify records from Kuwait including Kuwait in the northern Arabian Gulf region.

Since then the only significant study has been that of Behbehani and Ghareeb (2002). This study was initially published only as an internal Kuwait University Project Report and was not openly available. Given the timing of this survey (1997–2001), just a few years after the Gulf War of 2001 it is a valuable account on the state of the intertidal fauna after such a critical environmental event. This like most previous studies includes both live and dead shell records and is not truly quantitative although it does present relative abundance data. A total of 366 species were recognised in this study (Behbehani and Ghareeb, 2002).

2. Materials and methods

2.1. Intertidal sampling

A total of 36 sites (Fig. 1, Table 1) were sampled, from Khor Al-Subiya in the north to the border with Saudi Arabia in the south, including 22 sites on the mainland areas and 14 sites on five offshore islands. Qualitative and quantitative samples were taken during late autumn and winter seasons from December 2013 to December 2015. The sampling dates (Table 1) and time for each site, where possible, coincided with the lowest tides (as near to 0 chart datum as possible) using the tide tables (Kuwait Port Authority, 2013, 2014, 2015). The maximum tidal range in Kuwait is 1.6 m but the shore topography of a shallow slope creates extensive intertidal flats to over a kilometre in length in the vicinity of Boubiyan Island.

2.2. Collection and preparation

The Mollusca were collected as part of a total macrofaunal survey employing both quantitative sampling and qualitative collecting (Al-Kandari et al., 2017). Quantitative sampling methodologies followed Al-Bakri et al. (1985) and PERSGA (2004). This choice was made primarily to give some comparison with Al-Bakri et al. (1985) but also to give a repeatable yet practical regime for future monitoring. It was realised that the quantitative sampling alone would not produce a complete or near complete inventory and thus qualitative sampling was also done. For quantitative sampling three replicate samples were taken at three tidal levels; low-, mid-, and high-tide zones for each site, thus a total of 972 samples were taken overall. For hard substrata, based on observed macrofaunal richness, a square plastic frame (quadrat) size was chosen from the different frame sizes (1×1 m, 50×50-cm, 25×25-cm, 10×10-cm and 5×5-cm) and placed over the representative habitat. All major macrofauna within the frame were counted and collected; for smaller biota all specimens within a 10×10-cm quadrat were counted. For soft substrata, a $25 \times 25 \times 15$ cm metal box corer, was used. These samples were sieved with seawater using 0.5-mm mesh sieves, 45- and 75-cm diameter, and all sediment and organisms remaining were preserved with 5% buffered Formalin for subsequent picking and identification.

In addition macrofaunal molluscs were collected quantitatively from under rocks, among intertidal vegetation, and when necessary, burrows. Rocks containing biota were taken to the laboratory in seawater, photographed, and allowed to stand overnight without aeration. This process forced gastropods to leave their cryptic habitats and could then be collected from the bottom of the container. Specific sampling for smaller crustacean taxa (less than 5 mm) from selected cryptic habitats such as weeds, sponges, crevices, was made by Vladimir Grintsov and proved to be a productive method for finding micro-molluscs, gastropods in particular. The micro-mollusc data here is qualitative. Photographs were taken for all qualitative and quantitative samples.

Sampling was focussed on living molluscs alone for quantitative analyses and for total occurrence data. Dead shells were not targeted in any systematic way only those present in samples were noted. Studies such as those by Zuschin and Oliver (2003), Garcia-Ramos et al. (2016) illustrate the potential value in estimating environmental change through the examination of taphonomic assemblages but this approach was outside the scope of this intertidal survey. All of the relevant data were recorded with each quantitative and qualitative specimen and/or sample, including date, location (transect), Global Positioning System (GPS) location, abundance, habitat (substratum), position (lower, middle, upper) within the intertidal zone, and any other associated information. The nomenclature used is that from MolluscaBase available at http://www.molluscabase.org.

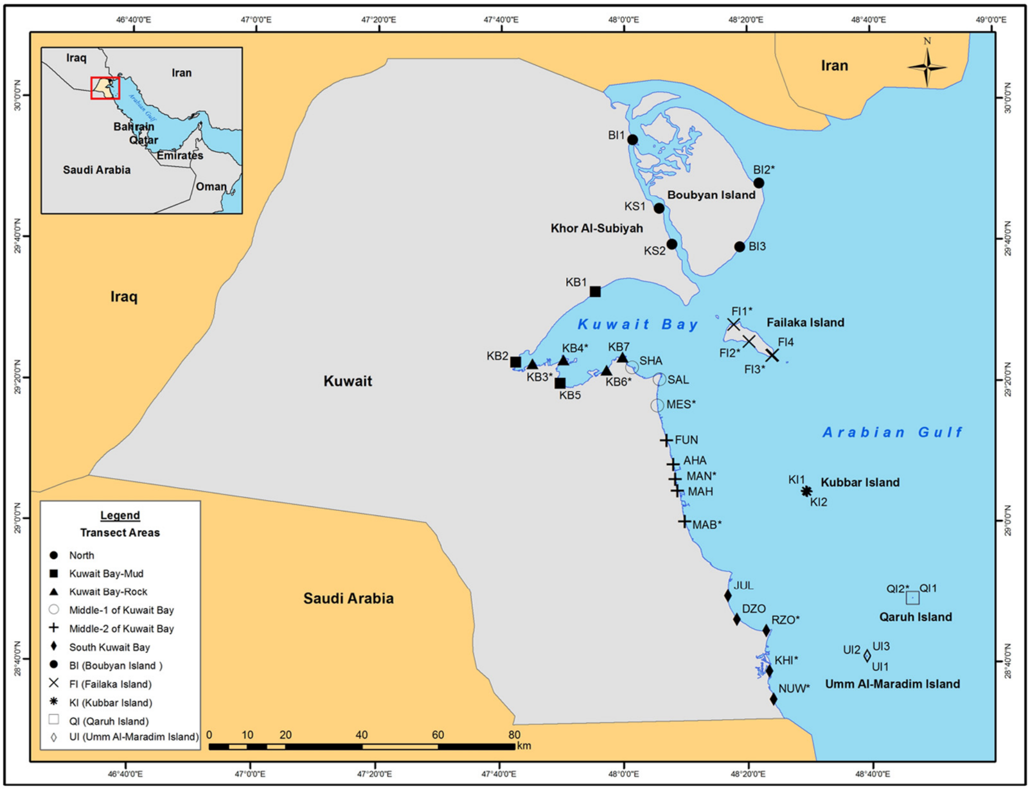

Fig. 1. Map of the 36 sites established in Kuwait's intertidal zone, site abbreviations corresponding to Table 1.

2.3. Habitat and specimens photography

For each site, photographs of the habitat and of selected individual specimens in the field were taken prior to collection. The molluscs were photographed primarily only as cleaned shells except for the nudibranchs that were photographed living in an aquarium.

2.4. Data description and statistical analysis

The combined list of species is a collation of species collected from each of the 108 quantitative samples (3 replicates averaged for each of the 3 samples × 36 sites) and all from qualitative sampling. If any species was identified in a quantitative sample, which was examined more closely than qualitative samples, it was added to the list of species occurring at that location. Mollusca data were analysed for all classes combined and separately for the dominant classes Gastropoda and Bivalvia. This was done to allow comparison with other studies that focus on single classes, primarily the gastropods, e.g. Al-Maslamani et al. (2015). The total number of individuals that occurred overall and at each intertidal zone (high, middle and low) for each species was calculated. This raw abundance data was used to calculate ecological indices using the following methods.

To study the diversity of marine community, Species richness (Margalef 1958) was calculated as follows:

$$SR = \frac{S-1}{\mathrm{Log}(N)}$$

where S is the number of species and N the number of individuals for all species.

Diversity (H') was calculated using the Shannon–Wiener equation (Shannon and Wiener, 1949):

$$H' = -\sum pi \times ln(pi)$$

where pi is the proportion of total sample belonging to ith species(Pi $= n/N$, n is the total number for ith species).

The Pielou's evenness index (Pielou, 1966) was calculated as:

$$J' = \frac{H'}{H'_{Max}}$$

where $\boldsymbol{H'}$ is the number derived from the Shannon diversity index and $\boldsymbol{H'_{max}}$ is the maximum possible value of $\boldsymbol{H'}$ (if every species is equally likely), equal to:

$$H'_{Max} = -\sum_{i=1}^{s} \frac{1}{\mathbf{S}} \ln \frac{1}{S} = \ln S$$

J' is constrained between 0 and 1. The less evenness in communities between the species (and the presence of a dominant species), the lower J' is, and vice versa. S is the total number of species

To further compare the species compositions and diversities among different areas, the species composition data for both transects and at different zones were grouped into 11 areas based on their locations (Table 1 and Fig. 1) from north to south. Kuwait Bay (KB) was divided into two areas based on their different habitat as follows: (1) bay mud and (2) bay rock. The islands were not grouped because of their different habitat, location, and area size.

2.5. Identification

The identifications were based largely on Dance et al. (1995) but with the species nomenclature following MolluscaBase. The

Table 1
Sampling locations and associated data. Clustering groups based on species composition and their location and characterisation of location for each transect.

Location	Site code	Collection dates	Tide level	Latitude	Longitude	Group*
Khor Al-Subiya (Al-Magasel)	KS1	23.11.2014	0.16	29° 44.483’	48°05.754’	North
Khor Al-Subiya (Al-Shumaima)	KS2	24.11.2014	0.02	29° 39.412’	48° 07.865’	North
Kuwait Bay (Mudairah)	KB1	30.12.2014 05.01.2015	0.30	29° 32.538’[1] 29° 32.322’[2]	47° 55.522’[1] 47° 55.908’[2]	Bay-mud
	KB2	17.11.2014 07.12.2014 09.12.2014	0.07	28° 49’00.8’’	48°46’36.8’’	Bay-mud
Kuwait Bay (Al-Judailiat)	KB3	02.02.14	−0.08	29° 22.510’[1] 29° 22.794’[2]	47° 45.157’[1] 47° 44.957’[2]	Bay-rock
Kuwait Bay (Aushairij)	KB4	03.02.14	−0.08	29° 23.092’[1] 29° 23.229’[2]	47° 50.153’[1] 47° 49.941’[2]	Bay-rock
Kuwait Bay (Sulaibikhat Bay)	KB5	06.11.2014 13.11.2014 16.11.2014	0.09	29° 04’23.0’’	48°29’27.9’’	Bay-mud
Kuwait Bay (Al-Salam Beach)	KB6	09.12.13	0.32	29° 21.634’[1] 47° 57.177’[2]	47° 57.206’[1] 47° 57.177’[2]	Bay-rock
Kuwait Bay (RasAjuza)	KB7	08.12.13	0.04	29° 23.495’[1] 29° 23.588’[2]	47° 59.803’[1] 47° 59.823’[2]	Bay-rock
Al-Sha’ab	SHA	19.01.14	0.26	29° 21.983’[1] 29° 22.024’[2]	48° 01.349’[1] 48° 01.393’[2]	Middle1
Al-Salmiya	SAL	19.12.13	0.18	29° 20.307’	48° 05.787’	Middle1
Al-Messilah	MES	18.12.13	0.17	29° 16.500’[1] 29° 16.496’[2]	48° 05.410’[1] 48° 05.436’[2]	Middle1
Al-Funaitees	FNI	21.12.13	0.16	29° 11.512’	48° 06.925’	Middle2
Abu Halifa	AHA	04.01.14	0.17	29° 08.155’	48° 07.998’	Middle2
Al-Mangaf	MAN	01.02.14	−0.06	29° 06.042’[1] 29° 06.037’[2]	48° 08.329’[1] 48° 08.349’[2]	Middle2
Masfat Al-Ahmadi	MAH	10.12.2014	0.04	29° 04.474’[1] 29° 04.447’[2]	48° 08.707’[1] 48° 08.689’[2]	Middle2
Mina Abdullah	MAB	16.02.14	0.29	29° 00.072’[1] 29° 00.083’[2]	48° 09.861’[1] 48° 09.898’[2]	Middle2
Al-Julaia’a	JUL	17.02.14	0.30	28° 49.478’[1] 28° 49.476’[2]	48° 16.822’[1] 48° 16.868’[2]	South
Dohat Al-Zour	DZO	02.03.14	0.21	28° 46.100’	48° 18.220’	South
Ras Al-Zour	RZO	08.01.2015	0.08	28° 44.517’	48° 22.950’	South
Al-Khiran	KHI	03.03.14	0.27	28° 38.811’[1] 28° 38.818’[2]	48° 23.438’[1] 48° 23.475’[2]	South
Al-Nuwaiseeb	NUW	04.03.14	0.38	28° 34.810’	48° 24.096’	South
Boubyan Island (Umm Al-Shajar)	BI1	29.12.2015	0.06	29° 54.293’	48° 01.426’	Boubyan
Boubyan Island (Ras Al-Gayed)	BI2	25.01.2015	−0.22	29° 48.207’[1] 29° 48.438’[2]	48° 22.103’[1] 48° 22.388’[2]	Boubyan
Boubyan Island (South)	BI3	24.01.2015	−0.23	29° 38.930’[1] 29° 38.867’[2]	48° 18.883’[1] 48° 18.937’[2]	Boubyan
Failaka Island (Northwest)	FI1	22.12.2014	0.04	29° 28.217’[1] 29° 28.334’[2]	48° 17.816’[1] 48° 17.790’[2]	Failaka
Failaka Island (South)	FI2	23.12.2014	−0.14	29° 25.539’[1] 29° 25.429’[2]	48° 20.245’[1] 48° 20.198’[2]	Failaka
Failaka Island (East 1)	FI3	24.12.2014	−0.23	29° 23.562’[1] 29° 23.497’[2]	48° 23.943’[1] 48° 23.935’[2]	Failaka
Failaka Island (East 2)	FI4	25.12.2014	−0.22	29° 23.709’[1] 29° 23.704’[2]	48° 24.228’[1] 48° 24.347’[2]	Failaka
Kubbar Island (East) Kubbar Island (West)	KI1 KI2	9.11.2014	0.09	29° 04.278’’ 29° 04.383’	48° 29.660’ 48° 29.465’	Kubbar Kubbar
Qaruh Island (North) Qaruh Island (South)	QI1 QI2	10.11.2014	0.07	28° 49.108’ 28° 49.013’	48° 46.552’ 48° 46.613’	Qaruh Qaruh
Umm Al-Maradim Island (East) Umm Al-Maradim Island (NorthEast) Umm Al-Maradim Island (Northwest)	UI1 UI2 UI3	11.11.2014	0.30	28° 40.778’ 28° 40.940’ 28° 40.967’	48° 39.215’ 48° 39.202’ 48° 39.172’	Umm Al-Maradim Umm Al-Maradim Umm Al-Maradim

