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Biodiversity of fish utilizing intertidal estuary of poigar river during high-tide (North Coast of North Celebes, Indonesia)

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Key words: Diversity, estuary, high-tide, fish.

Abstract

This study was carried out to describe periodic change in fish occurrence in the estuary of Poigar River, particularly those entering the estuary at high tide in new moon and full moon phases. Sampling areas at both moon phases were the freshwater area at low tide and the water depth of 1.5-2.5 M at high tide when the salinity ranged between 1.7 – 27.3 ppm. Sampling was done twice a month at the new moon and the full moon for 6 months from September 2012 to February 2013. A total of 4,596 individuals of 52 species of 28 families with 32,754.18 g body weight was caught with a beach seine. The best representive families by number of species were Leiognathidae (3 genera and 7 species), Carangidae (4 genera and 5 species), and Tetraodontidae (2 genera and 4 species), respectively. In dry season and wet season, 41 species of 23 families and 40 species of 22 families, respectively, were recorded, and there was no significant difference between both seasons in number of species, number of individuals and body weight. There were 22 species in the upper estuary and 41 species in the lower estuary. There was significant difference between the upper and the lower estuary in number of species, number of individuals and body weight. Based upon the Importance Value Index (IVI), the most dominant species was Ambassis interrupta (31.42%) in dry season, Ambassis urotaenia (IVI=16.91%) in wet season and Gazza achlamays (16.97%) in the upper estuary, while as a whole they were dominated by Ambassis interrupta (IVI= 22.32%).

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Introduction

Estuary is an aquatic ecosystem possessing high environmental fluctuations, such as salinity, temperature, turbidity, and river and tidal currents. As transitional area between seawater and freshwater, this waters is occupied by a combination of both marine and freshwater fish species. The estuary fish group comprise freshwater fish occasionally entering the brackishwater, anadromous and katadromous species in transit, fish group spending their entire life in the estuary (resident species), and marine fish utilizing the estuary as spawning and nursery ground, as described in detail by Elliott *et al.* (2007). The fish group in the estuary is characterized with low diversity, but high abundance, especially in juvenile phase (Whitfield, 1999). The estuarine ecosystem structure is controlled by environmental variables determining the characteristics of the ecosystem. These environmental condition variations will cause changes in the composition and the distribution of the estuarine fish (Arkeo-Caranza & Vega-Cendejas, 2009; Barletta & Blaber, 2007; Johnston *et al.,* 2007; Barletta *et al.,*2005). Beside that, the fish composition in the estuary is controlled by the combination of biotic and abiotic factors, particularly competition for space and food, and tolerance to changes in salinity, turbidity, daily temperature or season. One of the dominant factors causing the changes of the environmental condition is dry season and wet season. The dominant environmental factors affecting the fish composition in the estuary is salinity (Barletta *et al.,* 2005).

Information on fish assemblage in the estuary of north coast of North Sulawesi in relation to fish composition and seasonal variations, and biomass is still very few. Previous studies (Bataragoa *et al.*, 2009 and Bataragoa *et al.*, 2012) briefly addressed fishes utilizaing the estuary during the high tide in five estuaries in North Sulawesi, while the composition, number of species and biomass of fish assemblage in the estuary of Poigar River is poorly understood.

This study was aimed at describing the distribution and abundance of fish species migrating following the high tide into the intertidal estuary of Poigar River during dry season and wet season The main question addressed in the present study was how does the fish assemblage (number of individuals, species, and biomass vary in relation to salinity fluctuations during the wet and dry seasons.

Materials and method

Study Area

The estuary of Poigar River is located in northern penisula of Sulawesi Island, Indonesia, about geographic position of 1° 0' 37.71" E and 124°17' 52.89"N (Fig. 1). The length of the estuary is approximately 1450-1500 M in dry season and 850-900 M in wet season. Lower estuary is sandy (sites 2,3 and 4), muddy (site 5-8) and rocky (sites 9 and 10). At low tide, the study site is fresh water with a maximum depth of 0.5 meter. At ebb tide, particularly new moon and full-moon periods, the water becomes brackish, with salinity about 1.7 ppm in the upper edge estuary and 27.3 ppm in the lower edge estuary (Fig. 2), with a depth of 1.4-2.2 M.

