Pleuronectiformes species identification along the Iranian coastline of the Persian Gulf

M. Yasemi[1]*; A. Keyvan[2]; B. Falahatkar[3]; M. Farzingohar[4];

I. Sharifpour[5]; F. Owfi[6]; G.H. Vossoughi[7] and M.R. Ahmadi[8]

yasami_m@yahoo.com

1- Fisheries Dept., Institute of Technical and Vocational Higher Education,
   P.O.Box: 13145-1783 Tehran, Iran.
2- Fisheries Dept., Science and Research Branch, Islamic Azad University,
   P.O.Box: 19858-181 Tehran, Iran.
3- Fisheries Dept., Faculty of Natural Resources, University of Guilan,
   P.O.Box:1144 Sowmeh Sara, Iran
4- Faculty of Science, University of Hormozgan, P.O.Box:
   Bandar Abbas, Iran
5,6- Iranian Fisheries Research Organization, P.O.Box: 14155-6116
   Tehran, Iran
7,8- Faculty of Veterinary Medicine, University of Tehran,
   P.O.Box: 14155-6453 Tehran, Iran

Abstract: Pleuronectiforme fishes of the Persian Gulf coastlines along Khuzestan, Bushehr and Hormozgan provinces were morphometrically and meristically studied from April 2003 to September 2005, in order to identify species. In this experiment, 1551 fish samples were caught by trawl or collected from fish markets. The sampling was carried out in 27 regions seasonally. Thirty six traits and parameters including 18 morphometric, 11 meristic, and 7 phenotype characters were determined. Data obtained from morphometric parameters were analyzed and dendrograms were designed using cluster method. Comparision of the biometric data with the checklist identification index of species show that there are 6 main and dominant families including: Bothidae, Psettodidae, Citharidae, Soleidae, Cynoglossidae and Paralichthyidae in the area. In addition, the identification of above- mentioned families indicated that 25 species in Khuzestan area, 19 species in Bushehr area and 16 species in Hormozgan area inhabit the coastal waters of the Persian Gulf. Meanwhile, 13 species from 5 families in Persian Gulf that have not been reported so far are identified and reported in this research. According to these results and comparing with other studies, 30 species from 6 families were identified in coastal waters in the Persian Gulf on Khuzestan, Bushehr and Hormozgan areas which is the most complete study in Persian Gulf.

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* **Corresponding author**

Introduction

Pleuronectiformes is one of the fish orders with high diversity (Nelson, 2006). Mostly caught through bottom trawling (Parsamanesh, 1994), these fishes are valuable and their catch and consequently the income made by them is increasing (Diaz de Astarloa & Munroe, 1998).The world total catch of these fishes in 2001 reached to one million tons (FAO, 2002); the reported amount in Iran was 1858 tons for the same year (Iranian Fisheries Organization, 2003).

Different researches have identified various fish species through morphometric and meristic characteristics. These kind of studies are based on a set of measurements which represent size and shape variation and are continuous data in contrast to meristic characters which are discrete data. Identifying stocks of a species with unique morphological characters enables a better management of these stocks (Turan, 1999). These characters have also been commonly used in fisheries biology to measure discreteness and relationships among various taxonomic categories (Amaoka, 1984). These characters have been used widely to identifying species and populations (Sharp *et al.*, 1978; Ismen, 2001; Hermida *et al.*, 2005; Turan *et al.*, 2005). Khara (2004) identified the intraspecific variations of bream (*Abramis brama*) in Anzali lagoon in the southern part of the Caspian Sea, Aras Reservoir and Azerbaijan Republic utilizing 40 morphometric traits, 16 meristic and molecular characteristics. Koosha (1996) started the identification of the species of Pleuronectiformes by morphometric parameters and analyzing some biological traits of *Cynoglossus dubius* in the Oman Sea in part of Iranian coastline. Abbassi *et al.* (2004) studied *Vimba vimba persa* of the Sefidroud River by morphometric and meristic methods. Naddafi and Mojazi Amiri (2001) also studied the meristic characters of roaches in Gorganrud estuary and Anzali Lagoon.

