Bull. Nat. Inst. of Oceanogr. & Fish., A.R.E. 1995, Vol.(21) No. 2: 413 - 437

NUMERICAL ANALYSIS OF CHANGES IN THE BIVALVED MOLLUSC FAUNA ALONG THE SAUDI INTERTIDAL ZONE OF THE ARABIAN GULF

By

A. K. HASSAN*

*National Institute of Oceanography and Fisheries, Alexandria - Egypt.
Key Words : Mollusca, Bivalvia, Arabian Gulf.

ABSTRACT

The present study entails with the temporal and spatial changes in the bivalved mollusc populations of the intertidal zone on the west coast of the Arabian Gulf during 1993. The investigated area covered more than 250 km (> 50 percent of the Saudi coastline of the Arabian Gulf), extending from Jubayl in the North through Salwa on the Saudi Qatari borders. Sixty-eight bivalved mollusc species were identified, of which 5 species were found to inhabit the whole range of the studied area; 15 species were found in 91.7 percent of the area; 13 species were present in 83.3 percent of the area; 14 species were found distributed in 75 percent of the area, 13 species extended in 66.7 percent of the area; 4 species were limited to 58.3 percent of the area; and 4 species were procured in 50 percent of the area. Qatif and Aziziya were more densely populated by bivalved mollusc fauna than the other stations of the investigated area. Spring showed the maximum population, while autumn showed the lower bivalve diversity.

INTRODUCTION

Phylum Mollusca is the second largest group in the animal Kingdom. it includes about 100,000 identified species, 50% of which are marine forms (Wye, 1988). Class bivalvia includes about 10,000 species (Wye, 1989) and represents the second class of the phylum. Molluscs play an important role in the marine environment such as in the food chain and the general economy of

the marine environment such as in the food chain and the general economy of the sea Moreover, a considerable numbers of the popular and edible mollusc species have been extensively cultivated in many countries of the world either for pearls or animal protein production. However, few workers have studied the Saudi Arabian mollusc fauna of the Arabian Gulf.

According to the available literature, no work was done on the Saudi intertidal molluscs of the Gulf except that of McCain (1984b) who studied the intertidal infauna and the soft bottom benthic communities of the northern inshore area of the Saudi region of the Gulf.

Undoubtedly the 1991 Gulf War has certainly affected the whole ecosystem of the Arabian Gulf. The widely dispersed oil spill was southwardly drifting towards the eastern sandy coast of Saudi Arabia polluting all sorts of marine life.

According to the available literature, and unfortunately, no base line data were presented before the 1991 oil spill catastrophe dealing with the geographical distribution and seasonal abundance of the mollusc species and their populations along the Saudi Arabian coast line of the Arabian Gulf.

For this reason, the present work may be considered as the first attempt to study the bivalved mollusc fauna inhabiting fixed geographical locations along the Saudi Arabian coastline of the Arabian Gulf.

It is worth mentioning that, the identification and taxonomy of the bivalved species recorded during the present study were presented at the "Symposium on the Red Sea Marine Environment" held in the Faculty of Marine Sciences, King Abdulaziz University, Jeddah, April 25-28, 1994.

AREA INVESTIGATED

The bottom nature of the investigated area is mainly formed of an extended rocky flat mostly covered with sand, and muddy sand sediments. In some areas, the sandy shores were irregularly interrupted with narrow and shallow rocky depressions covered with scattered algal and seaweeds vegetations.

MATERIALS AND METHODS

Sampling locations

The investigated area was the Saudi Arabian intertidal zone of the Arabian Gulf covering a distance furtherly exceeding 250 km (< 50 percent of the total Saudi coastline of the Gulf). It extends from Jubayl (St. 1) at the north western side to Salwa (St. 12) at the Saudi Qatari borders. In between 10 other stations were located. These stations were. Rahima (St. 2), Ras Tanura (St. 7), adjacent to king Fahd bridge (K.F.b. St. 8), Aziziya (St. 9), Half-Moon Beach (H.M.B., St. 10) and Uquayr (St. 11).

During , 1993, quantitative seasonal sampling of the molluscan shells was carried out from the different stations of the studied area, using 1m2 metal frame to define the area of each sample. The scattered shells within the metal frame were picked up and kept in a labeled nyloh bag. 5 percent formalin was added for preservation. 3 samples were collected from each station to get the average number of the collected individuals. Sampled shells were washed, cleaned, dried sorted, identified to their species level and counted. The spatial and temporal changes of the bivalved population were studied to give an account of their ecological distribution and the percentages of seasonal and annual abundance of their individuals along the whole investigated area.

TEMPERATURE AND SALINITY

From each station, surface water temperature was measured by a normal thermometer, and surface water salinity was measured by a refractometer (model 10419 T/C meter Reichert Jung).

RESULTS AND DISCUSSION

I- Temperature and salinity :

The seasonal values of temperatures and salinities recorded from the sampled stations are represented in Table 1.

Table (1) : Surface water temperature and salinities measured from the sampled stations during the four seasons.

	Seasons	*St.1*	*St.2*	*St.3*	*St.4*	*St.5*	*St.6*	*St.7*	*St.8*	*St.9*	*St.10*	*St.11*	*St.12*
		Jubl	*Rah.*	*Rtan*	*Safw*	*Qat.*	*Damm*	*Khob*	*KFB*	*Aziz.*	*HMB*	*Uqur*	*Salwa*
Surface	Spring	29.0	30.0	29.3	31.7	32.2	28.0	26.5	29.5	26.0	25.5	24.0	25.0
Water	Summer	35.0	34.0	35.0	34.5	34.9	35.0	35.5	35.0	34.5	35.5	36.0	36.5
Temp.	Autumn	25.0	22.0	24.0	23.8	24.0	23.5	23.0	22.7	23.5	23.0	24.0	23.5
(°C)	Winter	12.0	11.5	11.0	13.0	12.5	11.5	11.5	12.8	13.0	12.5	11.5	11.0
Surface	Spring	43.5	45.0	45.0	44.0	43.0	46.5	47.0	44.0	43.0	43.0	52.0	59.0
Water	Summer	45.0	46.0	46.0	45.5	44.0	50.0	51.0	45.0	44.0	44.5	68.2	72.0
Salinity	Autumn	44.0	45.0	45.5	44.2	43.0	48.0	48.5	44.0	43.5	44.0	56.0	63.0
	Winter	43.0	44.0	44.5	43.5	42.5	46.0	46.0	43.5	42.5	42.5	51.0	56.0