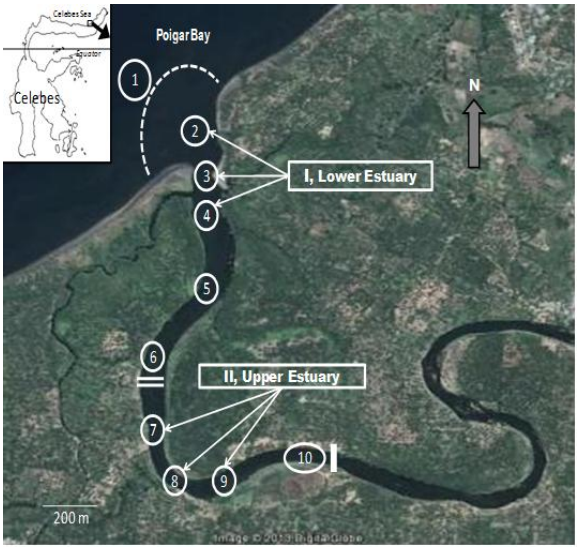

Fig. 1. Poigar River Estuary. Numbers 1-10 points of salinity measurements; I (Lower estuary 2,3,4) and II (Upper estuary 7,8,9) are fish sampling sites; ---,lower edge of the estuary at high tide; = upper edge of the estuary at high tide in wet season; ▬ upper edge of the estuary at high tide in dry season.

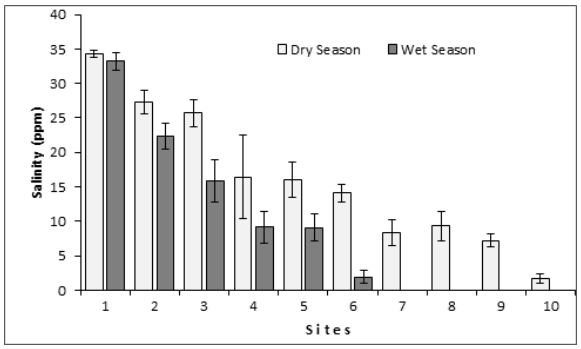

Fig. 2. Salinity distribution in dry season and wet season. Number 1-10 are measurement points shown in Figure 1. Vertical bars are SD.

Fish Sampling

Sampling was done for six months, September 2012-February 2013, at each full-moon and new moon phase, at 18.00-19.00, based on the tidal chart of 2012/2013 issued by Hidrographic and Oceanographic Office Indonesian Navy. Two sampling stations were determined, lower estuary as station I (2,3,4) and upper estuary as station II (7,8,9) (Fig. 1). In dry season, September-Nopember 2012, sampling was carried out in lower and upper estuary. To compare these two stations, only September-November 2012 data were used. In wet season, Desember 2012-February 2013, the estuarine area shifted from pont 10 to 6 (Fig. 1), so that sampling was only conducted in the lower estuary.

Sampling used a 40-m beach seine, 5-m purse/cod-end part with 0.5-cm mesh and 20-m wings, 3-m height, with 1.5-cm mesh. The beach seine was operated 3 times at each sampling station at new moon and full moon phase. Samples were packed in sample bags labelled with station and sampling time, then put into the cool box with ice crushes and taken to the laboratory and stored in a freezer at -24° C. Fish identification followed the identification guide of Kottelat *et al.,* (1993), Masuda *et al.,* (1984) and FAO Species Identification Guide for Fishery Purposes, (Fischer & Whitehead, 1974). Each fish species was grouped with station and sampling time, number of individuals counted by species, total length measured at a scale of 0.1 cm and weight recorded at 0.01 g.

Data Analyses

Species diversity (H'), dominance (C), evenness (E) and richness (S) were analyzed following Ludwig & Reynolds (1988). The dominant and important species were analyzed using the Importance Value Index (IVI) according to Arceo-Carranza and Vega-Cendejaz, 2009. IVI=Relative Density+Relative Frequency of Occurence+Relative Biomass, with slightly modifying the relative density to the relative number of individuals. The important dominant fish was determined by ranking the species from the highest IVI to the same or slightly bigger than 70%. As comparison, the values of relative number of individuals and relative weight were considered, ranked from the highest value to the same or slightly larger than 70% as implemented by Barlette *et al.,* (2003).