Although Pleuronectiformes are commercially important in the Persian Gulf and Oman Sea region, the species of this order have not been systematically and ecologically studied and their other biological traits are vague and incomplete. The first study on these fishes was conducted by Belgvad and Loppenthin (1942) and the last study was conducted by Carpenter (1997), in which 6 families of Pleuronectiformes were introduced from the Arabian regions of the Persian Gulf

(Kuwait, Saudia Arabia, Qatar, Bahrain and the United Arab Emirates). From these families 22 species were identified in all the Persian Gulf waters except for the Iranian coastline where only the scientific names without the record of morphometric and meristic characteristics are mentioned. Asadi and Dehghani (1996) identified some families and species of Pleuronectiformes in the Persian Gulf and Oman Sea region with some morphometric and meristic traits of the species mentioned in their studies. Since no complete studies have been conducted to identify the species of Pleuronectiformes, the identification of these species could be very important for determining the population parameters (distribution and abundance), ecological and biological characteristics of each species and also the study of species in the Iranian coastline. The general aims of this study is identification of families and species of Pleuronectiformes in the Persian Gulf coastline of Khuzestan, Bushehr and Hormozgan regions by morphometric and meristic methods.

Materials and methods

This study was carried out from April 2003 to September 2005. The samplings were from the fishes of the Persian Gulf coastlines along Khuzestan province from Bahrkansar to estuary of Bahmanshir River (29° 58′ to 33° 4′ N and 47° 41′ to 50° 39′ E), Bushehr province from Deylam in northwest to Naiband Bay in southeast (27° 14′ to 30° 16′ N and 50° 06′ to 52° 58′E), and Hormozgan province from Gavbandy in south west of Naiband Gulf to Hormoz Strait in south east (25° 24′ to 28° 57′ N and 53° 41′ to 59° 15′ E).
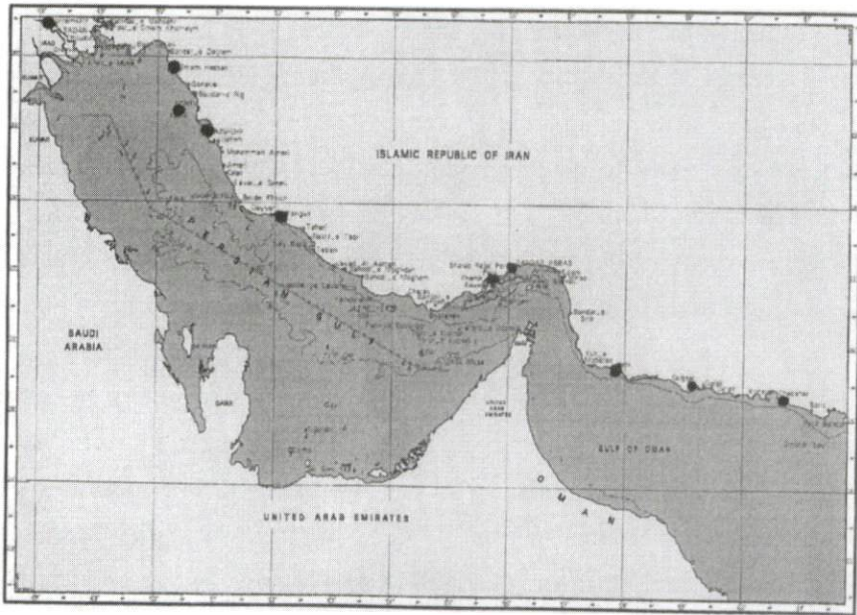
Figure 1: Map of sampling areas of Pleuronectiformes in the Persian Gulf

Samples were collected seasonally from bottom trawlers as well as active fishing harbors in Khuzestan province (Bandar Mahshahr, Choibdeh, Arvandkenar, Bandar Khoramshahr, Mahshahr estuaries, Mousa estuary and Bahrekan), Bushehr province (Delwar, Dayyer, Ameri, Rigsa, northern Bahrekan, southern Mutaf, Khark, Samangan and Nakhl-e-Taghi), and Hormozgan province (Gavbandy, Bandar Kong, Bandar Mogham, Bandar Lengeh, Bandar Abbass, Bandar Khamir, Gheshm, Lavan and Kish). In total, 1551 fish samples (741, 391, and 419 samples in Khuzestan, Bushehr and Hormozgan, respectively) were obtained which they were utilized for species identification and the study of morphometric and meristic traits.