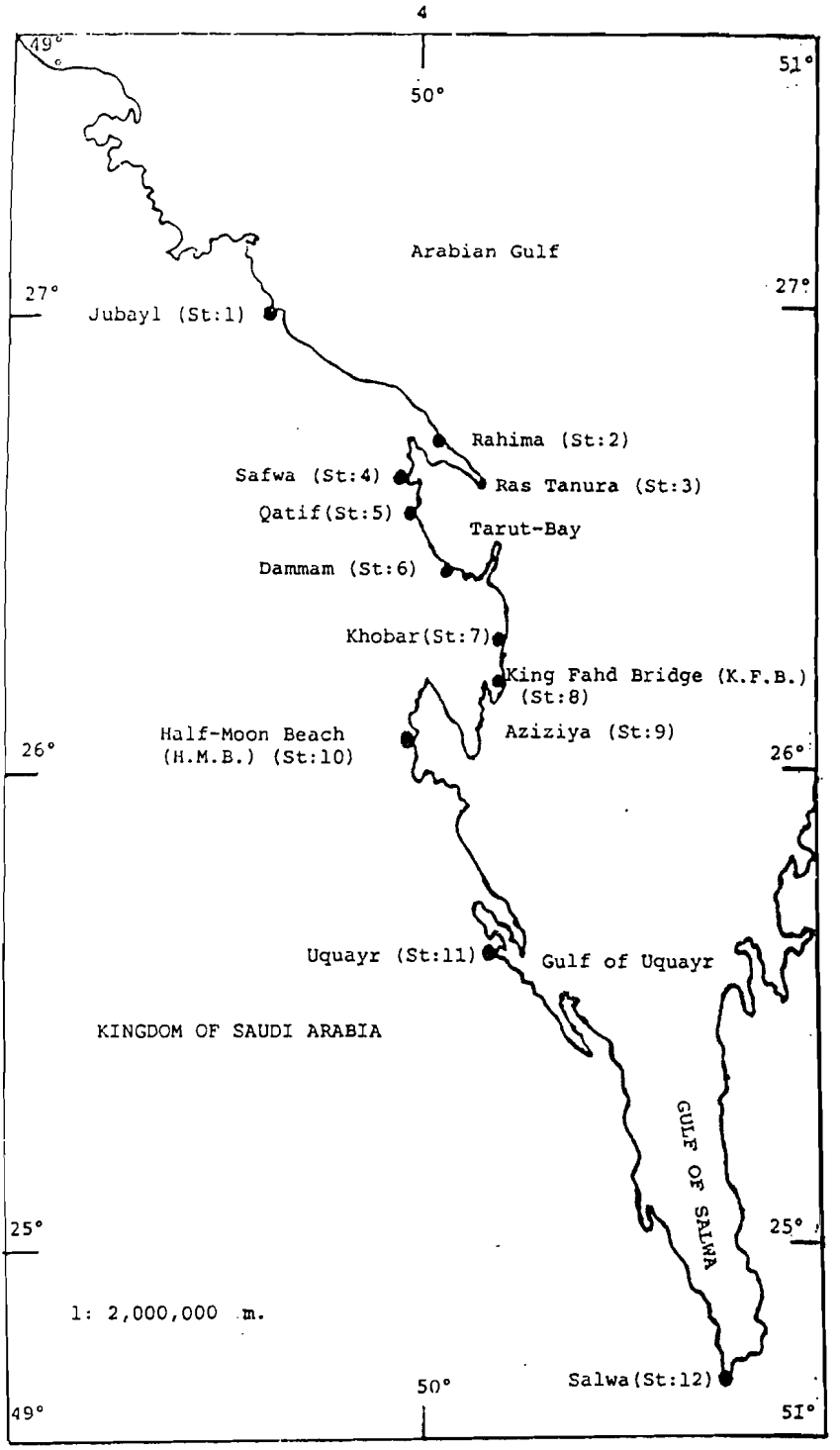

Figure 1 : Investigated area

II- The bivalved fauna :

68 bivalve species were recorded from the whole studied area. The zoogeographic affinities of these species showed that, they are intimately related to the Indian ocean origin, since a great majority of these species has been previously reported from different regions of the Indian Ocean (Hatai and Nisiyama 1952; Kira, 1955 and Habe 1961). However, previous works on the mollusc fauna sampled from different regions of the Arabian Gulf and its related marine environments are grouped in Table 2.

Table (2) : Number of species recorded by some workers from different regions of the Arabian Gulf and related marine environments.

	Authors	*Locations*	*Biv. Sp.*	*Total mollusc sp.*
1	Melvill, 1889.	Arab. & Omani Gulves & Arab. Sea	13	40
2	Melvill, 1928.	N.Arab, Oman & Pers. Gulves and Indian Ocean.	78	365
3	Biggs & Grantier, 1960.	Ras Tanura	32	64
4	Basson *et al.*, 1977.	Saudi Arab. biotopes & commun.	168	404
5	Smythe, 1979.	U.A.E. Gulf water	109	230
6	Sharabati, 1981.	Saudi Arab. ecological environ.	21	-
7	Bosch & Bosch, 1982.	Omani Gulf	98	384
8	Smythe, 1982.	Arabian Gulf	128	308
9	Glayzer, *et al.*, 1984.	Kuwaiti water of the A.G.	144	435
10	McCain, 1984a	Cores in the N.shores of Saudi Ar.	21	53
11	McCain, 1984b	Infauna of N.shores of Saudi Ar.	43	175
12	Bosch & Bosch. 1989	U.A.E. Gulf Water	69	

According to table 2, the following aspects were observed :

A- <u>The bivalve species recorded during the present study exceed some of those recorded by some other workers that can be detailed as follows</u> :

1. The lower number of bivalve species (32 species) recorded by Biggs and Grantier (1960) from Ras Tanura as compared to those recorded from the same region during the present study (54 species) may be related to sampling frequencies where 12 samples/station/season were collected during the present study compared to a single sample from the same area collected by Biggs and Grantier (1960).

2. The lower number of bivalve species (21 species) recorded by Sharabati (1981) may be related to some taxonomical problems, she reported her mollusc fauna as genera and families. and could only identify 21 bivalve species.

The lower numbers of bivalve species, 21 and 43 species respectively, recorded by McCain in (1984 a) and McCain (1984 b) from the northern shore of Saudi Arabia may be partly related to the use of a bottom core sampler of a remarkable limited volume and also partly due to the lower bivalve population of the infaunal community in this area.

B- The present investigation showed an equal abundance of bivalve species with those collected from the U.A.E. (Arabian Gulf) by Bosch and Bosch (1989). That may be a reflection of a more or less similar environmental conditions prevailing in both regions.

C. The present study showed a number of species lower than that recorded by some other workers; This may be attributed to the following reasons :

1. The sampling area of the present study was only limited to Saudi intertidal zone of the Arabian Gulf.

2. The lower biodiversity in the inshore region compared with that in the offshore region of the Arabian Gulf (Halim 1984).

3. The inshore area of the Arabian Gulf is more affected by any slight changes in the environmental conditions such as temperature, salinity, available

food and dissociation that the offshore region. Kinne (1972) reported that these factors are the most dominant ones limiting the distribution and abundance of the present organisms.

4. The lethal and severe catastrophic effect of the 1991 oil spill which was southwardly drifted towards the east coast of Saudi polluting its intertidal communities. Getter ***et al.*** (1984) stated that the effect of an oil spill may be detected over a period of decades when the ecosystem damage is severe and toxic material is retained in the sediment. Ehrhardt and Burns (1993) pointed out to the lethal effect of the 1991 oil spill and the severe damage of the salt marshes along the Saudi Arabian coast where substantial amounts of toxic materials were incorporated in the shore sediment.

As much as the distribution extent of the recorded bivalve species was concerned along the whole investigated area all the year round, the following categories were concluded:

1. 5 spp. (4.7 %) were widely extended in the whole studied area, these were: ***Pinctada radiata, Circe corrugata***, ***Cardita bicolor***, ***Asaphis deflorata*** and ***Ostrea cristagalli*** (Table 3). Distribution patterns of these species were previously traced in different regions of the Arabian Gulf from Kuwait to Oman and also in the Indian Ocean (Hatai and Nisiyama, 1952; Kira, 1955, Hobe, 1961, Bosh and Bosh 1982, and Smythe 1982).

2. 15 spp. (22.1 %) showed a considerable wide distribution where they were recorded in about 91.7 % of the whole area (11 stations). Of these are the following: ***Pinctada margaritifera***, ***Apolymetis dubia, Barbatia fusca,*** following: ***Pinctada margaritifera***, ***Apolymetis dubia, Barbatia fusca, Callista erycina*** and ***Glycymeris lividus*** (Table 3). Most of the species in this category were also previously recorded in the area from Kuwait to the Indian Ocean by the same authors mentioned in category 1.

3. 13 spp. (19.1 %) showed another extended distribution since they were captured from about 83.3 % of the whole area (10 stations), of these species: ***Anadara ehrenbergi, Chama pacifica, Spondylus exilis, Semele scabra*** and ***Tapes texturata*** (Table 3). Most of the species of this category

Table (3): Variable extents in the ecological distribution of the bivalve species and the % abundance of the bivalved individuals recorded from the different stations of the investigated area.