To test whether there are differences in data pairs between the lower and the upper estuary, dry season and wet season, the two-tail t-test was used (Zar, 1984). The data pairs tested between dry season and wet season were mean number of species, number of individuals and fish biomass.

Results

Species Composition

Combined all parts of the estuary and season: As a whole, 4,596 individuals were caught with a total weight 32,754.18 gram, consisting of 52 species and 28 families during the study (Table 1). Number of fish varied from 1-1581 individuals and the occurrece frequency varied from 1-18 in 18 sampling activities (Table 2). The best represented families by number of species were Leiognathidae (3 genera and 7 species), Carangidae (4 genera and 5 species), and Tetraodontidae (2 genera and 4 species). The most abundant species, *Ambassis interrupta* Bleeker, 1853, *Gazza minuta* (Bloch 1795), *Ambassis urotaenia* Bleeker 1852 and *Gazza* achlamys Jorand & Starks 1917, contribute to 71.26% of total number of individuals. From weight evaluation, *Ambassis interrupta* Bleeker,1853, *Gazza minuta* (Bloch,1795),

Ambassis urotaenia Bleeker,1852, *Gazza achlamys* Jorand & Starks,1917, *Valamugil cunnesius* (Valenciennes,1836), *Chelonodon patoca* (Hamilton, 1822), *Caranx sexfasciatus* Quoy and Gaimard, 1825, *Zenarchopterus dunckeri* Mohr, 1926, and *Strongylura leiura* (Bleeker, 1850) contribute to 70.52% of the total weight. Arceo-Carranza and Vega-Cendejas (2009) applied the highest Importance Value Index (IVI) up to about 70% as important and dominant species in the waters. Table 1 and Fig. 4A show 11 highest ranked species reaching total Importance Value Index (IVI) of 70.11%, *A.interrupta*, *G. minuta* , *A. urotaenia* , *G.achlamys* , *V.cunnesius*, *C.sexfasciatus*, *Z.dunckeri*, *Leiognathus bindus* (Valenciennes,1835), *Stolephorus commersonnii* Lacepède, 1803, *Upeneus sulphureus* Cuvier, 1829. *Ambassis interrupta* Bleeker,1853 (IVI= 22.32%) is the most representative species. All estuarine parts and seasons exhibit the richness index (R) of 6.05, diversity index (H') of 2.34, dominance index (C) of 0.17 and evenness index (E) of 0.41, respectively.

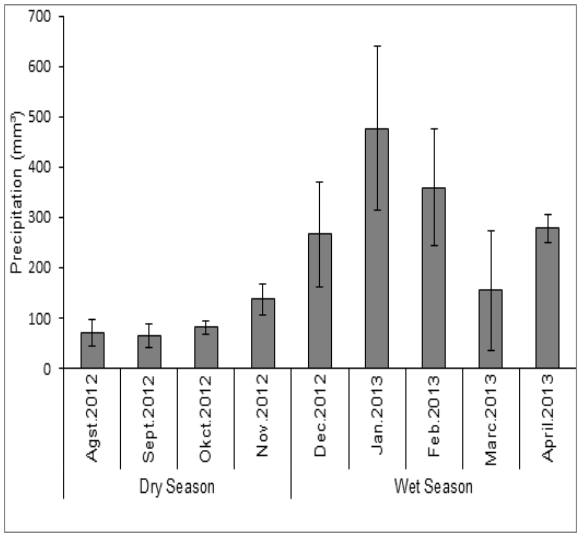

Fig. 3. Rainfalls in August 2012 to April 2013 (Climatology Meteorology and Geophysics Office, Climatology Station Manado, 2012/2013. Vertical bars are SD.

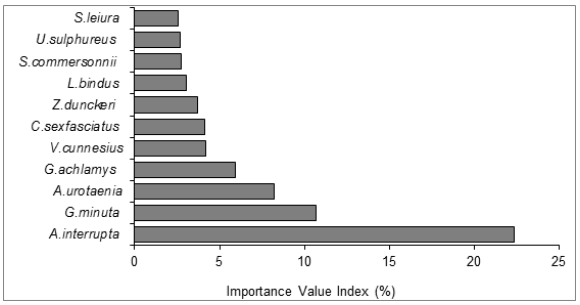

Fig. 4. Dominant Species in the estuary of Poigar River is ranked with Importance Value Index.