sequence of the families in the major list (Table 2) follows that of Bieler et al. (2010) for the Bivalvia and Bouchet et al. (2017) for the Gastropoda. Numerous changes have been made since the publication of Dance et al. such that numerous papers needed to be consulted but also reference back to the papers of Melvill were also required for some of the micro species. While the majority of identifications were made by PG Oliver the enormous help of Henk Dekker for the gastropods is acknowledged here.

Table 2
List of all molluscan species recorded. **Bold** – living; Normal – shell only. Occurrences; number of sites in which living specimens were present; New Records; **T** denotes taxonomic research required; **G**, new record for Arabian Gulf; **K**, new record for Kuwait. Habitat & zone; recorded habitat range and tidal level (high, middle, low) of living molluscs in current survey.

Family/Subfamily	Current name	Occurrences	Newrecords	Habitat and Zone
BIVALVIA				
Nuculidae	***Ennucula layardii* (A. Adams, 1853)**	1		Off shore
Yoldiidae	*Scissileda tropica* (Melvill,1897) †		G, K	–
Mytilidae/Mytilinae	***Brachidontes pharaonis* (Fischer, 1870)**	25		Rock (H,M,L)
Crenellinae	***Gregariella coralliophaga* (Gmelin, 1791)**	3	G, K	Rock (M,L)
	***Gregariella ehrenbergi* (Issel, 1869)**	14		Rock (H,M,L)
	***Musculus coenobitus* (Vaillant, 1865)**	5		Rock (M,L)
	***Musculus cf. costulatus* (Risso, 1826)**	6	T	Rock (M,L)
	Rhomboidella vaillanti (Issel, 1869) †	–	K	
Lithophaginae	***Botula cinnamomea* (Gmelin, 1791)**	16		Rock (H,M,L)
	***Lithophaga robusta* (Jousseaume in Lamy, 1919)**	2		Rock (L)
	***Leiosolenus tripartitus* (Jousseaume, 1894)**	21		Rock (H,M,L)
	Leiosolenus sp.	4	G.K	Rock (M,L)
Arcidae/ Arcinae	***Acar plicata* (Dillwyn, 1817)**	18		Rock,(H,M,L)
	***Barbatia parva* (Sowerby, 1833)**	1		Rock (L)
	***Barbatia setigera* (Reeve, 1844)**	4		Rock,(H,M,L)
	***Barbatia trapezina* (Lamarck, 1819)**	16		Rock,(H,M,L)
	Trisidos tortuosa (Linnaeus, 1758) †	–		–
Anadarinae	***Anadara ehrenbergi* (Dunker, 1868)**	1	T	Mud, sand (L)
Glycymerididae	*Tucetona audouini* Matsakuma, 1984†	–		
Noetiidae	***Congetia chesneyi* (Oliv. & Ches., 1994)**	4		Mud (H, M, L)
	***Didimacar tenebrica* (Reeve,1844)**	11		Rock (H,M,L)
	***Sheldonella lateralis* (Reeve,1844)**	5		Rock (M, L)
Pteriidae	***Pinctada radiata* (Leach, 1814)**	21		Rock, mixed
	Pteria tortirostris (Dunker, 1849) †	–	K	–
Isognomonidae	***Isognomon legumen* (Gmelin, 1791)**	12		Rock (M,L)
	***Isognomon nucleus* (Lamarck, 1819)**	9		Rock (H,M)
Malleidae	***Malleus regula* (Forsskål in Niebuhr, 1775)**	19		Rock (H,M,L)
Pinnidae	***Pinna bicolor*(Gmelin, 1791)**	4		Sand, Muddy Sand (High, Low)
Ostreidae/Ostreinae	***Alectryonella* cf. *crenulifera* (Sowerby, 1871)**	1		Rock (L)
	cf. Booneostrea subucula (Lamy, 1925)	5		Rock (H, M)
	***cf. Nanostrea deformis* (Lamarck, 1819)**	6		Rock (H, M)
Crassostreinae	***Crassostrea* sp? ***	4	T	Rock (H
Saccostreinae	***Saccostrea cuccullata* (Born, 1778)**	8		Rock (H,M)
Gryphaeidae	*Hyotissa hyotis* (Linnaeus, 1758)†	–		–
Placunidae	*Placuna placenta* (Linnaeus, 1758) †	–		–
Pectinidae	***Azumapecten ruschenbergerii* (Tryon, 1869)**	4		Rock (M,L)
Spondylidae	***Spondylus spinosus* Schreibers, 1793**	5		Rock (M,L)
Plicatulidae	***Plicatula complanata (*Deshayes in Maillard, 1863)**	9		Rock (M,L)
Limidae	*Limatula leptocarya* (Melvill, 1898) †	–		–
Lucinidae/ Lucininae	*Cardiolucina semperiana* (Issel, 1869) †			
	***Chavania erythraea* (Issel, 1869)**	1		Sand (L)
	***Pillucina vietnamica (*Zorina, 1978)**	4		Muddy sand (L)
	***Scabrilucina victorialis* (Melvill, 1899)**	1	K	Sandy mud (L)
Codakiinae	***Ctena divergens* (Philippi, 1850)**	7		Sand (H, M, L)
Pegophyseminae	*Euanodontia cf. ovum juv.* (Reeve, 1850) †			
Carditidae	***Beguina gubernaculum* (Reeve, 1843)**	6		Rock (H, M)
	Cardites bicolor (Lamarck, 1819) †	–		–
Condylocardiidae	***Carditopsis majeeda* (Biggs, 1973)**	1		Rock (M, L)
Trapezidae	***Neotrapezium sublaevigatum* (Lamarck, 1819)**	16		Rock, crevices (H,M, L)
Cardiidae/Cardiinae	***Fulvia fragilis* (Forsskål in Niebuhr, 1775)**	1		Mud (L)
Vasticardiinae	***Vasticardium lacunosum* (Reeve, 1845)**	6		Mud (M, L)
Fraginae	***Fragum sueziense* (Issel, 1869)**	1		Sandy mud (L)
Chamidae	***Chama asperella* (Lamarck, 1819)**	12		Rock (H, M, L)
	***Chama pacifica* (Broderip, 1835)**	7		Rock (H, M, L)
Galeommatidae	***Amphilepida peilei* (Tomlin, 1921**	3		Rock (L)
	***Amphilepida faba* (Deshayes, 1856)**	2	K	Rock (M, L)
	***Amphilepida elongata* (Sowerby, 1897)**	1	K	Rock (L)
	Galeommatidae sp. #A †		K	
	***Scintillula cf. variabilis* (Sturany, 1899)**	1	K	Rock (H
	Marikellia pustula (Deshayes, 1863) †		K	
Lasaeidae	***Kellia leucedra* (Melvill&Standen, 1907)**	10		Rock (M, L)
	***Mysella* sp. #1**	3	T, K	Rock (M, L)
	***Mysella* sp. #2**	3	T, K	Rock (M, L)
	***Mysella* sp. #3**	1	T, K	Rock (M, L)

(*continued on next page*)

Table 2 (*continued*).