	Bivalve species	Distrib extent of sp.	% abundance of the bivalved mollusc individuals collected from the different stations of the investigated area											
			St.1 Jub.	St.2 Rah.	St.3 Rast.	St.4 Salwa	St.5 Qatif	St.6 Dammam	St.7 Khobar	St.8 KFB	St.9 Aziz.	St.10 HMB	St.11 Uqr.	St.12 Salwa
1	Acar plicata	V	R	S	R	S	R	S	R	L	C	L	R	S
2	Amiancis umbonella	IV	R	S	R	R	R	S	R	L	L	R	R	S
3	Anadara ehrenbergi	III	R	R	L	R	R	S	R	L	R	R	L	S
4	Anadara uropigenlana	IV	R	L	R	R	R	S	S	R	R	R	R	S
5	Anomia laqueata	II	R	R	R	R	L	R	S	R	R	L	L	R
6	Apolymetis dubia	II	R	R	R	R	R	R	R	L	R	L	S	L
7	Asaphis deflorata	I	R	L	L	R	L	R	L	L	R	L	R	L
8	Barbatia fusca	II	L	R	L	R	R	R	R	L	R	L	L	S
9	Batbatia helblingi	II	R	R	R	R	R	R	R	L	R	R	S	R
10	Barbatia obliquata	IV	R	L	R	S	R	R	R	L	R	L	S	S
11	Bassina callophyla	IV	L	R	R	S	R	L	S	R	L	S	L	R
12	Brachiodontes variabilis	IV	C	C	C	C	C	L	S	R	R	R	S	S
13	Callista erycina	II	L	L	R	C	L	C	C	L	L	R	R	S
14	Callista multiradiata	II	R	L	R	R	R	S	R	L	R	R	L	L
15	Cardita bicolor	I	L	L	L	C	L	R	R	R	R	L	L	L
16	Cardita gubernaculum	VI	R	L	L	S	R	S	S	R	S	R	R	S
17	Chama pacifica	III	R	R	S	R	R	C	R	L	S	L	R	L
18	Chlamys ruschenbergii	III	R	R	S	R	R	R	R	R	R	S	R	L
19	Clamys senatorius	V	R	R	R	S	R	S	S	R	R	R	R	S
20	Circe corrugata	I	L	L	C	L	L	R	R	R	R	R	L	R
21	Circentia callipyga	IV	R	R	R	L	R	S	S	R	R	L	S	R
22	Codakia tigerina	IV	L	L	L	S	R	S	R	R	R	L	R	S
23	Corbula sulculosa	V	L	L	L	R	R	S	S	L	S	L	S	R
24	Decatopecten plica	VII	R	L	S	R	R	S	S	L	S	R	S	S
25	Diplodonta ravayensis	II	R	R	S	R	R	R	R	R	R	R	R	R
26	Divaricella cumingiana	IV	R	R	S	R	R	R	S	S	R	L	L	L
27	Donax cuneatus	VII	S	S	S	R	R	S	R	S	R	S	L	R
28	Donax scalpellum	VII	S	S	S	R	R	S	R	R	S	L	S	R
29	Dosinia tumida	IV	R	R	L	R	R	L	L	S	R	S	L	S
30	Dosinia tumida	II	R	R	L	R	R	R	R	S	L	R	R	L
31	Irus irus	V	R	R	R	R	R	S	S	S	R	R	S	L
32	Gafrarium pectinatum	IV	L	L	L	L	L	R	L	S	R	S	S	L
33	Glycymeris lividus	II	L	L	R	R	R	L	R	L	R	R	L	S
34	Gl.pectunculus maskatensis	II	C	L	L	L	R	R	L	R	S	R	R	R

	Bivalve species	Distrib extent of sp.	% abundance of the bivalved mollusc individuals collected from the different stations of the investigated area											
			St.1 Jub.	St.2 Rah.	St.3 Rast.	St.4 Safwa	St.5 Qatif	St.6 Dammam	St.7 Khobar	St.8 KFB	St.9 Aziz	St.10 HMB	St.11 Uqr.	St.12 Salwa
35	Laevicardium papyraceum	IV	C	L	C	C	L	S	S	R	R	S	R	L
36	Lima sowerby	V	R	R	S	R	R	S	L	L	L	S	S	R
37	Lithophaga cumingiana	III	R	R	S	R	R	C	L	R	S	L	R	L
38	Lutraria philippinarum	II	R	R	R	S	R	S	R	R	L	R	L	L
39	Mactra glabrata glabrata	V	L	L	S	L	R	S	R	L	R	S	L	S
40	Malleus regula	V	S	S	S	R	R	R	L	R	S	R	R	R
41	Marcia ceylonenis	V	S	S	R	R	R	S	C	R	R	L	R	S
42	Marcia hiantina	VI	S	S	L	R	R	S	L	S	R	L	S	R
43	Ostrea cuculata	IV	S	R	S	R	R	C	L	S	L	R	L	R
44	Ostrea cristagalli	I	R	R	R	L	R	L	C	R	R	L	R	C
45	Paphia gallus	IV	R	R	R	R	R	L	S	R	S	R	C	S
46	Paphia sulcaris	III	R	R	L	R	R	R	S	R	R	R	S	R
47	Paphia textile	II	R	L	R	R	R	L	R	R	R	S	R	R
48	Pecten erythraeensis	II	R	L	S	R	R	R	R	R	L	L	R	L
49	Periglypta reticulata	III	R	R	R	S	R	L	R	L	L	L	R	S
50	Phaxas cultellus	IV	R	R	R	S	C	S	S	R	R	R	L	R
51	Pinctada margaritifera	II	C	C	C	C	L	C	C	S	C	L	L	D
52	Pinctada radiata	I	C	L	C	L	L	C	C	R	C	L	L	A
53	Pinna muricata	VII	S	S	R	R	S	S	R	S	R	L	S	R
54	Plicatula imbricata	VI	S	S	R	R	R	S	R	S	R	L	R	S
55	Pteria marmorata	VI	S	S	S	R	R	R	C	L	R	R	S	S
56	Sanguinolari cumingiana	III	R	L	R	R	R	S	L	R	L	R	R	S
57	Semele scarba	III	R	R	R	S	R	R	R	L	L	L	S	R
58	Semele sinensis	III	R	R	R	S	R	R	R	R	R	S	L	R
59	Solen brevis	V	S	S	L	A	C	S	S	R	R	L	L	R
60	Spondylus exilis	III	L	R	R	S	R	L	L	L	R	R	R	S
61	Streptopinna saccata	V	S	S	R	R	R	S	S	R	R	R	L	R
62	Sunetta effosa	V	S	S	R	R	R	S	R	L	R	S	L	L
63	Tapes texturata	III	L	R	R	S	R	L	R	L	R	R	S	R
64	Tellina foliacea	III	R	R	R	S	R	R	R	S	R	R	R	L
65	Tellina inflata	II	R	R	R	R	R	R	R	L	R	R	L	S
66	Tivela adamoides	V	S	S	R	R	R	L	R	L	S	R	S	R
67	Trachycardium lacunosum	V	R	R	R	R	R	R	L	S	R	S	S	S
68	Tridacna maxima	III	C	L	L	L	L	C	L	S	R	L	R	S

LEGEND:

DISTRIBUTION EXTENT OF

I. Distributed in all stations
II. Distributed in 11 stations
III. Distributed in 10 stations
IV. Distributed in 9 stations
V. Distributed in 8 stations
VI. Distributed in 7 stations
VII. Distributed in 6 stations

% Individual abundances:

D: Dominant Sp. (> 80%)
A: Abundant Sp. (80 - 60%)
C: Common Sp. (60 - 40%)
L: Less common Sp. (40^-20%)
R: Rare Sp. (< 20%)
S: Not present

were also previously reported by the same authors mentioned in category 1) to inhabit the area from the Arabian Gulf to the Indian ocean.