Dry season and wet season: Number of species found in dry season was 41 species of 23 families and wet season was 40 species of 22 families with richness indices of 5.04 and 5.39, respectively. Seven species occurred only during the dry season and six species only during the wet season (Table 1). These species were only found in one fish sampling (F=1) in both dry and wet seasons. Based on the IVI value, there are 11 important dominant species in dry season (Fig. 5A) and dominated by *A.interrupta* (IVI=31.42%) and 11 species in wet season (Fig. 5B) and dominated by *A.urotaenia* (IVI=16.91%). However, three different dominant species were recorded between both seasons. *Upeneus vittatus, U.sulphureus and P.plebejus* are dominant and important species in dry season but not dominant in wet season. Also, *G.achlamays, Z.dunckeri and C.papuensis* are dominant and important species in wet season but not dominant in dry season.

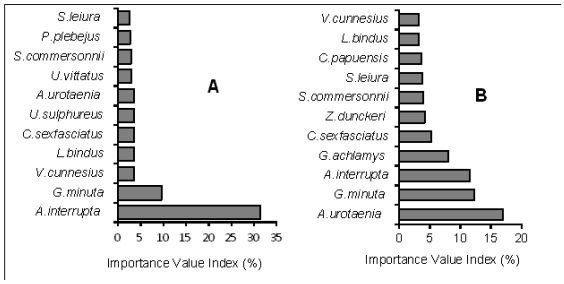

Fig. 5. Dominant Species is ranked with Importance Value Index. Dry season (A) and wet season (B).

Table 1. Number of species (s), number of individuals (n), and mass (m) of fosh samples caught during the study in the upper and the lower estuary for dry season and wet season. *)data used to compare dry season with wet season; **)data used to compare upper estuary and lower estuary.

	Upper Estuary			Lower Estuary			All Estuary		
Season	s	n	m	s*)	n*)	m*)	s	n	m
Dry	22**)	388**)	5309.84**)	41**)	2804**)	19324.28**)	44	3203	24634.12
Wet	-	-	-	40	1394	8120.06	40	1394	8120.06
Total	22	388	5309.84	50	4198	27444.34	52	4597	32754.18

Table 2. Total number of individuals (Ind.), mass, frekuency of occurrence (F), Index of Value Importance (IVI) and Rank of fish in Poigar River Estuary, pooled upper and lower estuary. *):species recorded in upper estuary; *)*): species only occur in upper estuary; **):species recorded in the lower estuary; ***):species only occur in dry season; ****): species only occur in wet season.