Family/Subfamily	Current name	Occurrences	Newrecords	Habitat and Zone
Mactridae	***Mactra lilacea* (Lamarck, 1818)**	2		Sandy mud (M)
	***Mactrotoma depressa* (Spengler, 1793)**	1		Sandy mud (L)
Mesodesmatidae	***Atactodea subobtusa* (Jousseame,1895)**	1		Sand (M)
Tellinidae	*Hanleyanus immaculatus* (Philippi, 1849) †			
	***Iridona methoria* (Melvill,1897)**	1		Muddy sand (L)
	***Jactellina clathrata* (Deshayes, 1835)**	1		Muddy sand (M, L)
	***Confusella muscatensis* (Oliver & Chesney, 1997)**	1		Rock (L)
	Tellinimactra edentula (Spengler, 1798) †			
	Macomopsis dubia (Deshayes., 1835) †			
	Pseudotellidora pellyana (A. Adams, 1873) †			
	***Jitlada arsinoensis* (Issel, 1969)**	2		Muddy sand (M, L)
	***Tellina (Pinguitellina) pinguis* (Hanley, 1844)**	2		Sand, Muddy sand (M, L)
	***Nitidotellina unifasciata* (Sowerby, 1867)**	1		Muddy sand (L)
Donacidae	***Donax cf. erythraeensis* (Bertin, 1881)**	1		Sand (M)
Psammobiidae	***Asaphis violascens* (Forsskål in Niebuhr, 1775)**	1		Sandy gravel
	***Gari* cf. *insignis* (Deshayes, 1855)**	1	K	Muddy sand (L)
	***Hiatula rosea* (Gmelin, 1791)**	1		Mud (L)
Semelidae	***Cumingia mutica* (G. B. Sowerby I, 1833)**	8		Rock (H, M, L)
	***Ervilia purpurea* (Smith, 1906)**	1		Sand (L)
	***Ervilia scaliola* (Issel,1869)**	3		Sand (M, L)
	***Semelangulus rosamunda* (Melv. & St., 1907)**	1		Sand (L)
	***Semele cordiformis* (Holten, 1802)**	1		Rock (M)
	***Theora cadabra* (Eames & Wilkins, 1957)**	4		Muddy sand (M, L)
Solecurtidae	*Solecurtus subcandidus* (Sturany, 1899 †			
Ungulinidae	***Diplodonta (Felaniella) crebristriata* (Sowerby, 1905)**	1		Sand (M)
	Diplodonta genethlia Melvill,1898 †			
	D. (Transkeia) globosa (Forsskål in Niebuhr, 1775) †		G,K	
	***Diplodonta holosphaera* (Melvill,1899)**	4		Rock and Muddy sand (H, M, L)
	***D. (Transkeia) moolenbeeki* (Aartsen & Goud, 2006)**	2		Sand (L)
	***Diplodonta subrotunda* (Issel,1869)**	7		Sand (H, M, L)
Veneridae	***Asaphinoides madreporicus* (Jousseame, 1895)**	1	K	Rock (L)
	***Callista florida* (Lamarck, 1818)**	2		Sand (M)
	***Callista umbonella* (Lamarck, 1818)**	4		Sand (H, M, L)
	***Circe scripta* (Linnaeus, 1758)**	2		Sand (L)
	***Circenita callipyga* (Born, 1778)**	11		Muddy sand (H, M, L)
	Clementia papyracea (Gray, 1825) †			
	***Dosinia alta* (Dunker, 1849)**	7		Sand (H, M, L)
	***Dosinia contracta* (Philippi, 1844)**	1		Rock, mixed (L)
	Dosinella caelata (Reeve, 1850) †			
	***Gafrarium pectinatum* (Linnaeus, 1758)**	9		Rock, gravel (H, M, L)
	Gouldiopa consternans (Oliver &Zuschin, 2001) †		K	
	***Irus macrophylla* (Deshayes, 1853)**	19		Rock (H, M, L)
	***Marcia cordata* (Forsskål in Niebuhr, 1775)**	3		Sand (M, L)
	Paratapes undulatus (Born, 1778) †			
	***Pelecyora ceylonica* (Dunker, 1865)**	3		Rock, mixed (H, M, L)
	***Petricola fabagella* (Lamarck, 1818**	18		Rock (H, M, L)
	Placamen lamellata (Röding, 1798) †			
	***Protapes cor* (Sowerby, 1853)**	5		Muddy sand (H, M, L)
	***Protapes rhamphodes* (Oliver & Glover, 1996)**	1		Muddy sand (L)
	Tapes deshayesi (Sowerby, 1852)			
	***Tapes sulcarius* (Lamarck, 1818)**	1		Muddy sand (M)
	***Timoclea arakana* (Nevill&Nevill, 1971)**	1		Muddy sand (L)
	***Venerupis rugosa* (Sowerby, 1854)**	7		Rock, crevices (H,M, L)
Corbulidae	*Corbula* cf. *subquadrata* (Melv. & Standen, 1907) †		K	
Pholadidae	***Aspidopholas tubigera* (Valenciennes, 1846)**	16		Rock (H, M, L)
Solenidae	***Solen dactylus* (Cosel, 1989)**	2		Muddy sand (L)
Hiatellidae	***Hiatella flaccida* (Gould, 1861)**	5	G,K	Rock (H, M, L)
Gastrochaenidae	***Cucurbitula cymbium* (Spengler, 1783)**	6	T	Rock (M, L)
	***Dufoichaena dentifera* (Dufo, 1840)**	12		Rock (H, M, L)
	***Gastrochaena cuneiformis* (Spengler, 1783)**	11		Rock (H,M,L)
	Gastrochaena sp.?	1	T, K	Rock (L)
Thraciidae	***Thracia cf. adenensis* (Melvill, 1898) juv.**	1		muddy crevise (L)
Laternulidae	***Laternula erythraea* (Morris & (Morris, 1993)**	3		Mud (M, L)
SCAPHOPODA				
Dentaliidae	*Antalis longitrorsa* (Reeve, 1842) †			
	***Dentalium octangulatum* (Donovan, 1804)**	2		Sand (L)
	***Tesseracme quadrapicalis* (G. B. Sowerby II, 1860)**	1		Muddy sand (L)
GASTROPODA				
Chilodontidae	***Euchelus persicus* (Martens, 1874)**	18		Rocks (M, L)

(*continued on next page*)

Table 2 (*continued*).

Family/Subfamily	Current name	Occurrences	Newrecords	Habitat and Zone
	***Euchelus edentulus* (A. Adams, 1853)**	1		Rocks (L)
	***Granata sulcifera* (Lamarck, 1822)**	10		Rocks (M, L)
	***Vaceuchelus delpretei* (Caramagna, 1888)**	1		Weeds, sponges (L)
Fissurellidae/ Diodorinae	***Diodora funiculata* (Reeve, 1850)**	13		Rocks (M, L)
	***Diodora ruppellii* (G. B. Sowerby I, 1835)**	3		Rocks (L)
	***Diodora townsendi* (Melvill, 1897)**	1		Rocks (L)
Emarginuliniae	***Emarginula sp. #1***	14		Rocks (L)
Trochidae/ Trochinae	***Clanculus pharaonis* (Linnaeus, 1758)** †			
	***Clanculus scabrosus* (Philippi, 1850)**	16		Rocks (M, L)
	***Trochus erithreus* (Brocchi, 1821)**	10		Rocks (M, L)
Cantharidinae	***Priotrochus kotschyi* (Philippi, 1849)**	15		Rocks (H, M, L)
Monodontinae	***Monodonta vermiculata* (P. Fischer, 1874)**	11		Rocks (H, M, L)
Stomatellinae	***Stomatella duplicata* (G. B. Sowerby I, 1823)**	1		Rocks (L)
Umboniinae	***Pseudominolia biangulosa* (A. Adams, 1854)**	1		Rocks (L)
	***Umbonium vestiarium* (Linnaeus, 1758)**	11		Sand (H, M)
Colloniidae	***Bothropoma mundum* (H. Adams, 1873)**	1		Rocks (H)
Liotiidae	***Cyclostrema ocrinium* (Melvill&Standen, 1901)**	2		Rocks (M, L)
Phasianellidae/Phasianellinae	***Phasianella solida* (Born, 1778)**	1		Rocks (L)
Tricoliinae	***Tricolia fordiana* (Pilsbry, 1888)**	4		Weeds, sponges (L)
Turbinidae	***Lunella coronata* (Gmelin, 1791)**	19		Rocks (H, M, L)
Neritidae	***Nerita albicilla* (Linnaeus, 1758)**	3		Rocks (H)
Cerithiidae / Cerithiinae	***Cerithium caeruleum* Sowerby, 1855**	18		Rocks (H, M, L)
	***Cerithium scabridum* Philippi, 1848**	15		Sand (H, M, L)
	***Clypeomorus persica* Houbrick, 1985**	17		Rocks (H, M, L)
	***Clypeomorus "morus"* (Lamarck, 1822)**		T	Rocks (M, L)
	Rhinoclavis kochi (Philippi, 1848) †			
Bittiinae	***Cerithidium diplax* (Watson, 1886)**	1		Weeds, sponges (L)
Dialidae	***Diala semistriata* (Philippi, 1849)**	1		Weeds, sponges (L)
Liotopidae	***Gibborissoia virgata* (Philippi, 1849)**	2		Rocks (L)
Planaxidae	***Planaxis savignyi* Deshayes, 1844**	21		Rocks, (H, M)
Pomatiidae	***Pirenella arabica* Reid, 2016**	14		Sand, muddy sand (H, M, L)
	***Pirenella conica* (Blainville, 1829)**	1		Sand, muddy sand (L)
Turritellidae	***Turritella fultoni* Melvill, 1897**	1		Sand (L)
Epitonidae	***Epitonium moolenbeeki* van Aartsen, 1996**			
	Epitonium sp. #1 †		T, K	
	Epitonium sp. #2 †		T, K	
	Acrilla acuminata (Sowerby, 1844) †		K	
	Eglisia tricarinata Adams & Reeve, 1850 †		K	
Littorinidae	***Echinolittorina arabica* (El-Assal, 1990)**	6		Rocks, (H, M)
Naticidae	***Natica ponsonbyi* Melvill, 1899**	1		Sand (M)
	***Neverita didyma* (Röding, 1798)**	1		Sand, muddy sand (L)
	Notocochlis sp. #1†		T, K	
	Eunaticina papilla (Gmelin, 1791) †			
Cerithiopsidae/Cerithiopsinae	***Cerithiopsis sp.#1***	1	K	Weeds, sponges (L)
	Joculator sp.#1	2	K	Sponges, weeds (L)
Seilinae	***Seila bandorensis* (Melvill, 1893)**	13		Rocks (L)
Vermetidae	***Thylacodes variabilis* (Hadfield & Kay, 1972)**	3		Rocks (M, L)
Rissoidae	***Alvania ogasawarana* (Pilsbry, 1904)**	2		Weeds, sponges (L)
	***Voorwindia tiberiana* (Issel, 1869)**	2		Weeds, sponges (L)
Rissoinidae	***Rissoina sismondiana* (Issel, 1869)**	4		Rocks (L)
Zebinidae	*Stosicia annulata* (Dunker, 1859) †			
Truncatellidae	***Pseudonoba aristaei* (Melvill, 1912)**	1		Weeds, sponges (L)
Caecidae	***Caecum sp. #1***	1	K	Sand (L)
Tornidae	***Circulus sp.#1***	9	K	Weeds, sponges (L)
Vanikoridae	***Vanikoro sp. #1***	1	T, K	Rocks (L)
	***Macromphalus thelacme* (Melvill, 1904)**	1		Rocks (L)
Eulimidae	***Sticteulima lentiginosa* (A.Adams, 1861)**	1	K	Rocks (L)
Calyptraeidae	*Calyptraea pellucida* Reeve, 1859 †			
	Ergaea walshi (Reeve, 1859) †			
Cypraeidae	*Naria turdus kuwaitensis* Heiman, 2014 †			
	***Palmadusta lentiginosa* (Gray, 1825)**	4		Rocks, (H, M)
Strombidae	*Canarium fusiforme* (Sowerby, 1842)†			
	***Conomurex persicus* (Swainson, 1821)**	13		Muddy sand (M, L)
Rostellariidae	***Tibia curta* (Sowerby, 1842)**	1		Sand (L)
Tonnidae	***Semicassis faurotis* (Jousseame, 1888)**	1		Sand (M)
Bursidae	*Bufonaria echinata* (Link, 1807)†			
Marginellidae	***Granulina oodes* (Melvill, 1898)**	1		Rocks (L)

(*continued on next page*)

Table 2 (*continued*).