4. 4 spp. (20.6 %) were extended in about 7.5 % of the whole area (9 stations), of these are the following species: ***Bassina callophyla, Gafrarium pectinatum, Laevicardium papyraceum, Amiantis umbonella, Brachiodontes variabilis*** and ***Circentia callipyga*** (Table 3). They were also recorded in the Arabian Gulf and southwards to the Indian Ocean by the same former workers mentioned in category 1.

5. 13 spp. (19.1 %) showed more or less considerable distribution where they were found are the following in ***Solen brevis, Acar plicata, Chlamys senatorius, Tivela adamoides*** and ***Sunetta effosa*** (Table 3).

6. 4 spp. (5.9 %) showed a limited distribution where they were confined to about 58.3 % of the whole area (7 stations), these were: ***Plicatula imbricata, Malleus malleus, Cardita gubernaculum*** and ***Marcia hiantina*** (Table 3).

7. 4 spp. (5.9 %) showed another limited distribution where they were recorded from about 50 % of the whole area (6 stations), these were: ***Decatopecten plica, Pinna muricata, Donax scalpellum*** and ***Donax cuneatus*** (Table 3).

It was generally noticed that the species presented in the latter three categories were recorded from Saudi Arabia to Omani Gulf by Bosch and Bosch (1982 and 1989) and Smythe (1982).

However, it is believed that the great majority of the intertidal species of the Arabian Gulf showed high degrees of tolerance and adaptations to withstand unfavorable conditions such as high temperature, high salinity, water circulation, available food. Hence they are described as Eurythermal and euryhaline species. Basson ***et al.*** (1977) pointed out to the stressful environment of the Arabian Gulf where higher temperatures and salinities severely affect the survival, distribution, and diversity of the present organisms. Grasshoff (1976) and Hunter (1986) stated that the distribution pattern of the

Gulf species was affected by variations in both, the nutrient contents, and the water circulation prevailing there.

The seasonal variations of the abundance percentages of bivalved individuals recorded from the investigated area showed that :

St. 1, Jubayl:

55 spp. (80.9 %) were recorded from this station during the whole year. Spring population was the richest by having 53 spp. and 37. % of the whole individuals. Winter and autumn seasons showed a lower diversity of 33 spp. for each. Winter population was the lowest and only contributed 15.6 % to the population of the four seasons. Summer fauna showed 41 spp. and represented 25.9 % of the whole individuals, while autumn fauna formed 21.5 % (Figs. 2 and 3). The species showed that: 7 spp. (12.7 %) were of common occurrence, 12 spp. (21.8 %) were less common and 36 spp. (65.5 %) were rarely represented (Table 3, Fig. 4).

St. 2: Rahima:

54 spp. (79.4 %) were found in this station during the whole year. The highest bivalve fauna (46 spp. represented by 32.6 % of the total population were recorded in spring. Summer biodiversity and population were 34 spp. and 22.8 % of the total individuals respectively. Autumn showed 40 spp. and 25.6 % of the whole individuals while winter population and biodiversity were 16 % of the whole population and 36 species respectively (Figs. 2 and 3). The abundance of represented by the species showed that: 2 spp. (3.7 %) were common; 21 spp. (38.9 %) were less common, and 31 spp. (57.4 %) were rare (Table 3, Fig. 4).

St. 3, Ras Tanura:

54 spp. (79.4 %) were sampled from this locality during the whole year. Summer biodiversity and spring population were the richest by having 42 species and 32.9 % of the total population respectively, while autumn biodiversity and winter population were the lowest by having 35 spp. and contributing to the total population respectively. Winter and spring were represented by 38 and 38 species respectively, while autumn and summer populations contributed 30.3 % and 26.4 % to the total population respectively (Figs. 2 and 3). The abundance of the species showed that: 5 sp. (9.3 %) were

common; 15 sp. (27.8 %) were less common, and 34 sp. (63 %) were rare (Table 3, Fig. 4).

St. 4, Safwa:

54 spp. (79.4 %) were collected from this station during the whole year. Spring fauna was enriched by 41 spp. and 29.8 % of the whole individuals, while summer and winter seasons showed the poorest (representing 20 % of the total population). Autumn population showed 37 spp. and 27.1 % of the whole individuals, while summer population formed 23.1 percent of the whole population (Table 3, Figs. 2 and 3). The abundance of the species showed that: 5 spp. (9.3 %) were common, 8 spp. (14.8 %) were less common, and 40 spp. (74.1 %) were rare (Table 3, Fig. 4).

St.5, Qatif:

67 spp. (98.5 %) were recorded from this station during the whole year. The spring population was the maximum since it showed 60 spp. and represented 33.5 % of the whole individuals, while autumn population 45 spp. and 19.9 % of the whole individuals was the minimum. Winter population was composed of 51 spp. and 21.1 % to the total population individual, while summer fauna reached 50 spp. and 25.5 % of the whole population (Figs. 2 and 3). The occurrence of the spp. showed that: 3 sp. (4.5 %) were common; 10 sp. (14.9 %) were less common, and 54 sp. (80.6 %) were rare (Table 3, Fig. 4).

St. 6, Dammam :

42 spp. (61.8 %) were found in this station during the whole year. Spring was enriched by 36 sp. and 52.9 % of the total individuals, while winter was poor and represented by 23 sp. and 17.9 % of the total individuals. Autumn population showed 26 sp. and 24.7 % of the whole individuals. Summer fauna reached 25 spp. and 24.6 % of the whole population individuals. (Figs. 2 and 3). The occurrence of the spp. showed that: 7 sp. (16.7 %) were common; 11 sp. (26.2 %) were less common, and 24 sp. (57.1 %) were rare (Table 3, Fig. 4).

St. 7, Khobar:

51 spp. (75 %) were collected from this station during the whole year. Spring fauna were populations was the highest contributing 38 spp. and 32.6 % to the total individuals. A minimum Autumn population was the minimum 27 spp. contributing 21.1 % to the total individuals. Winter community showed 30

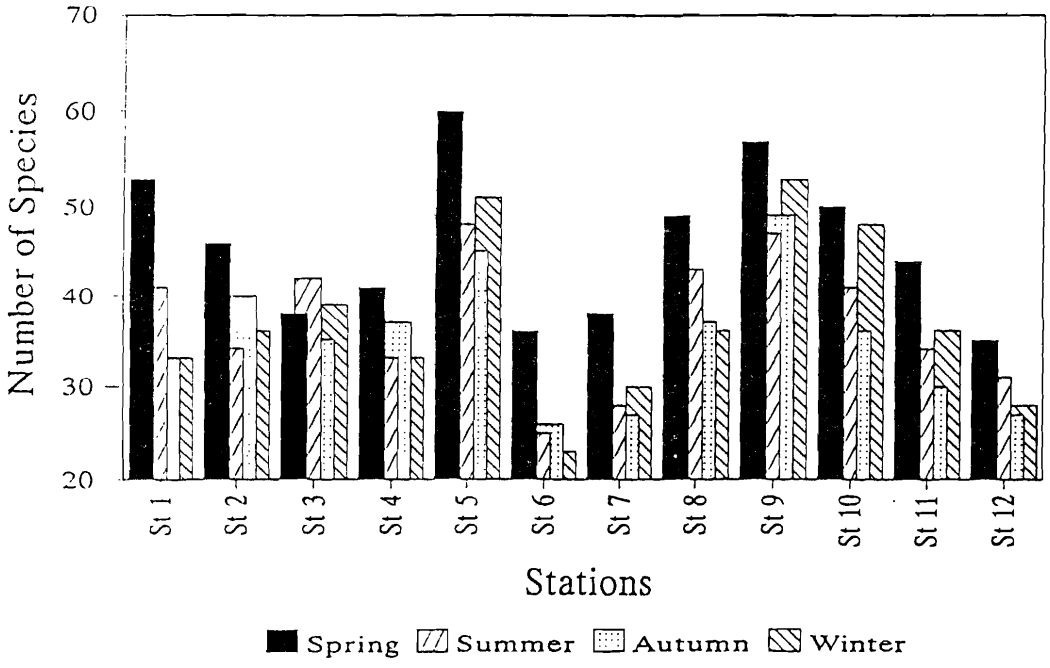

Figure 2 : Seasonal variation of the number of bivalve species in each of the sampled stations along the coast of Saudi Arabian Gulf.