Family	Species	No.Ind.	Mass (g)	F	IVI	
					Value	Rank
CARANGIDAE	***Caranx sexfasciatus* Quoy and Gaimard,**	108	1287,66	16	4,11	**6**
	Caranx papuensis Alleyne & Macleay, 1877 *) **)	59	472,05	12	2,42	12
	Carangoides coeruleopinnatus (Rüppell, 1830)	1	13,24	1	0,15	41
	Scomberoides lysan (Forsskål, 1775) *) **)	3	5,19	3	0,41	34
	Trachinotus blochii (Lacepède, 1801) **) ***)	3	8,38	1	0,16	40
AMBASSIDAE	***Ambassis interrupta* Bleeker, 1853 *) **)**	1581	8931,78	14	22,32	**1**
	***Ambassis urotaenia* Bleeker, 1852 *) **)**	472	2445,71	18	8,18	**3**
POLYNEMIDAE	*Polydactylus plebejus* (Broussonet, 1782) **)	44	653	8	1,99	14
	Polydactylus sexfilis (Valenciennes, 1831) **)	81	271,9	4	1,37	19
LEIOGNATHIDAE	***Gazza minuta* (Bloch, 1795) *) **)**	809	2964,17	14	10,65	**2**
	***Gazza achlamys* Jorand & Starks, 1917 *) **)**	414	1763,34	9	5,93	**4**
	***Leiognathus bindus* (Valenciennes, 1835) *)**	185	825,7	7	3,07	**8**
	Leiognathus splendens (Cuvier, 1829) *) **)	84	295,52	6	1,67	16
	Leiognathus longispinis (Valenciennes, 1835) **)	3	275,15	1	0,43	33
	Secutor ruconius (Hamilton, 1822) **)	14	34,7	3	0,52	31
	Secutor insidiator (Bloch, 1787) **)	13	108,35	2	0,46	32
BELONIDAE	***Strongylura leiura* (Bleeker, 1850) **)**	38	1114,46	9	2,55	**11**
	Strongylura strongylura (van Hasselt, 1823) *) **)	5	157,81	4	0,70	28
HEMIRHAMPIDAE	***Zenarchopterus dunckeri* Mohr, 1926 *) **)**	97	1224,16	14	3,72	**7**
	Hemiramphus far (Forsskål, 1775) **) ***)	2	59,3	1	0,20	39
ENGRAULIDAE	***Stolephorus commersonnii* Lacepède, 1803**	103	962,28	8	2,74	**9**
	Thryssa baelama (Forsskål, 1775) *) **)	23	272,3	4	0,95	23
TETRAROGIDAE	*Tetraroge niger* (Cuvier, 1829) *) **)	17	129,71	8	1,27	20
MUGILIDAE	***Valamugil cunnesius* (Valenciennes, 1836)**	118	1758,26	12	4,16	**5**
	Mugil cephalus Linnaeus, 1758 *) **) ***)	8	347,29	5	1,04	22
GERREIDAE	*Gerres filamentosus* Cuvier, 1829 *) **)	16	254,39	10	1,64	17
TETRAODONTIDAE	*Chelonodon patoca* (Hamilton, 1822) *) **)	10	1608,37	5	2,34	13
	Arothron hispidus (Linnaeus, 1758) *) **)	1	209,16	1	0,35	36
	Arothron manilensis (Marion de Procé, 1822) **)	2	11,4	2	0,28	38
	Arothron reticularis (Bloch & Schneider, 1801) **)	1	236,52	1	0,37	35
CALLIONYMIDAE	*Eleutherochir opercularis* (Valenciennes, 1837) **)	30	204,49	6	1,18	21
MULLIDAE	***Upeneus sulphureus* Cuvier, 1829 *) **)**	68	782,61	11	2,68	**10**
	Upeneus vittatus (Forsskål, 1775) *) **)	81	683,4	5	1,91	15
SILLAGINIDAE	*Sillago sihama* (Forsskål, 1775) *) **)	17	305,78	9	1,57	18
KUHLIIDAE	*Kuhlia marginata* (Cuvier, 1829) **)	13	303,95	3	0,78	26
ELEOTRIDAE	*Oxyleotris gyrinoides* (Bleeker) **) ****)	1	7,06	1	0,14	42
GOBIIDAE	*Awaous ocellaris* (Broussonet, 1782) *)*)****)	7	59,28	4	0,62	29
	Glossogobius celebius (Valenciennes, 1837) **) ****)	2	6,64	1	0,15	41
SCATOPHAGIDAE	*Scatophagus argus* (Linnaeus, 1766) **)****)	1	4,63	1	0,14	42
SOLEIDAE	*Heteromycteris* sp**) ***)	2	6	1	0,15	42
MONODACTYLIDAE	*Monodactylus argenteus* (Linnaeus, 1758) **)	3	71,71	2	0,35	36
HAEMULIDAE	*Plectorhinchus gibbosus* (Lacepède, 1802) **) ****)	1	4,33	1	0,14	42
TERAPONTIDAE	*Terapon jarbua* (Forsskål, 1775) **) ***)	1	1,05	1	0,13	43

	Terapon theraps Cuvier, 1829**) ***)	1	11,7	1	0,15	41
CHANIDAE	*Chanos chanos* (Forsskål, 1775) **) ***)	2	583,12	1	0,73	27
SPHYRAENIDAE	*Sphyraena* sp**) ***)	13	175,96	2	0,53	30
CLUPEIDAE	*Amblygaster sirm* (Walbaum, 1792) **)	27	337,51	3	0,92	24
	Amblygaster leiogaster (Valenciennes, 1847) **)	1	10,7	1	0,14	42
	Sardinella melanura (Cuvier, 1829) **) ***)	1	12,01	1	0,15	41
LOBOTIDAE	*Lobotes pacificus* Gilbert, 1898**) ***)	1	7,57	1	0,14	42
LUTJANIDAE	*Lutjanus ehrenbergii* (Peters, 1869) **)	5	23,54	2	0,31	37
ANTENNARIIDAE	*Antennarius* sp *)*)	4	449,89	3	0,87	25
Total		4597	32754,18			

Mean number of species, number of individuals, and mass in dry season and wet season are shown in Fig. 7. In dry season, mean number of species is 17.83±5.15 and in wet season 17.17±2.64. Mean number of individuals in dry season was 467.33±309.84 and in wet season 232.33±145.08. The t-test (P>0.05) shows no difference in mean number of species, mean number of individuals and mass in both seasons.