Family/Subfamily	Current name	Occurrences	Newrecords	Habitat and Zone
Cancellariidae	***Merica oblonga*** **(Sowerby, 1825)** †		K	
	Scalptia harmulensis **(Verh. & Van Laeth., 2015)**	4	K	
Columbellidae	***Mitrella blanda*** **(Sowerby, 1844)**	14		Sand, muddy sand (M, L)
	Mitrella cartrighti **(Melvill, 1897)**	1		Weeds, sponges (L)
	Zafra selasphora **(Melvill&Standen, 1901)**	1		Weeds, sponges (L)
	Zafra sp.#1	1	K	Weeds, sponges (L)
Fasciolariidae	***Fusinus townsendi*** **(Melvill, 1899)**	3		Muddy (M, L)
Nassariidae/Nassaiinae	***Nassarius frederici*** **(Melvill&Standen, 1901)** †			
	Nassarius jactabundus **(Melvill, 1906)**	6		Muddy sand (L)
	Nassarius persicus **(Martens, 1874)**	3		Rocks (M, L)
	Nassarius rufus **(Martens, 1874)**	1		Muddy sand (M, L)
	Nassarius tadjallii **Moolenbeek, 2007**	1		Muddy sand (L)
Bulliinae	*Bullia sp.* #1 †		K, G, U	
Muricidae/Muricinae	***Murex carbonnieris*** **(Jousseaume, 1881)** †			
	Hexaplex rileyi **(D'Attilio& Myers, 1984)**	3		Rocks (M, L)
Ergalataxinae	***Ergalatax contracta*** **(Reeve, 1846)**†		K	
	Ergalatax junionae **(Houart, 2008)**	22		Rocks (H, M, L)
Rapaninae	***Indothais scalaris*** **(Schub. & Wagr, 1829)**	14		Sand, muddy sand (M, L)
	Rapana rapiformis **(Born, 1778)**	1		Rocks (L)
	Semiricinula tissoti **(Petit de la Saus., 1852)**	13		Rocks (H, M, L)
	Tylothais savignyi **(Deshayes, 1844)**	15		Rocks (H, M, L)
Mitridae	***Mitra bovei*** **Kiener, 1839** †			
Ancillariidae	***Ancilla castanea*** **(G. B. Sowerby I, 1830)**	3		Sand, muddy sand (M, L)
	Ancilla farsiana **(Kilburn, 1981)**†	1		Sand (L)
	Ancilla ovalis **(G. B. Sowerby II, 1859)**	1		Muddy sand (L)
Clathurellidae	***Nannodiella acricula*** **(Hedley, 1922)** †		K	
Drilliidae	***Spendrillia cf. lucida*** **(G&H Nevill, 1875)** †			
Mangeliidae	***Agathotoma sp.*** #1 †		K	
Pseudomelatomidae	***Epidirona multiseriata*** **(EA Smith, 1877)** †			
	Inquisitor sp.#1 †		K	
Raphitomidae	***Pseudodaphnella lemniscata*** **(G&H Nevill, 1869)**	1		Rocks (L)
	Pseudodaphnella sp. #1 †		K	
	Pseudodaphnella sp. #2 †		K	
Terebridae	***Duplicaria duplicata*** **(Linnaeus, 1758)**	1		Muddy sand (L
	Duplicaria spectabilis **(Hinds, 1844)**	1		Muddy sand (M)
	Euterebra fuscobasis **(EA Smith, 1877)**	9		Muddy sand (M, L)
	Granuliterebra tricincta **(EA Smith, 1877)** †			
Omalogyridae	***Omalogyra sp.#1***	1	K, T	Rocks (L)
Rissoellidae	***Rissoella sp. #1***	1	K, T	Rocks (L)
Ringiculidae	***Ringicula cf. minuta*** **(H. Adams, 1872)**	1		Muddy sand (L
Discodorididae	***Discodoris***	2		Rocks (M, L)
Dendrodorididae	***Dendrodoris fumata*** **(Rüppel & Leuckart, 1830)**	2		Rocks (L)
	Doriopsilla	1		Rocks (L)
Polyceridae	***Plocamopherus ocellatus*** **(Rüpp. & Leuck., 1830)**	2		Rocks (H, L)
Bullidae	***Bulla arabica*** **(Malaquias & Reid, 2008)**	1		Rocks (L)
Tornatinidae	***Acteocina persiana*** **(EA Smith, 1872)**	1		Sand (L)
Cylichnidae	***Cylichna sp. #1***†		K, G, T	
Haminoeidae/Haminoeinae	***Haminoea sp. #1***	1		Weeds, sponges (L)
	Haminoea sp. #2	1	T	Weeds, sponges (L)
Atydinae	***Atys sp. #1*** †		T	
Siphonariidae	***Siphonaria asghar*** **(Biggs, 1958)**	1		Rocks (H)
	Siphonaria crenata **(Blainville, 1827**	14		Rocks, (H, M)
Pyramidellidae	***Chrysallida sp. #1***	1	K, T	Rocks (L)
	Chrysallida sp. #2	1	K, T	Rocks (L)
	Chrysallida sp. #3	1	K, T	Rocks (L)
	Chrysallida sp. #4	1	K, T	Rocks (L)
	Chrysallida sp. #5	1	K, T	
	Egilina callista **(Melvill, 1893)**	2	K, T	on tube worms (L)
	Miralda sp. #1	1	K, T	Rocks (L)
	Odostomia sp. #1	1	K, T	Weeds, sponges (L)
	Orinella sp. #1†		K, T	
	Oscilla sp.#1	1	K, T	Rocks (L)
	Rissosyrnola aclis **(A. Adams, 1853)**	2		Weeds, sponges (L)
	Syrnola sp. #1 †		K, T	
	Turbonilla sp. #1	1	K, T	Rocks (L)
	Turbonilla sp.#2	1	K, T	Rocks (L)
Amathinidae	***Amathina tricarinata*** **(Linnaeus, 1767)** †			Rocks (L)
Ellobiidae	***Allochroa layardi*** **(H. & A. Adams, 1855)**	3		Rocks, (H, M)
	Laemodonta monilifera **(H. & A. Adams, 1854)** †			
Onchidiidae	***Peronia verruculata*** **(Cuvier, 1830)**	9		Rocks, (H, M)
POLYPLACOPHORA				
Acanthochitonidae	***Acanthochitona woodwardi*** **Kaas& V. Belle, 1988**	2		Rocks (M, L)

(*continued on next page*)

Table 2 (*continued*).

Family/Subfamily	Current name	Occurrences	Newrecords	Habitat and Zone
Chitonidae	***Chiton (Rhyssoplax) affinis*** **Issel, 1869**	1		Rocks (L)
Ischnochitonidae	***Ischnochiton yerburyi*** **(EA Smith, 1891)**	3		Rocks (M, L)
CEPHALOPODA				
Sepiidae	***Sepia pharaonis*** **Ehrenberg, 1831**	2		Eggs on Rocks (M, L)
Octopodidae	***Octopus cf. cyanea*** **Gray, 1849**	2		Rocks (M, L)

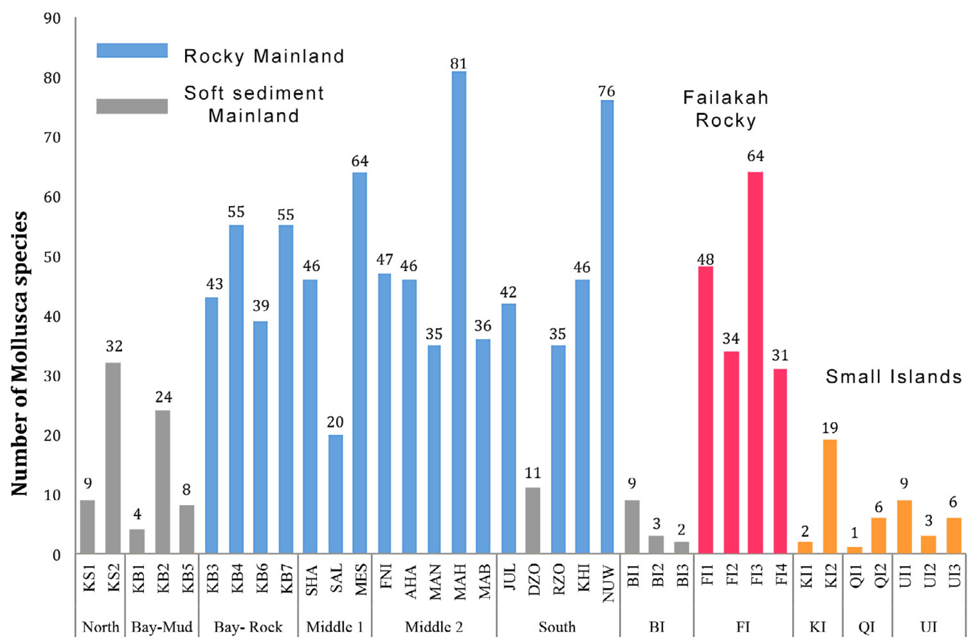

Fig. 2. The total number of molluscan species along the 36 transects from north to south arranged in grouping as in Table 1 and indicating shore types.

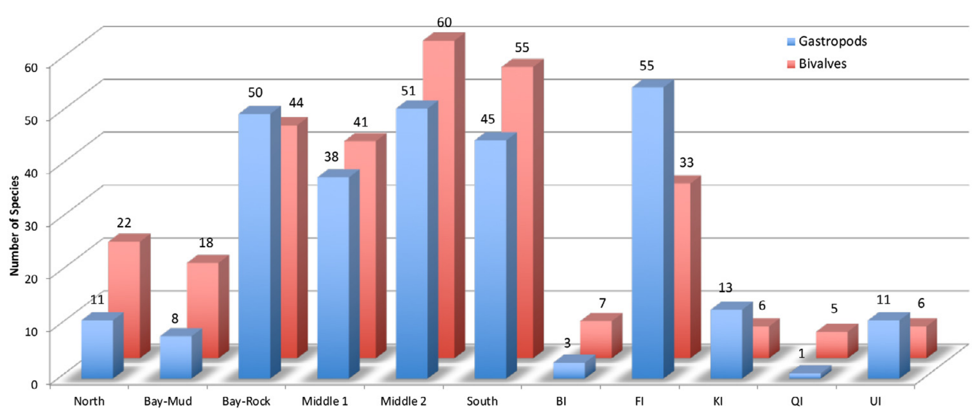

Fig. 3. The total number of bivalve and gastropod species (top of the bars) in 11 intertidal areas from north to south of Kuwait based on the grouping in Table 3 and Fig. 7; BI = Boubyan, FI = Failaka Island, KI = Kubbar Island, QI = Qaruh Island, UI = Umm Al-Maradim Island.

3. Results

3.1. General diversity

The Mollusca ranked second in terms of number of living species in the intertidal area after the Annelida. A total of 271 species belonging to five classes, 26 orders, and 87 families were identified of which 211 were collected living. The gastropods were represented by 104 living species; the bivalves by 100 living species; three living species of polyplacophorans and two living species were recorded for each of the scaphopods, and cephalopods. Although dead shells were not targeted by the sampling, they were kept and identified bringing the total species identified to 271. A complete list of all identified taxa is given in Table 2.

Distributions of both Bivalvia and Gastropoda followed similar patterns with respect to high, mid, and low intertidal zones. The highest frequency of occurrence, species richness, evenness, and diversities occurred at the low intertidal zone and the lowest numbers occurred at the high intertidal zone. The number of sites from which each species was recorded, the habitat and the tidal zone for each recorded molluscan species are shown in Table 2.

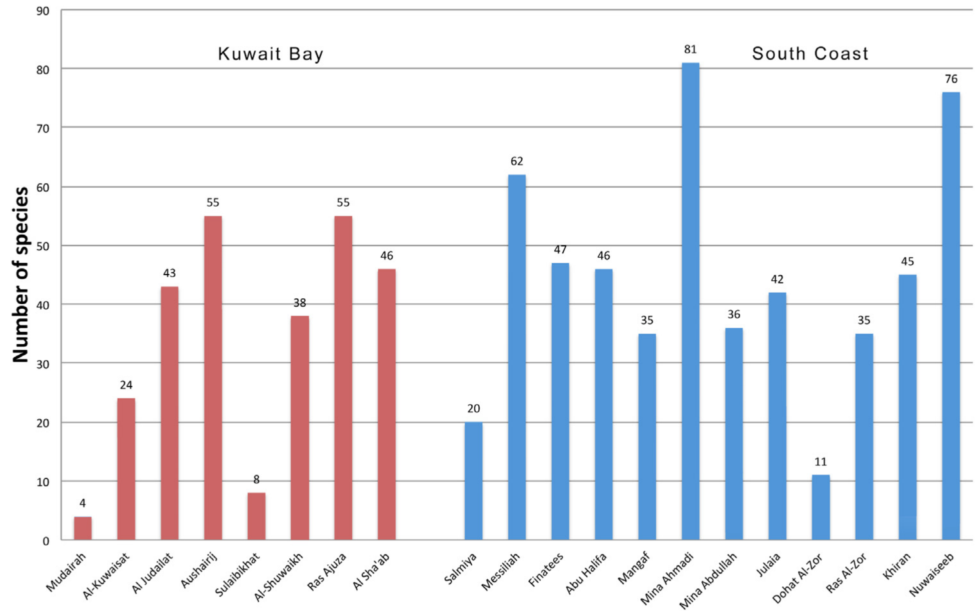

Fig. 4. Comparative number of species occurring at sites in Kuwait Bay and on the south coast.

3.2. New records for science, the Arabian Gulf and Kuwait

Many molluscan species were reported for the first time for Kuwait waters and the entire Arabian region. A total of 61 molluscan species including 21 bivalves, and 40 gastropods are listed (Table 2) as new to Kuwait; most are micro-species or from cryptic habitats. Confirmation of their status cannot be made without a complete review of the Glayzer/Smythe collection in London and that made by Behbehani & Ghareeb now in Kuwait University. Of these, 5 bivalves are recorded from the Arabian Gulf for the first time and many of the micro gastropods are probably also new to the Gulf. A more detailed discussion of the taxonomy of the Kuwait molluscs will be found below.

3.3. Distribution and abundance

The number of molluscan species differed among transects (Fig. 2). In the mainland transects, the highest number of species were found in Musfat Al-Ahmadi (MAH) with 81, Al-Nuwaiseeb (NUW) with 76 species, Al-Messilah (MES), and Failaka Island east 1 (FI3) with 62, Ausairij (KB4), and Ras Ajuza (KB7) with 55, Finatees (FNI) with 48, Failaka Island northwest (FI1) with 47, Sha'ab (SHA) and Abu Halifa (AHA) with 46 species for each transect. In the Island transects, the highest number of species was found in Failaka Island (FI) followed by Kubbar (KI), Umm Al-Maradim (UI) Boubyan Island (BI) and Qaruh island.

Based on grouping transects in areas (Table 1 and Fig. 1), the highest total number of species was in the Middle 2 (Fig. 2) followed by, in descending order, South, KB-Rock, Failaka Island (FI), Middle 1, North, KB-Mud, Kubbar Island (KI), Umm Al-Maradim (UI), Boubyan Island (BI), and Qaruh Island (QI) species.