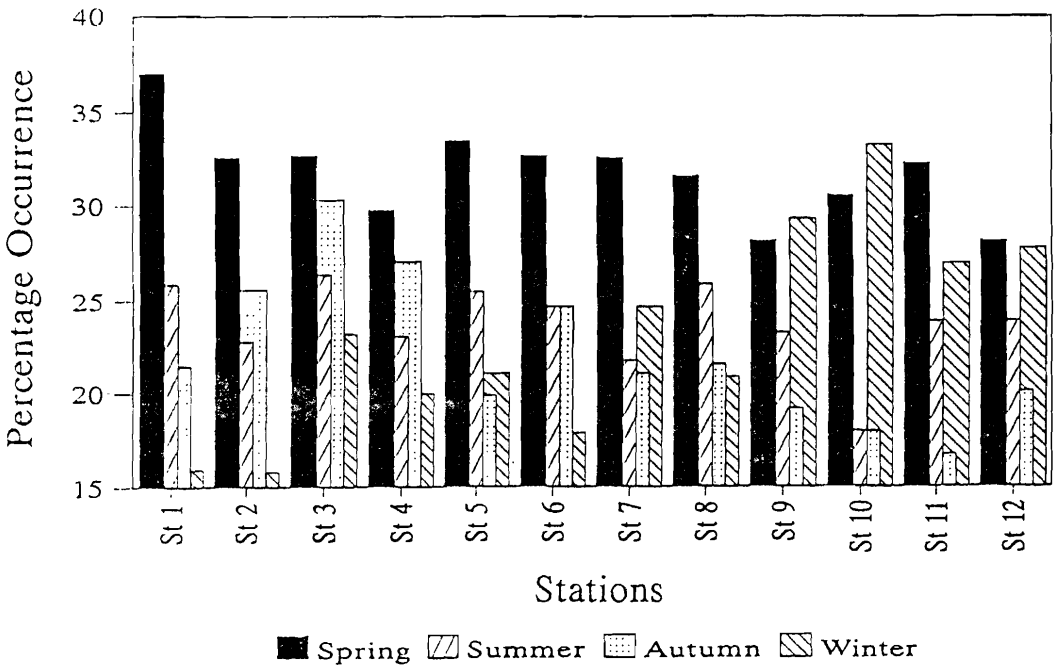

Figure 3 : Seasonal variation of the individual occurrence percentage in each of the sampled stations along the coast of Saudi Arabian Gulf.

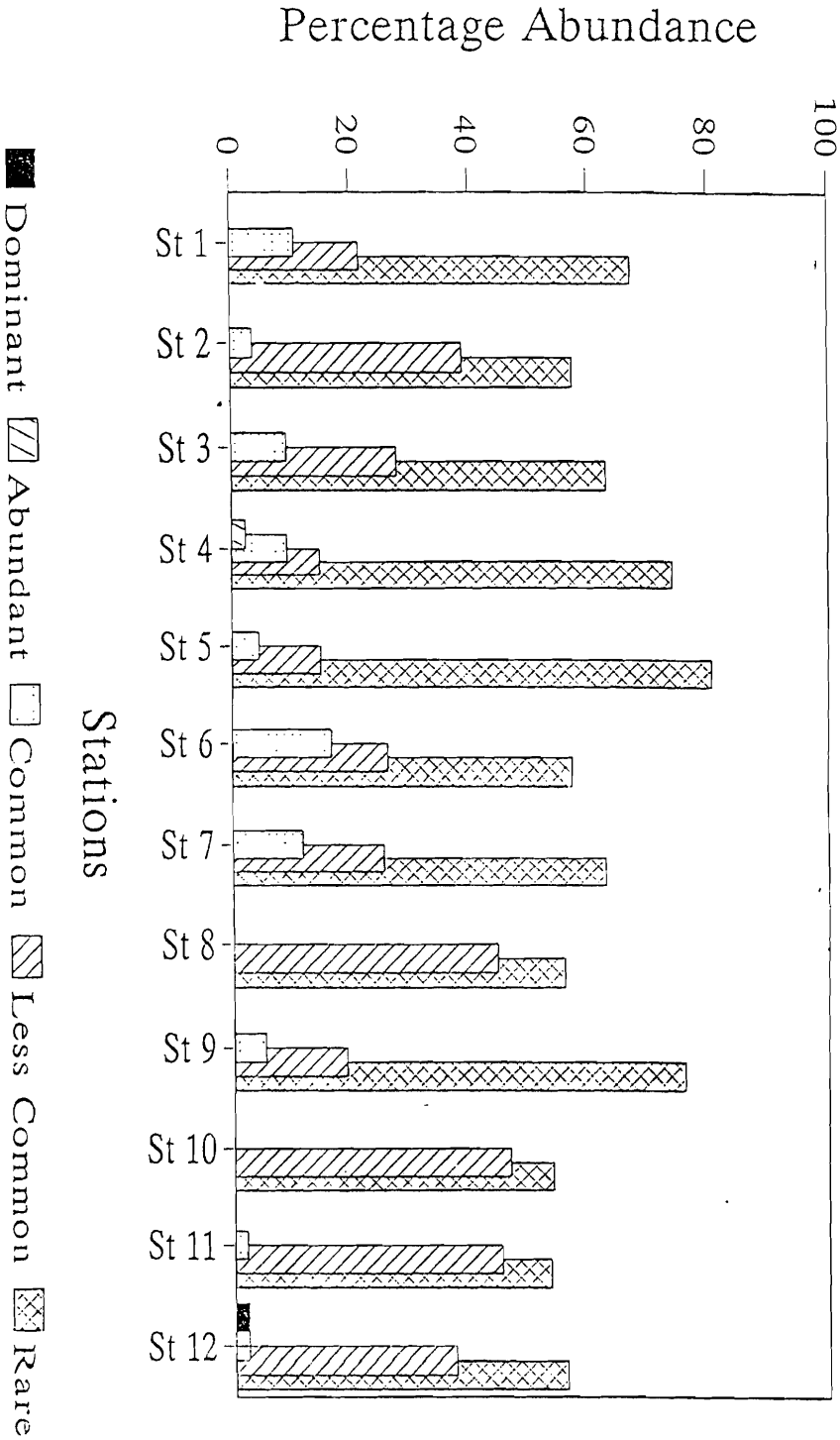

Figure 4: Abundance percentage of bivalve species in each of the sampled stations along the coast of Saudi Arabian Gulf.

spp. and 24.7 % of the whole population, while summer population was formed of 28 sp. and represented 21.8 % of the whole population (Figs. 2 and 3).

The species abundance showed that: 6 spp. (11.8 %) were common, 13 spp. (25.5 %) were less common, and 32 spp. (62.7 %) were rare. (Table 3, Fig. 4).

St. 8, K.F.B :

54 spp. (79.4 %) were sampled from this station during the whole year A rich spring population were composed of 49 spp. and represented 31.2 % of the total individuals. While the poor winter population composed of 36 spp. and represented by 20.9 % of the total individuals were recorded summer pollution reached 43 spp. and 25.9 % of the total population , while autumn population showed 37 spp. contributing 21.6 % to the whole population (Figs. 2 and 3). The population abundance of the spp. showed that: 24 spp. (44.4 %) were less common and 30 spp. (55.6 %) were rare (Table 3, Fig. 4).