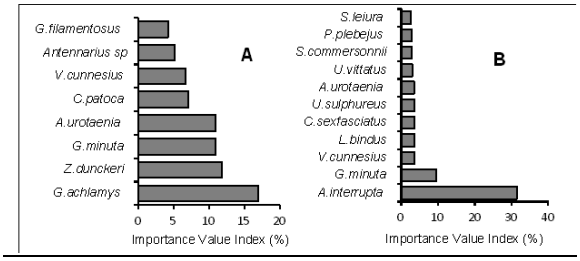

Fig. 6. Dominant Species is ranked with Importance Value Index. Upper estuary (A) and lower estuary (B).

Upper and lower estuary

In upper estuary, there were 22 species of 14 families recorded and in lower estuary, there were 41 species of 23 families recorded, with species richness index of 3.52 and 5.04, respectively. Species composition of upper estuary was different from that of lower estuary (Fig. 5), in which dominant species of both sites possessed simlarity in two species, *Gazza minuta* (Bloch, 1795) and *Valamugil cunnesius* (Valenciennes, 1836). *G.achlamays* (16.97%) is the most representative species in upper estuary and *A.interupta* (31.42 %) in lower estuary. Frogfish, *Antennarius* sp, was species found only in upper estuary. It is one of the dominant species in the upper estuary. Mean number of species, number of individuals and fish mass in the upper and the lower estuary are given in Fig. 6. Mean number of species in the upper estuary and the lower, respectively, with mean number of individuals of 64.67±29.88 and 469.17±309.21, respectively. The fish biomass in the upper and the lower estuary was 884.97±511.37gram and 3220.71±1969.17gram, respectively. The t-test (P>0.05) indicated significant difference in mean number of species, number of individuals, and fish mass between dry season and wet season.

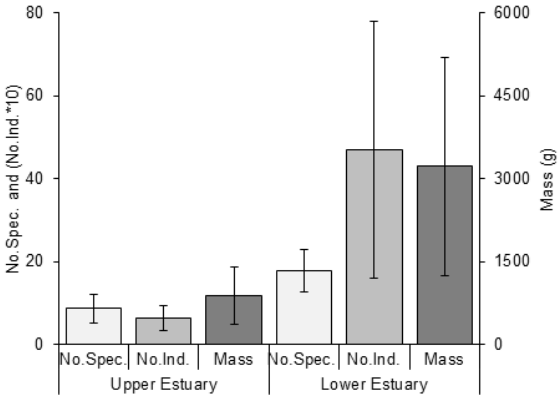

Fig. 7. Mean number of species (No.Spec.), number of individuals (No.Ind.), and fish weight caught in Upper Estuary and Lower Estuary. Vertical bars are SD.

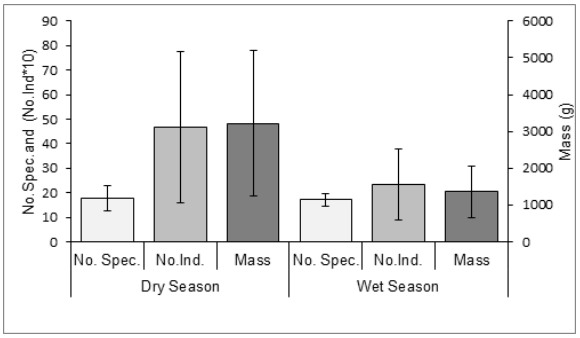

Fig. 8. Mean number of species (No.Spec.), number of individuals (No.Ind.), and fish weight caught in dry season and wet season. Vertical bars are SD.