Based on transect grouping by area (Table 1 and Fig. 1), the highest total number of gastropod species was in Failaka Island (FI) (Fig. 3) followed by Middle 2, Bay Rock (KB), South, Middle 1, Kubbar Island (KI), North and Umm Al-Maradim (UI), Bay-Mud, Boubyan Island (BI), and Qaruh Island (QI).

Based on grouping transects by areas (Table 1 and Fig. 1), the highest total number of bivalve species was in the Middle 2 (Fig. 3) followed by South, Bay-Rock (KB), Failaka Island (FI), Middle 1, North, Bay-Mud, Boubyan Island (BI), Umm Al-Maradim (UI), Kubbar Island (KI) and Qaruh Island (QI) species.

Species richness varied greatly between sites often those in close proximity of each other. Within Kuwait Bay (Fig. 4) the site at Sulaibikhat was especially impoverished while there was a general trend of decreasing richness to the west. The richness of the sites south of Kuwait Bay (Fig. 4) to the border with Saudi Arabia shows no trend but there were two sites that were much more impoverished than the others; those at Salmiyah and Dohat Al-Zor.

3.3.1. The common Mollusca families and species

The most widely distributed molluscan families identified in the more than half of the 36 transects in descending order were Mytilidae, 25 transects; Planaxidae and Pteriidae, 21 transects; Veneridae, Malleidae and Turbinidae, 19 transects; Chilodontidae and Arcidae, 18 transects; Trochidae, Trapezidae, and Pholadidae, 16 transects; and Cerithiidae from 15 transects.

The most widely distributed molluscan species in descending order were *Brachidontes pharaonis* from 25 transects, *Ergalatax juionae*, 22 transects; *Planaxis savignyi, Leiosolenus tripartitus* and *Pinctada radiata* in 21 transects; *Lunella coronata*, *Irus macrophylla*, *Malleus regula* in 19 transects, *Cerithium caeruleum, Euchelus persicus, Acar plicata* and *Petricola flabagella* in 18 transects, and *Clypeomorus persica* in 17 transects (Table 3)

3.3.1.1. Bivalvia. The class Bivalvia was represented by 100 living species belonging to 5 subclasses, 9 orders, and 33 families. The Family Veneridae was the best represented with 18 species, followed by Mytilidae (13 species), Tellinidae (7), and Semelidae (6). Sixteen families were represented by just a single species.

The most frequently occurring species were *B. pharaonis*, followed by *L. tripartitus* and *P. radiata* (Table 4). Both *B. pharaonis* and *L. tripartitus* occurred most frequently in the low intertidal zone and were present in 18 of 36 transects (50%). In all cases except one, frequency of occurrence increased from high intertidal to low intertidal. The exception was *Neotrapezium sublaevigatum*, which was most prevalent in the mid intertidal area (Table 4). A selection of the common bivalves is illustrated in Plate 1.

The number of bivalve species varied among different transects. For the mainland transects, the highest number of species in descending order was found in Musfat Al-Ahmadi (MAH) with 45, Al-Nuwaiseeb (NUW) with 40 species, Al-Messilah (MES) with 33, Ausairij (KB4) and Abu Halifa(AHA) with 31, Ras Ajuza (KB7)

Table 3
The most frequently occurring Mollusca species overall and at three different Intertidal height locations for 36 Sites; the numbers in parentheses represent relative ranks, and the species are ranked alphabetically if their occurrences are the same. The habitat, habit and feeding guild are presented.

Species	Transect	Low zone	Mid zone	High zone	Habitat	Feeding Guild
Brachidontes pharaonis	25(1)	18(2)	14(2)	6(2)	Rock/Epibyssate	Suspension
Ergalatax junionae	22(2)	19(1)	13(3)		Rock	Carnivore
Leiosolenus tripartitus	21(3)	18(3)		5(8)	Rock/Endolithic	Suspension
Pinctada radiata	21(4)	17(5)			Rock/Epibyssate	Suspension
Planaxis savignyi	21(5)	18(4)	17(1)		Rock	Micro grazing
Irus macrophylla	19(6)	16(7)			Rock/Crevice	Suspension
Lunella coronata	19(7)		13(4)	6(4)	Rock	Micro grazing
Malleus regula	19(8)	16(8)			Rock/Epibyssate	Suspension
Acar plicata	18(9)	16(6)			Rock/Epibysate	Suspension
Cerithium caeruleum	18(10)		11(7)		Rock	Micro grazing
Euchelus persicus	18 (11)	12 (12)	10 (11)		Rock	Micro grazing
Petricola flabagella	18 (12)	14 (11)		3 (11)	Rock/Endolithic	Suspension
Clypeomorus persica	17 (13)		10(9)	5(7)	Rock	Micro grazing
Barbatia trapezina		15(9)			Rock/Epibyssate	Suspension
Botula cinnamomea		14(10)			Rock/Endolithic	Suspension
Neotrapezium sublaevigatum			12(5)	6(5)	Rock/Crevice	Suspension
Cerithium scabridum			11(8)		Rock	Micro grazing
Pirenella arabica			12(6)		Stable sediment	Micro grazing
Seila bandorensis				4(10)	Rock	Micro grazing
Semiricinula tissoti				6(6)	Rock	Carnivore
Circenita callipyga				4(9)	Muddy sand	Suspension
Didimacar tenebrica			10(10)		Rock/Epibyssate	Suspension
Isognomon nucleus				6(3)	Rock/Epibyssate	Suspension
Nudibranchia g. sp.				7(1)	Rock/Hydroids	Carnivore

Table 4
The 10 most frequently occurring Bivalvia species overall and at three different intertidal heights; the numbers in parentheses represent relative ranks, the species are ranked alphabetically if their occurrences are same.

Species list	Transect	Low zone	Mid zone	High zone
Brachidontes pharaonis	25(1)	18(1)	14(1)	6(1)
Leiosolenus tripartitus	21(2)	18(2)	9(6)	5(4)
Pinctada radiata	21(3)	17(3)	10(4)	
Irus macrophylla	19(4)	16(5)	8(8)	
Malleus regula	19(5)	16(6)		
Acar plicata	18(6)	16(4)	9(5)	2(9)
Petricola flabagella	18(7)	14(9)		3(7)
Aspidopholas tubigera	16(8)	12(10)	6(9)	3(6)
Barbatia trapezina	16(9)	15(7)	8(7)	
Botula cinnamomea	16(10)	14(8)		
Neotrapezium sublaevigatum			12(2)	6(3)
Circenita callipyga			6(10)	4(5)
Didimacar tenebrica			10(3)	
Isognomon nucleus				6(2)
Saccostrea cuccullata				3(8)
Congetia chesneyi				2(10)

Table 5
The 10 Most frequently occurring gastropod species overall and at three different intertidal height locations among 36 Sites; the numbers in parentheses represent relative ranks, the species are ranked alphabetically if their occurrences are same.

Species list	Transect	Low zone	Mid zone	High zone
Ergalatax junionae	22(1)	19(1)	13(2)	
Planaxis savignyi	21(2)	18(2)	17(1)	3(9)
Lunella coronata	19(3)	11(9)	13(3)	6(2)
Cerithium caeruleum	18(4)	12(4)	11(5)	
Euchelus persicus	18(5)	12(5)	10(8)	
Clypeomorus persica	17(6)		10(7)	5(4)
Clanculus scabrosa	16(7)	13(3)	9(10)	
Cerithium scabridum	15(8)	11(8)	11(6)	
Priotrochus kotschyi	15(9)		10(9)	
Tylothais savignyi	15(10)			
Emarginula sp.		12(6)		
Pirenella arabica			12(4)	4(6)
Siphonaria crenata				3(10)
Diodora funiculata		10(10)		
Seila bandorensis				4(5)
Semiricinula tissoti				6(3)
Monodonta vermiculata				3(8)
Granata sulcifera		12(7)		
Nudibranchia g. sp.				7(1)
Echinolittorina arabica				3(7)

with 29, Al-Fnaitees Beach (FNI), Al-Khiran (KHI) and Failaka Island east 1 (FI3) with 28 species. In the Island transects, the highest number of species were found in Failaka Island (FI) followed by Boubyan Island (BI), Umm Al-Maradim (UI), Kubbar (KI), and Qaruh island species, respectively.

The most widely distributed bivalve families among the 36 transects in descending order were Pteriidae recorded from 21 transects; Veneridae and Malleidae from 19; Arcidae from 18; Pholadidae, Mytilidae, and Trapezidae from 16; Gastrochaenidae, Isognomonidae and Chamidae from 12 transects. The most widely distributed bivalve species among the 36 transects in descending order included *L. tripartitus* and *P. radiata* from 21 transects; *I. macrophylla* and *M. regula* from 19; *P. flabagella* from 18; *Aspidopholas tubigera, Barbatia trapezina*, and *B. cinnamomea* from 16 transects.

3.3.1.2. Gastropoda. The 104 live collected gastropod species represented 51 families. With 11 species, the Pyramidellidae was the best represented; while the Trochidae and Muricidae were represented by seven and six species, respectively. Six families had four species, namely Cerithiidae, Chilodontidae, Columbellidae, Fissurellidae, Nassariidae, and Naticidae. Twenty-nine families were represented by only one species.

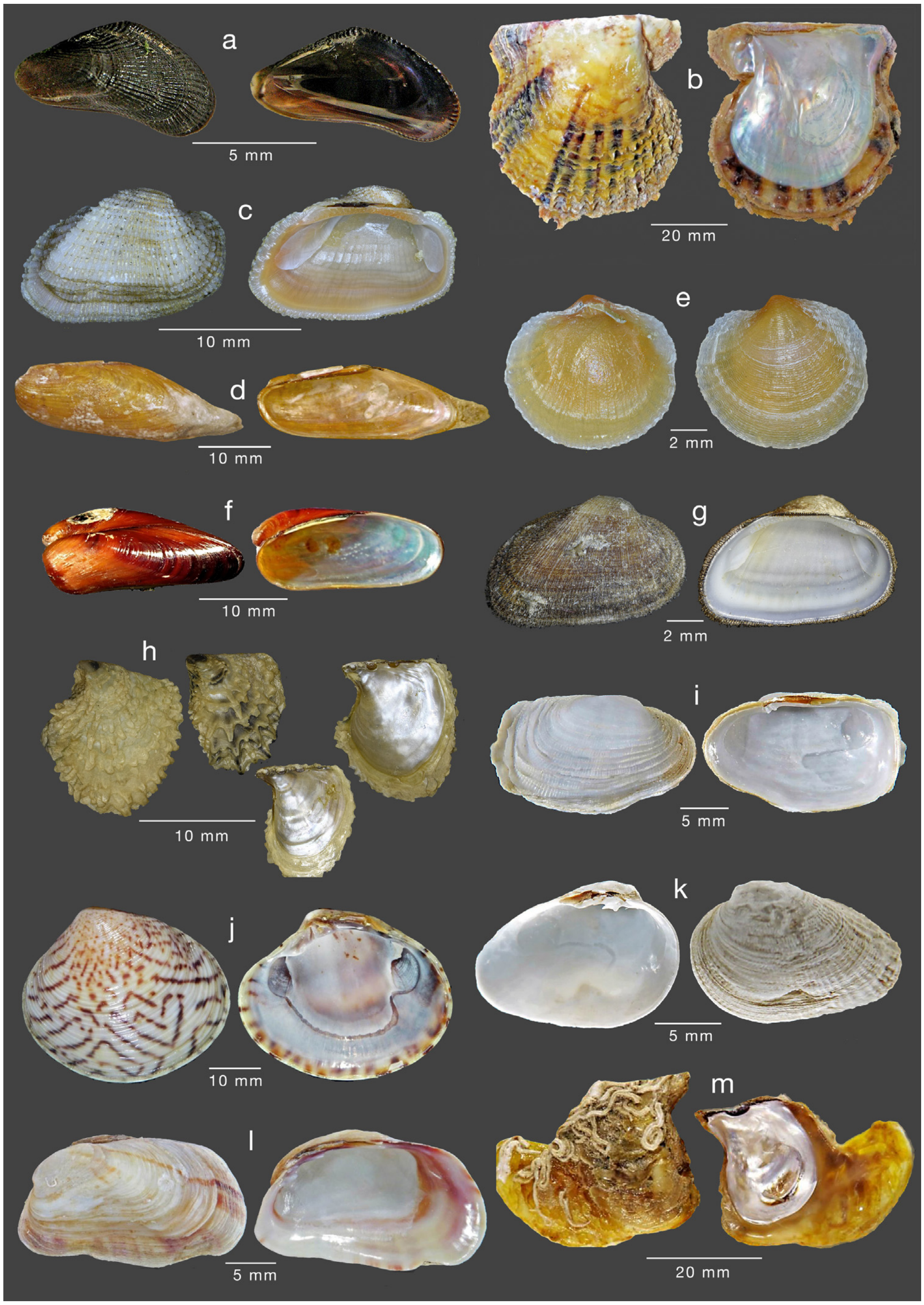

Plate 1. A selection of the more common bivalve species. **a**, *Brachidontes pharaonis*; **b**, *Pinctada radiata*; **c**, *Acar plicata*; **d**, *Leiosolenus tripartitus*; **e**, *Pillucina vietnamica*; **f**, *Botula cinnamomea*; **g**, *Didimacar tenebrica*; **h**, *Isognomon nucleus*; **i**, *Irus macrophylla*; **j**, *Circenita callipyga*; **k**, *Petricola flabagella*; **l**, *Neotrapezium sublaevigatum*; **m**, *Malleus regula*.