St. 9, Aziziya :

58 spp. (85.3 %) occurred in this station during the whole year. Spring and Summer showed the maximum (57 spp.) and minimum (47 spp.) biodiversity respectively, while rich and poor contribution of individuals to the total population were found in spring (28.2 %) and autumn (19.2 %) respectively. Winter fauna showed 53 spp. and 29.3 % of the total population. Autumn biodiversity reached 49 species and summer population contributed to the whole population (Figs. 2 and 3). The occurrence of the spp. showed that: 3 spp. (5.2 %) were common, 11 spp. (19 %) were less common and 44 spp. (75.9 %) were rare (Table 3, Fig. 4).

St. 10, H.M.B :

56 spp. (82. 4 %) were recorded from this station during the whole year. Among species, spring was the richest by having 50 spp. followed by winter (48), summer (41), and a poor representation of 36 spp. in autumn. Among individuals, winter showed a higher population constituting 33.3 % of the total population, followed by spring (30.6 %), and both summer and autumn 18% for each, (Figs. 2 and 3). The abundance of the spp. showed that: 26 spp. (46.4%) were less common; 30 spp. (53.6 %) were rare (Table 3, Fig. 4).

St. 11, Uquayr :

49 spp. (72.1 %) were found in this station during the whole year. Spring population (44 species contributing 32.3 % to the total pollution) was the maximum, while autumn population (30 species constituting 16.8 % of the total individuals) . Winter population formed 36 spp. and 27 % of the total individuals and summer population was the poorest formed 34 spp. and 23.9 % of the total individuals (Table 3, Figs. 2 and 3). The occurrence of the spp. showed that: a single sp. (2 %) was common, 22 spp. (449 %) were less common, and 26 spp. (53.1 %) were rare (Table 3, Fig. 4).

St. 12, Salwa :

43 spp. (63.2 %) were sampled from this station during the whole year. Spring showed the richest fauna (35 sp. and 28.2 % of the total population).

The poorest population (31 spp. and 23.9 % of the total individuals) appeared in autumn. Winter fauna was formed of 28 spp. and 41.2 % of the total individuals (Figs. 2 and 3). The species abundance showed that: a single dominant sp. (2.3 %), a single abundant sp. (2.3 %), a single common sp. (2.3 %), 16 spp. (37.2 %) of less common occurrence, and 24 spp. (55.8 %) of rare abundance (Table 3, Fig. 4).

The study of the observed seasonal variations in population abundance of the bivalved fauna collected from the whole studied area among the different seasons showed that:

Spring was the richest season by having 60 spp. and 31.2 % of the total individuals, St. 5 (Qatif) was the richest by having 60 spp. and 13.1 % of the total individuals, followed by St. 9 (Aziziya) which showed 57 spp. and 12 % of the total individuals, while stations 7 (Khobar), 6 (Dammam) and 12 (Salwa) were poorly represented by (38 spp. and 5 % of the total individuals), 36 spp. and 4.8 % of the total individuals), and (35 spp. and 6 % of total population), respectively (Fig. 5 and 6).

Autumn was the season of the poorest fauna (49 sp. and 19.4 % of total individuals). St.9 (Aziziya) was dominating the others by having 49 spp. and 11.9 % of the individuals, followed by a considerable population of 45 spp. and 11.3 of the total individuals in St. 5 (Qatif), while other stations such as 11 (30

spp. and 5.1 % of the individuals), 12 (27 spp. and 6.3 % of the individuals), 7 (27 spp. and 4.8 % of the individuals), and 6 (26 spp. and 5.3 % of the individuals) were of remarkable lower population (Fig. 5 and 6).

Winter Composition represented the 2nd order in the seasonal population abundance where 53 sp. and 25.6 percent of the individuals, were recorded. Stations 9 (Aziziya) and 5 (Qatif) were the richest by having 53 spp. represented by 16.5 % of the total individuals and 51 spp. represented by 10.9 % of the total individuals respectively. The poorest populations were present in Stations 7 (30 spp. and 5.1 % of the total individuals), 12 (28 spp. and 7.9 % of the total individuals), and 6 (23 spp. and 3.5 % of the total individuals) (Fig. 5,6).

Summer population occupied third order in the seasonal abundance where 50 spp. and 23.8 % of the total individuals were recorded. St. 5 (Qatif) was the richest by having 50 spp. and 13.1 % of the total individuals, followed by St. 9 (Aziziya) which showed 47 spp. and 13 % of the individuals. The poorest populations were represented in stations 12 (31 spp. and 6.7 % of the individuals), 7 (28 spp. and 4.4 % of the individuals) and 6 (25 spp. and 4.8 % of the individuals) (Fig. 5 and 6).

However, the observed seasonal variation of the bivalve fauna among the different stations may be due to the seasonal changes of the environmental conditions prevailed along the studied area. Al- Kaisi (1976), Huq ***et al.*** (1978), Jacob and Zarba (1979) and Halim (1984) showed a significant variable distribution of the biomass along the western side of the Arabian Gulf.

On the other hand, the remarkable rich spring and high winter bivalve populations reported during the present study may be related to spawning seasons of bivalves, water circulation and nutrient contents of the Gulf water. The water circulation and nutrient contents of the Gulf water. The water circulation of the Arabian Gulf affect the settlement of the veliger larvae of bivalves among the different studied littoral substrata. Grasshoff (1976) and Hunter (1986) correlated between distribution of the organisms, water circulation and nutrition concentrations in the Arabian Gulf. Durgham and Hussien (1991) estimated the veliger larvae of bivalves to form about 30 % of

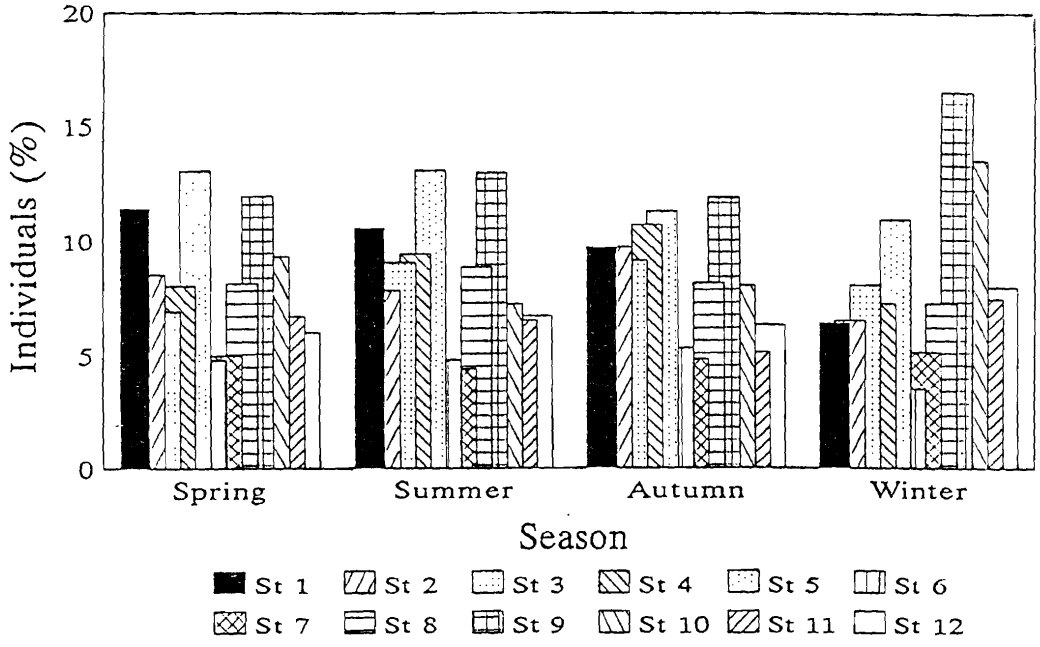

Figure 5 : Spatial variation in the occurrence of bivalves collected from the sampled stations along the coast of Saudi Arabian Gulf dueing the four seasons.