Richness, Diversity, Dominance and Evenness Indices

The lowest richness index was recorded in the upper estuary, 3.52, and the highest, 5.39, in wet season. Based on the diversity, dominance and eveness indices (Table 3), fish communities in the estuary of Poigar River during high tide are classified as moderate diversity and evenness, but low dominance (C approaches to zero). Nevertheless, the values of diversity, dominance, and evenness indices indicate that in dry season (also lower estuary, the same data) the diversity and the evenness are lower and more dominated by certain species than those of wet season and upper estuary.

Table 3. Dversity, Dominance, and Evenness indices in the estuary of Poigar River. (Est, Estuary; Lo., Lower; Up., Upper).

Index	All Est.	Dry eason and Lo.Est.	Wet Season	Up.Est.
Richness (R)	6.05	5.04	5.39	3.52
Diversity (H')	2.34	2.05	2.28	2.23
Dominance (C)	0.17	0.27	0.15	0.14
Evennes (E)	0.41	0.34	0.43	0.50

Discussion

Decrease in salinity from lower to upper estuary is shown in Fig. 2. Each salinity measurement point in Fig. 2 is mean salinity of the three measurement levels, bottom, middle water column and water surface. Nevertheless, our data (unpublish data) indicate salinity difference between water surface and bottom, where drastic salinity increment occurs with depth and thus, the estuary is classified as moderately stratified estuary (Mann and Lazier, 2006).

In wet season (December 2012-February 2013), water salinity decreases in the entire estuary. Even the upper estuary occurred during the dry season (August-November 2012), the salinity was zero in all water columns during the wet season. The salinity difference between water surface and bottom is higher in wet season, especially at the lowest part of the estuary.

Fifty-two fish species utilizing the intertidal estuary at high tide (flood-tide), 35 species seem to be independent of season and 17 species dependent upon season. In general, season-dependent species (occur only in one of the seasons, dry or wet season) were found once in 12 fish sampling activities. Eleven dominant and important species in the estuary of Poigar River (Fig. 4), as a whole, are those independent of wet and dry seasons.

Number of species, number of individuals and fish biomass between dry season and wet season did not exhibit differences during the study. Rueda and Dafeo (2003) found fish biomass differed between seasons, in which the time period of 1993/1994 showed higher density in wet season and 1997 higher density in dry season. Barletta *et al.*, (2003) found that there is no difference in number of species between dry season and wet season, but they found difference in fish biomass between the seasons. Change in fish community structure could result from temporal migrational patterns along the year. Fish migration from one habitat to the other around the estuary is affected by salinity fluctuations (Barletta *et al.*, 2005). Water temperature and salinity are important hydrological factors influencing the species composition and distribution in the estuary (Arceo-Carransza and Vega-Cendejas, 2009). The pattern of fish occurrence in the estuary could be closely related with the pattern of salinity distribution, so that water salinity takes important role in the community dynamics and structure in the estuary (Pavan *et al.,* 2010; Barletta *et al.,* 2008; Akin *et al.,* 2005; Baran, 2000). The present study found significant difference

in mean number of species, mean number of individuals, and fish biomass between the upper and the lower estuary. Regarding salinity distribution, the sampling sites of lower estuary (site 2,3,4) and upper estuary (site 7,8,9), have salinity of 23±5.87ppm and 8.30±1.40 ppm, respectively, during the dry season, and the lower estuary (site 2,3,4) has 15.81±6.62 ppm in wet season. The present study does not statistically show differences between dry season and wet season, but numerically (64.67±29.88 in dry season and 469.17±309.21 in wet season; biomass of 884.97±511.37g in the wet season and 3220.71±1969.17g in the dry season), there is a tendency to obtain more fish in wet season, even though mean number of species do not exhibit similar trend.

The combination of IVI, H', C and E values indicates fish community instability in dry season. The diversity and evennes indices in dry season are lower (H'=2.05 and E=0.34) and the dominance index is higher (D=0.34) than those in wet season and upper estuary (Table 3). It reflects that in dry season certain species occurs in higher numbers than other species. Fig. 5A shows that the IVI value of *A.interrupta* covers 31.42% of the 41 species found during the dry season in the lower estuary. It is apparent that Long-spined glass perchlet, *A. Interrupta,* prefer high salinity brackish water (23±5.87 ppm in the present study), but they were found in low number in the upper estuary (IVI=2.48%; rank-12 of 22 species; 8.30±1.40 ppm) and the wet season (IVI=11.50%; rank-3; salinity 15.81±6.62ppm).

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