The most frequently occurring gastropod species was *Ergalatax junionae* followed by and *P. savignyi* and *L. coronata*. These three gastropods were found at 22, 21, and 19 of the possible transect intertidal locations, respectively (Table 5). With two exceptions, gastropod presence at an intertidal site increased from high to low tide. The exceptions were *C. persica* and *Pirenella arabica*, which were more frequently collected in the mid intertidal zone than in the lower intertidal zone (Table 5). A selection of the common gastropods is illustrated in Plate 2.

The number of gastropod species differed among transects. For the mainland transects, the highest number of species was found in Musfat Al-Ahmadi (MAH) and Failaka Island east 1 (FI3) with 35, followed by Al-Nuwaiseeb (NUW) with 34 species, and Failaka Island northwest (FI1) with 31, Al-Messilah (MES) with 30, Ras Ajuza (KB7) with 26, Ausairij (KB4) and Al-Sha'ab (SHA) with 23, Al-Salam Beach (KB6), Al-Julai'a (JUL) and Failaka Island east 2(FI2) with 21, (KB3), Ras Al-Zour (RZO) with 20 species. For the island transects, the highest number of species were found in Failaka (FI) followed by Kubbar (KI), Umm Al-Maradim (UI), Boubyan (BI), and Qaruh.

The gastropod families most widely distributed among the 36 transects in descending order were Muricidae recorded from 22 transects; Planaxidae and Mytilidae from 21; Turbinidae from 19; Chilodontidae and Cerithiidae from 18; Trochidae from 17; and Columbellidae, Pomatiidae, and Siphonaridae from 14.

Plate 2. A selection of the more common gastropod species. **a**, *Ergalatax junionae*; **b**, *Lunella coronata*; **c**, *Planaxis savignyi*; **d**, *Tylothais savignyi*; **e**, *Clanculus scabrosus*; **f**, *Pirinella arabica*; **g**, *Euchelus persicus*; **h**, *Cerithium scabridum*; **i**, *Priotrochus kotschyi*; **j**, *Cerithium caeruleum*; **k**, *Siphonaria crenata*; **l**, *Clypeomorus persica*; **m**, *Peronia verruculata*; **n**, *Echinolittorina arabica*.

3.4. Quantitative data

Quantitative sampling produced 105 species of molluscs comprised of 70 bivalves, 33 gastropods, and 2 Polyplacophora (chitons). Representatives of the Classes Scaphopoda and Cephalopoda were not collected quantitatively. Gastropods and bivalves were present at all intertidal levels, but were about twice as abundant in the mid and low intertidal zones when compared to the high intertidal zone. Overall, gastropods were twice as dense as bivalves (27,902 vs. 12,656 per 108 m^2), but this ratio varied with respect to intertidal height. Gastropods outnumbered; bivalves 6:1 at the high intertidal zone, and 2.6:1 at the mid intertidal zone. Numbers were nearly equal at the low intertidal zone. Overall, species richness was higher for bivalves than gastropods, but evenness and diversity were about the same. Species richness for gastropods and bivalves decreased from low intertidal to high intertidal locations. Diversity indices increased from high tide to mid tide locations, but not necessarily from mid tide to low tide locations. The quantitative data for each molluscan group at each tidal zone are summarised below in Table 6.

3.4.1. Bivalvia

Quantitative samples produced 70 species of Bivalvia representing 29 families. The Family Veneridae was best represented

Table 6
Total species, total number, species richness, evenness and diversity for different classes of Mollusca for overall and at different intertidal zones.

	Total species (S)	*Total number (N)*	*Species richness (d)*	*Pielou's evenness (J)*	*Shannon's diversity (H')*
Overall					
Gastropoda	33	27 902	3.126	0.680	2.379
Bivalvia	70	12 656	7.305	0.610	2.592
Polyplacophora	2	17	0.350	0.776	0.538
High zone					
Gastropoda	16	8357	1.661	0.313	0.868
Bivalvia	23	1356	3.050	0.474	1.487
Polyplacophora					
Middle zone					
Gastropoda	27	13 600	2.732	0.671	2.213
Bivalvia	51	5252	5.837	0.584	2.294
Polyplacophora	2	7	0.502	0.684	0.474
Low zone					
Gastropoda	28	5945	3.107	0.579	1.929
Bivalvia	54	6048	6.087	0.668	2.664
Polyplacophora	2	10	0.432	0.831	0.576

Table 7
The 10 most abundant bivalve species overall (Sum of Average Density/m^2 for each tidal height for 36 Sites, i.e., 108 m^2) and at three intertidal heights (36 m^{-2})

No.	Species name	Overall	High	Middle	Low	Habitat/habit
1	*Brachidontes pharaonis*	3537	837	1818	881	Rock/epibyssate
2	*Leiosolenus tripartitus*	2655	0	1330	1325	Rock/endolithic
3	*Petricola flabagella*	830	0	111	718	Rock/endolithic
4	*Irus macrophylla*	696	21	167	507	Rock/cryptic
5	*Gregariella ehrenbergi*	662	43	52	567	Rock/epibyssate
6	*Neotrapezium sublaevigatum*	616	0	433	183	Rock/cryptic
7	*Acar plicata*	570	160	147	263	Rock/epibyssatate
8	*Aspidopholas tubigera*	469	0	84	385	Rock/endolithic
9	*Pillucina vietnamica*	225	0	120	105	Sandy mud/infaunal
10	*Pinctada radiata*	211	21	57	133	Rock/epibyssate

Table 8
The 10 most abundant gastropod species overall (Sum of Average Density/m^2 for each tidal height for 36 Sites, i.e., 108 m^2) and at three intertidal heights (36 m^{-2}).

Order	Species	Overall	High	Middle	Low	Habitat
1	*Echinolittorina arabica*	7169	6537	630	2	Rocky HTL
2	*Umbonium vestiarium*	3676	7	3635	34	Sandy MTL
3	*Cerithium caeruleum*	3669	0	1763	1905	RockyM-LTL
4	*Clypeomorus persica*	3151	0	2998	153	Rocky MTL
5	*Cerithium scabridum*	2200	7	352	1841	RockM-LTL
6	*Siphonaria crenata*	2146	436	1710	0	RockH MTL
7	*Ergalatax junionae*	1056	19	327	711	Rock M-LTL
8	*Lunella coronata*	94	179	336	426	Rock M-LTL
9	*Pirenella arabica*	817	482	324	10	Stable muddy
10	*Priotrochus kotschyi*	645	12	504	129	Rock MTL

with 14 species, followed by Mytilidae with 8 species. The Families Carditidae, Gastrochaenidae, and Ungulinidae were each represented by four species. The overall most abundant species was *B. pharaonis*, (Table 7) followed by *L. tripartitus* and *P. flabagella*. Densities of both *B. pharaonis* and *L. tripartitus* were higher in the mid intertidal area than either the high or low intertidal areas (Table 7). The other species among the top ten whose density was highest in the mid intertidal zone was *N. sublaevigatum*. Densities of the other species increased from high to low intertidal heights (Table 7).

3.4.2. Gastropoda

Quantitative samples produced a total of 33 species of gastropods representing 21 families. The best represented families were Muricidae and Trochidae, each with five species, followed by Cerithiidae with three species, and Chilodontidae and Fissurellidae with two species each. The remaining 16 families were each represented by a single species. The overall most abundant species was *E. arabica*, which was twice as abundant as *Umbonium vestiarium*, the next most numerous species. Densities of *U. vestiarium* and *C. caeruleum*, the third most abundant gastropod, were about the same (Table 8). With densities of 182 m^{-2}, *E. arabica* was also the most abundant species at the high intertidal zone. Densities of this species dropped by a factor of 10 in the middle intertidal zone and to nearly zero at the lower intertidal areas. The most abundant species at the middle intertidal zone was *U. vestiarium* with densities of 101 m^{-2}. Densities of *U. vestiarium* at the highest and lowest intertidal areas were <1 m^{-2}, showing that this species was a mid-intertidal specialist. Two species of *Cerithium* dominated the lower intertidal zone. *C. caeruleum* and *C. scabridum* exceeded 50 individuals m^{-2}(Table 8).

4. Discussion

4.1. Diversity differences

The results show some marked differences in the number of species recorded at the sites and the compositions. Of greatest influence is the gross habitat of the shores such that soft sediment sites have much lower numbers of species (Fig. 2). The sites around Boubiyan (BI1-3), Northern Kuwait Bay (KS1-2) Inner Kuwait Bay (KB1-2) are dominated by extensive soft muddy shores and included in this group can be Sulaibikhat Bay (KB5) although in addition it is often polluted by sewage discharge. Although not a muddy intertidal that at Dohat A-Zor (DZO) is mainly of coarse sand on a steeply sloping beach where the habitat is uniform and species poor. These soft sediment shore are dominated by the Bivalvia with species numbers typically twice that of the gastropods (Fig. 3).

Elsewhere is a general pattern of the southern shores of Kuwait Bay being less diverse than those of the south coast (Fig. 4). Kuwait Bay is dominated by Kuwait City with extensive sea-defences and other anthropogenic influences as well as having turbid conditions. The low diversity found at Salmiya (SAL) is also due to the urbanisation of this suburb and the considerable recreational use of its beaches. The intertidal areas of Aushairij and Ras Ajuza are the most species-rich transects in Kuwait Bay, here is a complex mosaic of soft sediment flats overlying rock to various depths. At the lower shore, emergent rocks and boulders are present many encrusted with calcareous tube-worms. In places small scale reefs are formed by this tube-worm (*Spirobranchus kraussi* Baird) and these create another cryptic environment for small molluscs including the pyramidellid *Egilina*, which is an ectoparasite on the tube worm.

The southern coast is less developed and has more open wave washed shores with less turbid water. There is, however, considerable variation between shores on this sector despite all being of a similar formation of beach rocks interspersed with patches of soft sediment. Variations in qualitative collecting effort may play a role in these variations and the influence of collecting in cryptic habitats can be considered. Collecting in cryptic habitats for micro species was carried out across all sites so cannot be the cause alone. The majority of the micro gastropods were collected only at single sites but despite their rarity they were often very diverse with for example the Pyramidellidae contributing 14 species overall. The presence of intertidal sponges and seaweeds on the shores of Failaka were especially rich in micro-molluscs. Micro-molluscs were also prominent in the malacofaunas of Mina Ahmadi and Nuwaiseeb. The hidden diversity of these small species was also noted from the Red Sea where the diversity of molluscs in reef flats was studied (Zuschin and Oliver, 2005). That study also found that many small species were undescribed and that the malacofauna was probably under-estimated (Zuschin and Oliver, 2005).

The outer islands var markedly with all of the smaller ones surveyed being species poor while the largest Failaka was one of the richest sites examined in the survey. The intertidal of Failaka is almost unique in having remnants of intertidal corals as well as many intertidal sponges. These provide a complex three dimensional habitat populated by many gastropod species and Failaka recorded the highest number of gastropod species. The contrasting paucity on the smaller islands is probably a result of the restricted extent of the intertidal zone.

In Table 7 the dominance of the endolithic bivalves *Aspidopholas*, *Petricola*, *Leiosolenus* is evident A second form of cryptic environment is created by these rock boring in the form of a complex three dimensional environment largely protected from extremes of temperature and predation. When the burrows are vacated they are then populated by a variety of dwelling of species such as *Cumingia, Irus, Neotrapezium, Venerupis, Asaphinoides* and many unidentified small gastropods.