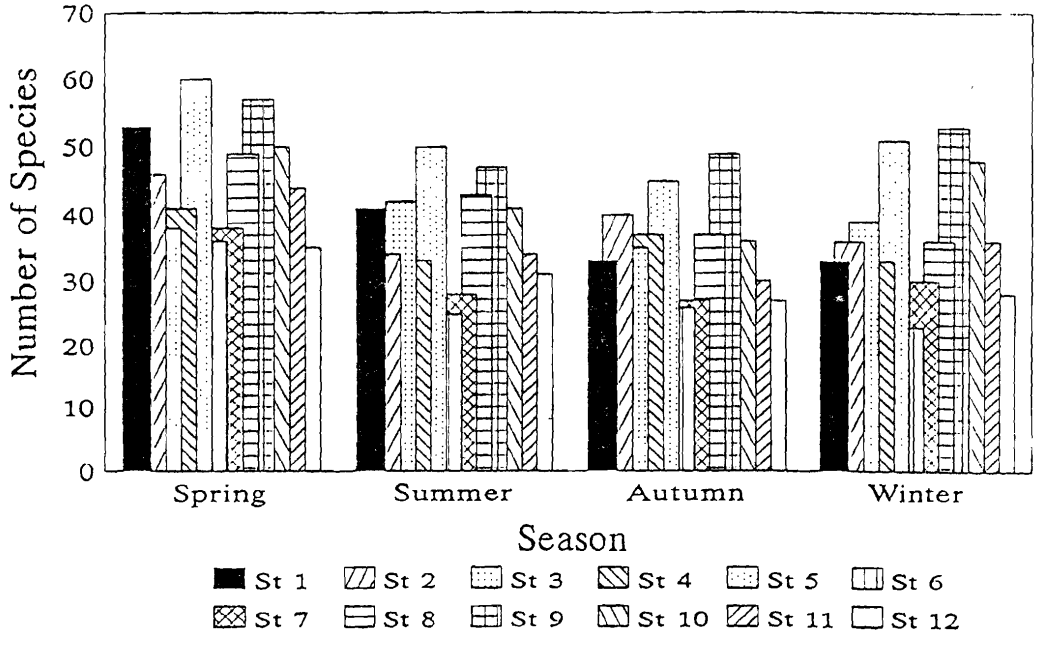

Figure 6 : Spatial variation in the seasonal occurrence of bivalve species collected from the sampled stations along the coast of Saudi Arabian Gulf during the four seasons.

the total zooplankton inhabiting the Qatari waters of the Arabian Gulf, they also determined two spawning periods for these bivalves extending from February to March and from June to October. Their conclusion can be used to interpret the results observed during the present study, where the first winter spawning may enrich the spring bivalve fauna, while the latter spawning may increase the winter fauna.

Furthermore, according to the annual population of bivalve spp. and abundance percentage of their individuals recorded from the stations of the whole investigated area, the following results were concluded :

1. Stations : 5 (Qatif) and 9 (Aziziya) dominated other stations by having 67 spp. constituting 12.2 % of the total individuals and 58 spp. constituting 13.2 % of the total individuals respectively (Fig. 7). This may be explained due to favorable environmental conditions characterizing these stations such as: temperature, salinity, suitable substrata, vegetations, fertility and available
food. However, the maximum summer and minimum winter surface water salinities measured in these stations were: 44 and 42.5 % respectively. (Table 1). The dense algal and seaweed vegetations which were also observed in both regions may increase their water fertility. Basson ***et al.*** (1977) and Sharabati (1981) pointed out to the high productivity of Qatif as being a major shrimp nursery ground. Hunter (1986) reported that population density of the organisms increased by protection of algal growth.

2. Stations : 7 (Khobar), 11 (Uquayr), 12 (Salwa) and 6 (Dammam) showedthe poorest populations of 51 spp. constituting 4.9 % of the total individuals, 49 spp. constituting 6.5 % of the total individuals, 43 spp. constituting 6.7 % of the total individuals and 42 spp. constituting 4.6 % of the total individuals respectively (Fig. 7). This may be due to the unfavorable circumstances existed in these stations particularly their abnormal high salinities. The maximum (summer) and minimum (winter) surface water salinities measured in these stations were: 51 and 46), (68 and 51), (72 and 56 %), and (50 and 46) respectively (Table 1). According to Purser (1973), the higher salinity of the southern water of the Gulf may limit the species to those which can tolerate the severe environmental conditions. Basson ***et al.***

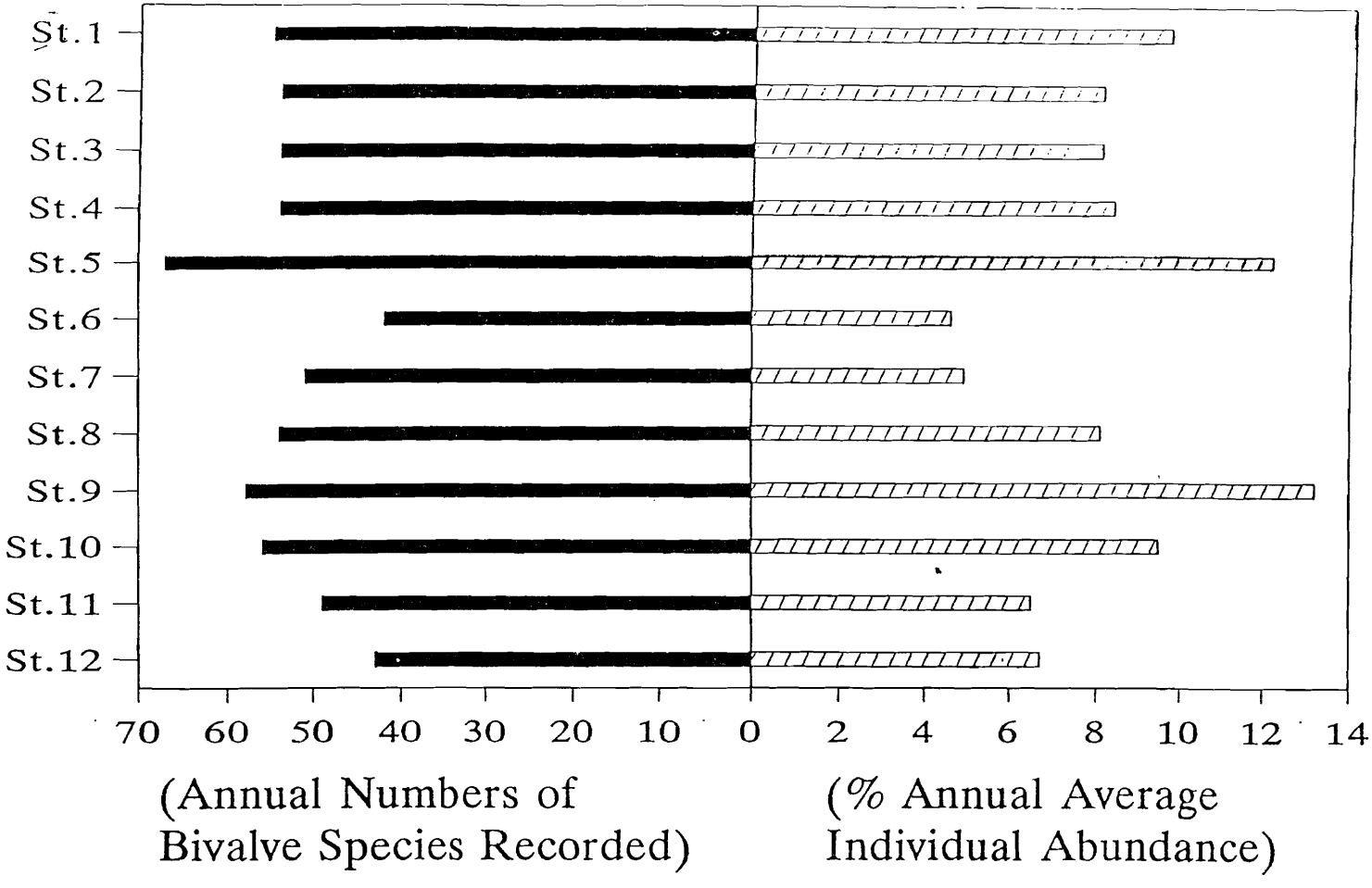

Figure 7 : Average abundance of the number of bivalve species and average percentages of number of individuals recorded from the sampled stations along the coast of Saudi Arabian Gulf during the whole period of investigation.