Table 8 indicates the dominance of surface living gastropods of the families Cerithiidae, Trochidae, Turbinidae and Muricidae. The former three families are all grazing on micro-algae or on surface films while only the muricids are carnivorous feeding primarily on tube worms and bivalves. *E. junionae* and *T. savignyi* both feed *B. pharaonis* and *S. kraussi* (Alsayegh, 2015) while *Hexaplex rileyi* was also observed on oysters (pers. comm.).

Overall four sites are marked out as having the highest diversity, in sequence these are Masfat Al-Ahmadi (MAH), Al-Nuwaiseeb (NUW), Al-Messilah (MES) and Failaka Island (FI3). All four sites are primarily rocky shores with areas of soft sediment in southern or offshore locations distant from Kuwait Bay. It may be coincidental that the site at Masfat Al-Ahmadi is restricted from public access and this will certainly deter any casual collecting of edible species. Failaka is the only site where remnants of intertidal corals are present and it is further unusual in having many intertidal sponges., both habitats likely to host numerous small species of mollusc.

4.2. Comparisons through time

Inventories and faunal surveys are necessary tools for the estimation of environmental change. Among marine invertebrates the Mollusca have an extensive temporal record although in the Arabian Gulf the data are sporadic and inconsistent. The present survey provides the first repeatable quantitative assessment but comparison with older qualitative studies is restricted to species numbers and rather subjective abundance values. However, such comparisons were made for the UAE by Grizzle et al. (2018) and were justified in that there are no other data available, while accepting that such comparisons were limited.

There are only three comparable studies (Al-Bakri et al., 1985; Glayzer et al., 1984; Behbehani and Ghareeb, 2002). We have excluded Jones (1986) because it is a field guide and does not purport to be comprehensive. The Behbehani & Ghareeb study has not yet been openly published but is in prep (Behbehani, Ghareeb & Oliver, in prep).

Table 9 compares the number of species found by each survey. Comparisons of the aforementioned data sets can only be done at a superficial level for a number of reasons. For the earlier studies by Al-Bakri et al. (1985) and Jones (1986), no voucher material was available. It was therefore not possible to verify the identifications of any of the species cited by them. This is particularly disappointing for the Al-Bakri study, where numerous taxa were identified only to the genus or family level. A taxonomic review of the Smythe collection, which contains the material from the Glayzer et al. (1984) study, was beyond the scope of this project making some comparisons tentative. The study by Behbehani & Ghareeb was focused on the Mollusca alone over a four-year period. The collection is maintained in Kuwait University and the that report illustrates each species.

The relative effort involved between the Glayzer et al. (1984) study and the current study differs substantially. The Glayzer study concerned molluscs alone and was carried out over a 10-year period; sites were visited repeatedly throughout the year, and special effort was made to find small and rare species. The Behbehani and Ghareeb (2002) study also only focused on the Mollusca and was similar to that of Glayzer, but carried out over a shorter time period of four years. The present study sampled the total intertidal fauna over a period of 3 years with most effort on quantitative data and relative tidal zone during only late autumn and winter seasons. These differences need to be considered when making comparisons (Table 9). The time gap between the Glayzer and Al-Bakri studies (1984–85) and the present study (2013–16) is roughly 30 years.

Glayzer et al. (1984) study recorded the highest number of species, but 55% were represented by dead shells, giving a total of living species as 194. Behbehani and Ghareeb (2002) recorded 309 living species. In the present study, only 20% were recorded from dead shells giving a living total of 218 living species. Both

Table 9
Comparisons of live mollusc species numbers recorded from studies spanning 1984 to 2016. Numbers in parentheses are species represented by dead shells.

Study	Bivalves	Gastropods	Chitons	Scaphopods	Total live	Total
Present study	100 (26)	104 (33)	3 (0)	2 (3)	211	271
Behbehani	153 (13)	151(40)	2 (0)	3 (3)	309	366
Glayzer et al. (1984)	86 (74)	102 (178)	5 (0)	1 (4)	194	450
Al-Bakri et al. (1985)	69	45	1	1	116	116

Table 10
Comparisons of relative abundance between the present study and those of Glayzer et al. (1984) and Behbehani and Ghareeb (2002). The list is ordered in descending frequency of occurrence in this study.

Species	Glayzer	Behbehani, % number of sites	Present study % number of sites
Brachidontes pharaonis	Occasional	67	69
Ergalatax junionae	Abundant	78	61
Leiosolenus tripartitus	Common	63	58
Planaxis savignyi	Common	52	58
Pinctada radiata	Frequent	52	58
Lunella coronata	Abundant	78	53
Irus macrophylla	Common	59	53
Malleus regula	Common	44	53
Acar plicata	Frequent	56	50
Cerithium caeruleum	Abundant	41	50
Euchelus persicus	Common	81	50
Petricola flabagella	Occasional	33	50
Clypeomorus persica	Abundant	74	47
Clanculus scabrosa	Rare	7	44
Aspidopholas tubigera	Common	15	44
Barbatia trapezina	Frequent	44	44
Botula cinnamomea	Common	41	44
Neotrapezium sublaevigatum	Occasional	63	44
Cerithium scabridum	Common	42	42
Pritrochus kotschyi	Abundant	78	42
Tylothais savignyi	Common	48	42
Indothias scalaris	Frequent	70	39
Mitrella blanda	Abundant	74	39
Pirenella arabica	Abundant	63	39
Siphonaria spp.	Abundant	52	39
Conomurex persicus	Abundant	37	36
Diodora funiculata	Frequent	37	36
Semiricinula tissoti	Frequent	19	36
Chama spp.	Common	48	33
Umbonium vestiarium	Abundant	67	31
Circenita callipyga	Common	37	31
Trochus erithreus	Frequent	26	28
Parviperna nucleus	Frequent	70	25
Dosinia alta	Occasional	59	19
Echinolittorina arabica	Abundant	52	17
Callista umbonella	Common	19	11
Hexaplex spp.	Common	37	8
Nassarius persicus	Abundant	59	8
Thylacodes variabilis	Common	22	8
Marcia cordata	Common	37	8
Tapes sulcarius	Common	11	3
Timoclea arakana	Frequent	52	3

Glayzer et al. (1984) and Behbehani and Ghareeb (2002) note the large number of taxa represented by small rare species. These are more unlikely to be found in a quantitative survey and their rarity makes them unsuitable for monitoring purposes. Changes in the intertidal are better reflected in the numbers and distribution of common species.

Glayzer et al. (1984) provided relative frequency information in a 5-point scale from Abundant–Common–Frequent–Occasional–Rare (Table 10). In Behbehani and Ghareeb (2002) abundance can be inferred from the number of sites a species is recorded from. Table 9 lists all the abundant and common species from all three surveys; for Behbehani & Ghareeb all species found in more than 14 of the 27 (52%) transects are included and from the present survey all species that were found in more than 50% of the sites. In general, there was considerable congruence between the abundant and common species in both surveys.

There were, however, some discrepancies. Some of the larger infaunal bivalves were considered common by Glayzer, notably *Callista*, *Marcia*, and *Tapes*, but these were not common in the present survey or in Behbehani and Ghareeb (2002).

The temporal changes noted here are not quantified but a number of factors may be involved. It is known that there have been environmental changes in water quality: Devlin et al. (2015) report on long term changes in water quality; Lyons et al. (2015) more specifically on pollution by sewage and Al-Sarawi et al. (2015) on long term contaminants. Al-Yamani et al. (2017) and Allosaur and Pokavanich (2017) review the hydrographic changes and specifically the changes in salinity related to the Shatt Al-Arab River discharges. Increasing salinity, turbidity and nutrification are likely to be deleterious to many molluscs through altering the physical environment, increasing physiological stress and feeding patterns.

The past decline of the *Pinctada* stocks is testament to the population declines that follow over-exploitation (Al-Shamlãn, 2000) but while casual artisal collection of edible molluscs is evident (Personal observation, M. Al-Kandari) there are no data on its extent or impact Another obvious but as yet un assessed feature is the extent of ribbon development along the coast including the removing of rocks and dumping of desert sand to create bathing beaches.

4.3. Comparisons within the Arabian peninsula

There are no directly comparable studies from the Arabian Gulf although there are studies on molluscan communities from localised sites. Salehi et al. (2015) reports on the inter-tidal gastropod fauna of a bay on the north-east coast of Iran on a latitude equivalent to that of Kuwait. Only seven species of gastropod were recorded of which two stated as dominant were not recorded in the present survey of Kuwait.

The next adjacent surveys are from Saudi Arabia (Hasan, 1996) and from Tarut Island, Saudi Arabia at 26° 34N some 200 km south of Kuwait (El-Sorogy et al., 2016). Both sampled mollusca from live and dead shells and recorded the former recording 62 gastropod species and 68 bivalve species and the latter 30 gastropods and 32 bivalves. As in Kuwait the Cerithiidae was the dominant gastropod family but for the bivalves the Veneridae were most numerous. The extensive sand and muddy sand flats found on the Saudi Arabian coast contrast with the much softer sediments around Kuwait and this may be the reason behind the paucity in numbers of venerids in Kuwait.

In a most recent study from the UAE Grizzle et al. (2018) identified only 27 living gastropod species and 22 living bivalve species and as above the gastropod fauna is similar to that of Kuwait but the bivalve fauna once again reflects the presence of extensive sand flats not seen in Kuwait. Grizzle et al. (2018) concluded using comparisons with early checklist data from the 1960s and 70s that there had been considerable changes in the molluscan fauna due to anthropogenic alterations of the coastline.

In Qatar a project limited to the gastropod fauna revealed that the rocky shore community was very similar to that of Kuwait with similar dominance (Al-Maslamani et al., 2015). The methodology used was different using the Rapid Assessment Survey of Smith (2005) and also including dead shells. A much earlier study from Qatar by Mohammed and Al-Khayat (1994) which takes the form of a checklist with relative abundance recorded only 41 gastropod species and 27 bivalve species. Once again there is considerable commonality with the gastropod fauna of Kuwait but once again the bivalve list indicates the presence of sand flats.

One study recently intensely examined the living and dead molluscs from a two sites in the UAE (Garcia-Ramos et al., 2016). Both sites are described as carbonate tidal flats, so are primarily of sandy sediments with some beach rock and scattered mangroves. This methodology makes use of the taphonomic assemblages from which changes in species composition and abundance can be measured. This spatially restricted survey did reveal a rich fauna with 77 gastropod species and 55 bivalve species. Unfortunately the systematic collection of dead shells was not included in our survey, its scope already being extensive. One observation, from Boubiyan, may reflect the potential of studying taphonomic assemblages for here there are dense aggregations of long dead *Placuna* shells, a species that was not found alive in our survey.

From the comparisons with the above surveys it can be seen that the inter-tidal molluscan fauna of Kuwait is not simply a reflection of that of the Arabian Gulf as a whole. While there is considerable similarity for the rocky intertidal gastropods the soft sediment communities are rather unique to Kuwait. The fine muddy sediments and turbid waters of Kuwait Bay and the areas adjacent to Boubiyan are not present elsewhere and it is these sediments that we find species not seen elsewhere in the Gulf such as *Congetia chesneyi*, *Protapes cor*, *Tellimactra edentula* and *Bullia* n. sp.

4.4. Taxonomy

Given that the molluscan fauna of the Gulf has been investigated for over 100 years, it should not be surprising that the number of species new to science discovered in the current project was low. This does not infer that the taxonomy is resolved and some major problems require resolution, made more conclusive by the use of molecular methods.

Of most importance is the need to clarify the identity of the reef-forming oyster that is such a prominent feature of the intertidal areas in Khor Al-Sabiya and Boubyan Island (Plate 3a, b). This oyster is not the *Saccostrea cuccullata* (Plate 3d) that is common on the artificial shores around the urbanised areas. Rather it is dominant in the turbid areas and may be the same oyster that attaches to dead shells lying on the mud on the northern shores of Kuwait Bay. The true identity of this oyster has never been confirmed, and the literature records are inconsistent. It is not known if this oyster is unique to the northern Gulf, or to the Gulf as a whole, or if it is found elsewhere in the northern Indian Ocean. This oyster could be a key indicator species but without its true identity would render ecological studies and conservation management difficult. This is further exacerbated by not knowing how many species are present in Kuwait waters and a small elongated species living under rock on Miskan Island (Plate 3c) is a further example of the taxonomic problems posed by the oysters.