3. Stations 10 (H.M.B.) and 1 (Jubayl) showed a more or less considerable equal species (50 and 55 respectively) and contribution to the total population (9.5 %, 9.7 % respectively) (Fig. 7). Summer (maximum) and winter (minimum) surface water salinities measured at these stations were (44.5 and 42.5 %) and (45 and 43) respectively (Table 1).

4. Stations 2 (Rahima), 3 (Ras Tanura), 4 (Safwa), and 8 (H.M.B) showed a bivalved fauna of considerable equal number of species (54) and percentages of the total population (8.4 % - 8.1 %) (Fig. 7). The higher and lower surface water salinities measured at these stations fluctuated from 46 to 45 (in summer), and from 44.5 to 43.5 (in winter) (Table 1).

SUMMARY

The present work may be considered as the first attempt to study the Saudi Arabian intertidal bivalved molluscs inhabiting 12 geographical locations along the Saudi coastal line of the Arabian Gulf. The study entails with ecological distribution, seasonal variations, temporal and spatial changes of the bivalve species and their individual abundance particularly after the 1991 oil spill in the Arabian Gulf. The investigated area exceeded 250 km (> 50 % of the total Saudi coastal line of the Arabian Gulf). 68 bivalve species were collected from the whole studied area. The distribution extents of these species among the whole investigated area showed that some species have a winder distribution while others were limited. The seasonal and annual abundance of the bivalved fauna presented in the different stations showed that Qatif and Aziziya were the richest localities. The present data were discussed and interpreted with those reported by the other workers.

ACKNOWLEDGMENTS

I am deeply gratituted to Dr. A. M. I. Al- Suwailem, the Head of the Department of Aquatic Resource Development for his encouragement while conducting this work. My best regards were also due to Dr. C.F.H. Hosny for his faithful help in providing computer data analysis, tables and figures, also for the useful discussions and exchanging opinions.

REFERENCES

Al- Kaisi, K.A., 1976. On the phytoplankton of the Arabian Gulf. In: 2nd joint Oceanography Assembly, Edinburgh, 13-24 pp.

Basson, P.W., Burchard, J.E., Hardy, J.T. & Price, A.A.G., 1977. Biotopes of the western Arabian Gulf, "ARAMCO" Marine Life and Environments of Saudi Arabia, 284 pp.

Biggs, H.E.J. & Grantier, I., 1960. A preliminary list of molluscs of Ras Tanura, Persian Gulf. J. Conch., Lond., 24: 387-392.

Bosch, D. & Bosch, E., 1982. Sea shells of Oman. London, 206 pp.

Bosch, D. & Bosch, E., 1989. Sea shells of South. Arab., Lond., 95 pp.

Durgham, M.M. & Hussien, M.M., 1991. General remarks on the hydrography and Plankton of the Doha Harbour, Qatar. Proc. Inter. Symp. Envir. Prot. is Must. 11-14. March 1991. Alex, Egypt: 35-52.

Ehrhardt, M.G. & Burns, K.A., 1993. Hydrocarbons and related photo-oxidation products in Saudi Arabian Gulf coastal waters and hydrocarbons in underlying sediments and bioindicator bivalve. Mar. Poll. Bull., 27: 187-197.

Getter, C.D.; Cintron, G.; Lewis, R.R. & Senca, E.D., 1984. The recovery and restoration of salt marshes and mangroove following an oil spill, Chap. 3: 65-113, Cairns, J.; Buikema, Jr. Restoration of habitat impacted by oil spill. Ann. Arbor. Sci. Book, Butterworth Publ., Stonentram, M.A.

Glayzer, B.A. Glayzer, D.T. & Smythe, K.P., 1984. The marine mollusc of Kuwait, Arabian Gulf J. Conch, Lond., 31: 311-330.

Grasshoff, K., 1976. Review of hydrographical and productivity conditions in the Gulf region. In: UNESCO technical papers in marine science, 26.

Habe,T.,1961. Coloured illustrations of shells of Japan, Isaka, (II),182 pp.66 pls.

Halim, Y., 1984. Plankton of the Red Sea and Arabian Gulf. Deep Sea Research, 31 (6-8): 969-982.

Hatai, K. and Nisiyama, S., 1952. Check list of the Japanese Tertiary marine molluscs. Tohoku Univ. Sci. Rept. 3 (2): 464 pp.

Hunter, J.P., 1986. The physical oceanography of the Arabian Gulf. A review and theoretical interpretation of previous observations. In: Proceeding of the Ist. Arabian Gulf Conference on Environment & Pollution, Kuwait. 7-9 Feb. 1982.

Huq, M.E.; Al- Saadi, H.A. and Hadi, R.A., 1978. Preliminary studies on the primary production of the northwest Persian Gulf during Postmonsoon period. J. Ocean. Soc. Japan, 34: 78-80.

Jacob, P.G. and Zarba, M.A., 1979. Observations on the plankton and related features of the Kuwaiti waters. Marine Plankton Bioindicator Project. Mar. Poll. Progr. II, Kuwait Inst. Scient. Res. 170 pp.

Kinne, O., 1972. Marine ecology, London, vol. 1 (3): 1247-1773.

Kira, T., 1955. The shells of Japan, Osaka, 204 pp.

McCain, J.C., 1984a. Marine ecology of Saudi Arabia, the intertidal infauna of the sand beaches in the northern area, Arabian Gulf, fauna of Saudi Arabia, Vol. 6: 53-78.

McCain, J.C., 1984b. Marine ecology of Saudi Arabia, the near shore soft bottom benthic communities of the northern area, Arabian Gulf, Fauna of Saudi Arabia, Vol. 6: 79-101.

Melvill, J.C.H.A., 1889. Further investigations into the molluscan fauna of the Arab. sea, Pers. Gulf & Gulf of Oman, with description of 40 sp. Manch. Mem. Vol. X1ii (4), 39 pp.

Melvill, J.C.H.A., 1928. The marine mollusca of the Persian Gulf, Gulf of Oman and north Arabian sea through the collection of Capt. F.W. Townsend, 1893-1914. Proc. Mal. Soc. London: 93-117.

Purser, B.H., 1973. The Persian Gulf, Berlin, 471 pp., 7 pls.

Sharabati, D.P., 1981. Saudi Arabian seashells, selected Red Sea and Arabian Gulf Mollusca, Netherlands, 119 pp.

Smythe, K.R., 1979. The marine mollusca of the U.A.E., Arabian Gulf. J. Conch. London, 30: 57-80.

Smythe, K.R., 1982. Sea shells of the Arabian Gulf, Lond. 123 pp.

Wye, K.R., 1988. The Mitchael Beazley pocket guide to shells of the world, London, 192 pp. % Coloured illustrations.