The genus *Clypeomorus* is a dominant feature of the intertidal but these like the cerithiids in general are taxonomically difficult. We have recognised two species of *Clypeomorus* (Plate 3e & f) from shell characters but this needs confirmation with molecular data. Beyond separating these two forms their relationships to other populations in the Arabian Gulf and Indian Ocean are unclear. Once again unresolved taxonomy renders the use of this dominant species problematic.

At one time it was considered that the malacofauna of the Arabian Gulf was a subset of that found in the Arabian Sea but increasingly Gulf populations are being given separate species status based on shell characters. Typical of this is the example of *H. rileyi* and *H. kusterianus*, the former now erected as a species restricted to the Gulf. Confirmation of the separation of these and other species pairs using molecular techniques is recommended. It is important to discover how unique the Gulf fauna actually is.

Some previously recognised species are now considered to be undescribed. Species identified as *Anadara* cf. *ehrenbergi* (Plate 3h), *Musculus costulatus*, *Bullia* sp.(Plate 3g), *Notochlis* sp., and *Vanikoro* sp. require description.

Small and cryptic species are most likely to be undescribed, and this is the case with the three, minute, species of bivalves belonging to the genus *Mysella*. Many of the micro-gastropods might be undescribed, but careful comparison with shells described by Melvill from the Gulf of Oman is needed for confirmation. Given that Melvill listed only a few species from Kuwait, it is likely that these micro-gastropods are all first records for Kuwait and perhaps for the Gulf.

4.5. Taxonomic congruence

One of the most negative influences on creating inventories is the lack of taxonomic congruence between projects. This arises through the use of differing identification tools, changes in taxonomy and nomenclature and misidentification. Arriving at an

Plate 3. **a**, Oyster reef in Khor Sabiya; **b**, Oysters from Khor Sabiya: **c**, Oysters under rock on Miskan Island; **d**, typical *Saccostrea cuccullata* from harbour at Salmiya; **e**, *Clypeomorus persica* and **f**, *C. cf morus*; **g**, undescribed species of *Bullia* from Boubiyan; **h**, undescribed species of *Anadara* from Boubiyan.

inventory by amalgamating all taxa recorded across numerous publications will vastly overestimate the fauna. For the Red Sea Oliver (1992) estimated that there were at least three names for every species present. The only certain method to resolve such over estimation is to examine voucher collections or high-quality images from each project. Sadly voucher collections are not always kept as here for the study by Al-Bakri et al. (1985) and the field guide by Jones (1986). Often collections are kept but not in the public domain making access difficult or the location of voucher material may not be obvious from the publication. The latter is true for the material collected by Glayzer et al. (1984) which was eventually deposited in the Natural History Museum, London as part of the Kathleen Smythe collection. The pertinent material is however not isolated making any examination requiring sorting through many thousands of samples from a wide variety of locations. Without such congruence the estimation of change within a fauna is rather subjective.

Comparisons between faunas are made equally difficult. To illustrate this the intertidal fauna of Qatar (Mohammed and Al-Khayat, 1994), that lists 70 species, is compared with the names used in the present survey. Thirty-seven, more than half, species names are not in common with the current survey. Does this really indicate such a difference between the intertidal faunas or is much due to lack of congruence?

This paper urges the creation of a national collection, open to all researchers, in Kuwait where voucher specimens can be deposited and examined.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Gratitude goes to the Kuwait Petroleum Company (KPC) and the Kuwait Institute for Scientific Research (KISR) for providing financial support for this project. Special thanks go to Dr. James Bishop for all his support during the project and to Miss Muneera Aljeri for preparing the GIS map. Extended thanks to all KISR staff in project FM075C for their help in macrofauna sampling in the field and processing the samples in Laboratory.

PG Oliver wishes to give special thanks to Henk Dekker for his invaluable help with the identification of the gastropods and nomenclature in genera. To Prof. Manaf Behbehani for allowing access to his unpublished research on the molluscs of Kuwait. Also to Brett Lyons (Centre for Environment, Fisheries and Aquaculture Science) for directing me towards literature relevant to marine environmental conditions in Kuwait. Finally to the review of the paper by Prof. Martin Zuschin which considerably improved the discussion and interpretation of the data.

References

Al-Bakri, D., Foda, M., Behbehani, M., Khalaf, F., Shublaq, W., El-Sayed, M.I., Al-Sheikh, Z., Kittaneh, W., Khuraibit, A., Al-Kadi, A., 1985. Environmental Assessment of the Intertidal Zone of Kuwait. Kuwait Institute for Scientific Research, Kuwait.

Al-Kandari, M., Bishop, J., Chen, W., Skryabin, V., Polikarpov, I., Sattari, Z., Taqi, A., Hussain, S., 2017. Biodiversity, Distribution and Abundance of Intertidal Macrofauna in Kuwait. Final Report FM075C, KISR 14461, Kuwait Institute for Scientific Research.

Al-Maslamani, I., Al-Masdi, A., Smyth, D.M., Chatting, M., Obbard, J.P., Giraldes, B.W., 2015. Baseline monitoring gastropods in the intertidal zone of Qatar- target species and bioindicators for hyper-thermic and hyper-saline conditions. Int. J. Res. Stud. Biosci. 3 (12), 62–72.

Al-Sarawi, H.A., Jha, A.N., Al-Sarawi, M.A., Lyons, B.P., 2015. Historic and contemporary contamination in the marine environment of Kuwait: an overview. Mar. Pollut. Bull. 100, 621–628.

Al-Shamlãn, S.M., 2000. Pearling in the Arabian Gulf. A Kuwaiti Memoir. The London Centre of Arab Studies, p. 199.

Al-Yamani, F., Yamamoto, T., Al-Said, T., Alghunaim, A., 2017. Dynamic hydrographic variations in northwestern Arabian Gulf over the past three decades: Temporal shifts and trends derived from long-term monitoring data. Mar. Pollut. Bull. 122, 488–489.

Allosaur, Y., Pokavanich, T., 2017. Residence and transport time scales associated with Shatt Al-Arab discharges under various hydrological conditions estimated using a numerical model. Mar. Pollut. Bull. 118, 85–92.

Alsayegh, L., 2015. The Ecology, Age and Growth of Two Muricacean Gastropods from Shores of Kuwait (Ph.D. thesis). University of Bangor, Wales, UK.

Behbehani, M., Ghareeb, I., 2002. (unpublished). Survey of thr mollusca of the state of Kuwait. Report Kuwait university, 66pp + 4 appendices.

Bieler, R., Carter, J.G., Coan, E.V., 2010. Classification of bivalve families. Pp. 113–133, in: Bouchet, P., Rocroi, J.-P. nomenclator of bivalve families. Malacologia 52 (2), 1–184.

Biggs, H.E.J., 1958. Littoral collecting in the Persian Gulf. J. Conch. Lond. 24, 270–275.

Biggs, H.E.J., 1973. The marine mollusca of the trucial coast. Persian Gulf. Bull. Brit. Mus. (Nat. Hist.) 24, 343–421.

Biggs, H.E.J., Grantier, I., 1960. A preliminary list of the Mollusca of Ras Tanura. Persian Gulf. J. Conch. Lond. 24, 387–392.

Bouchet, P., Rocroi, J.-P., Hausdorf, B., Kaim, A., Kano, Y., Nützel, A., Parkhaev, P., Schrödl, M., Strong, E.E., 2017. Revised classification, nomenclator and typification of gastropod and monoplacophoran families. Malacologia 61 (1–2), 1–526.

Dance, S.P., Bosch, D., Moolenbeek, R., Oliver, P.G., 1995. Seashells of Eastern Arabia. Motivate, Dubai, p. 296.

Devlin, M.J., Massoud, M.S., Hamid, S.A., Al-Zaidan, A., Al-Sarawi, H., Al-Enezi, M., Al-Ghofran, L., Smith, A.J., Barry, J., Stentiford, G.D., Morris, S., da Silva, E.T., Lyons, B.P., 2015. Changes in the water quality conditions of Kuwait's marine waters: Long term impacts of nutrient enrichment. Marine Poll. Bull. 100, 607–620.

El-Sorogy, A., Youssef, M., Al-Kahtany, K., Al-Otaiby, N., 2016. Distribution of Intertidal Molluscs along Tarut Island Coast, Arabian Gulf, Saudi Arabia. Pak. J. Zool. 48 (3), 611–623.

Garcia-Ramos, D.A., Albano, P.G., Harzhauser, M., Piller, W.E., Zuschin, M., 2016. High dead-live mismatch in richness of molluscan assemblages from carbonate tidal flats in the Persian (Arabian) Gulf. Palaeogeogr. Palaeoclimatol. Palaeoecol. 457, 98–108.

Glayzer, B.A., Glayzer, D.T., Smythe, K.R., 1984. The marine molluscs of Kuwait. Arab. Gulf. J. Conch. Lond. 31, 311–330.

Grizzle, R.E., Bricelj, V.M., AlShihi, R.M., Ward, K.M., Anderson, D.M., 2018. Marine molluscs in nearshore habitats of the United Arab Emirates: Decadal changes and species of public health significance. J. Coast. Res. 34 (5), 1157–1175.

Hasan, A.K., 1996. A taxonomic review of the bivalve and gastropod mollusc fauna along the saudi intertidal zone of the Arabian Gulf. J. KAU. Mar. Sci. 7, 245–253.

Jones, D.A., 1986. A Field Guide to the Seashores of Kuwait and the Arabian Gulf. University of Kuwait & Blandford Press, p. 192.

Lyons, B.P., Devlin, M.J., Abdul Hamid, S.A., Al-Otiabi, A.F., Al-Enezi, M., Massoud, M.S., Al-Zaidan, A.S., Smith, A.J., Morris, S., Bersuder, P., Barber, J.L., Papachlimitzou, A., Al-Sarawi, H.A., 2015. Microbial water quality and sedimentary faecal sterols as markers of sewage contamination in Kuwait. Mar. Pollut. Bull. 100, 629–636.

Melvill, J.C., 1928. The marine Mollusca of the Persian Gulf, Gulf of Oman and North Arabian Sea as evidenced mainly through the collections of Capt. F. W. Townsend, 1893–1914. addenda, corrigenda and emendanda. Proc. Malac. Soc. Lond. 18, 93–117.

Mohammed, S.Z., Al-Khayat, J.A., 1994. A preliminary checklist of benthic Mollusca on the Qatari coasts. Arab. Gulf. Qatar Univ. Sci. J. 14, 201–206.

Oliver, P.G., 1992. The Bivalve Seashells of the Red Sea. An Identification Guide. Christa Hemmen Verlag & The National Museum of Wales, p. 330, 46 col. pls.

Oliver, P.G., 2015. (unpublished) The bivalvia of the intertidal of Kuwait. Results of the KISR intertidal survey 2013–2015. 33pp.

Oliver, P.G., 2016. (unpublished) The gastropoda, polyplacophora and scaphopoda of the intertidal of Kuwait. results of the KISR intertidal survey 2013–2015. 33pp.

PERSGA, 2004. Standard Survey Methods for Key Habitats and Key Species in the Red Sea and Gulf of Aden. Technical Series No. 10. The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA).

Salehi, H., Pazira, A.R., Noorbakhsh, H.Z., 2015. Ecological status assessment of intertidal zone of the Persian Gulf coastal field using Gastropod biodiversity (a case study of Deylam County, Bushehr Province, Iran). AES Bioflux 7 (1), 70–81.

Smith, S., 2005. Rapid assessment of invertebrate biodiversity on rocky shores: where there's a whelk there'sa way. Biodivers. Conserv. 14, 3565–3576.

Smythe, K.R., 1972. Marine mollusca from Bahrain Island. Persian Gulf. J. Conch. Lond. 27, 491–496.

Smythe, K.R., 1979. Marine mollusca of the UAE. Arab. Gulf. J. Conch. Lond. 30, 57–80.

Tadjalli-Pour, M., 1974. Contribution a l'etude de la systematique et de la repartition des Mollusques des cotes iraniennes du Golfe Persique. Academie de Montpellier, Universite des Sciences et Techniques du Languedoc.

Zuschin, M., Oliver, P.G., 2003. Bivalves and Bivalve Habitats in the Red Sea. Verlag des Naturhistorischesn Museum, Wien, p. 304, 57pls.

Zuschin, M., Oliver, P.G., 2005. Diversity patterns of bivalves in a coral dominated shallow-water bay in the northern Red Sea - High species richness on a local scale. Mar. Biol. Res. http://dx.doi.org/10.1080/17451000500456262.