In this study, 18 morphometric traits were analyzed including body weight (BW), total length (TL), standard length (SL), head length (HL), head height (HH), nose length (NL), ventral fin length (VFL), base dorsal fin length (BDL), dorsal fin height (DFH), base anal fin length (BAL), anal fin height (AFH), pre-fin dorsal

length (PDL), anal pre-fin length (APL) and body height (BH). Weight parameter was measured by grams and length by millimeter preciseness.

Eleven meristic traits including the number of scales on the lateral line, as well as the first row above and below the lateral line, the number of hard and smooth radials of dorsal, anal, ventral and pectoral fins, branchial spine (left or right), lower jaw teeth (left or right), upper jaw teeth (left or right), and the number of scutes with radiography method (Amoaka & Yamamoto, 1984).

Seven apparent body characteristics including body color and stains (their number and location) of the freshly caught samples, the nature of lateral line, the type of anal fin, the type and situation of teeth, the scale type and form and also sexuality (if possible) were analyzed, which in total included 36 features.

Then, all the samples were analyzed with morphometric and meristic values and the data were recorded in biometry forms and eventually analyzed with SPSS program. At first morphometric trait (Hermida *et al.*, 2005) and data records in Excel software program and their analysis with SPSS were utilized. To complete the identification of fishes on the basis of morphometric and meristic traits, hierarchical cluster analysis, which is the classification with the design of dendrogram, were used (Valinassab, 1999) and the SPSS statistical program was utilized. To increase the preciseness of identification with regard to the diversity of the studied samples the check list of species identification index that included 64 species from 6 families of Pleuronectiformes inhabiting warm waters was obtained from different sources as Randall (1995); Carpenter (1997); Fischer and Bianchi (1983); Blegvad and Loppenthin (1942); Atlas of the Persian Gulf and Oman Sea Fishes (Asadi & Dehghani, 1996); Smith (1986); Nelson (2006), and fishbase website. Morphometric traits and their relations on the basis of the ratio of total length to standard length were calculated for each of the species of all families, and a special index code was determined for all species separately. Then, the studied traits in samples from Khuzestan, Bushehr and Hormozgan waters were compared with the coded check list of species identification (Nazari, 2002) and the relative code was recorded. So, the conclusion of the data in SPSS software made precise identification of the Pleuronectiformes species in these three provinces.

Results

Using statistical method of morphometric in Khuzestan, Bushehr, and Hormozgan, some 741, 391 and 419 samples (morphometric), using hierarchical analysis (dendrogram design), 276, 165 and 129 samples, and using checklist of name index for species identification, 741, 391 and 419 (morphometric and meristic), were analyzed respectively. The results of these analysis are outlined in Tables 1 and 2.

The results of analyzing 13 morphometric characteristics imply 16 species belong to 4 families in Khuzestan, , 17 species from 5 families in Bushehr, and 14 species from 5 families in Hormozgan (Table 1).

As for the hierarchical cluster analysis and dendrogram design, in Khuzestan region from 741 collected samples, only 276 fishes had similar morphometric and meristic traits while this record for Bushehr was 165 out of 391 samples and in 419 collected samples in Hormozgan 129 fishes were similar and were recorded in EXCEL. These data were utilized and hierarchical cluster analyses were conducted on variables.

The results of dendrograms in three provinces showed that in Khuzestan the samples were separated in 5 clusters in a way that 5 families were present in this region. In Bushehr, 3 clusters meaning the presence of three families in this area, while in Hormozgan three different clusters were recorded.

With preparing the checklist of species identification index and the comparison of each sample in Khuzestan (n=741), Bushehr (n=391) and Hormozgan (n=419), it was determined that 25 species in Khuzestan waters are from 6 families, Bushehr has 19 species belonging to 5 families and in Hormozgan region, there were 16 species belonging to 6 families (Table 2).

Table 1: Results from analysis of morphometric traits and phenotype of Pleuronectiformes along the Persian Gulf coastline of Khuzestan, Bushehr and Hormozgan provinces.

Families & species identified / characteristic	Khuzestan				Bushehr					Hormozgan			
	Cynoglossidae (1) n = 276	Paralichthyidae (2) n = 248	Soleidae (3) n = 136	Psettodidae (4) n = 18	Psettodidae (5) n = 41	Soleidae (6) n = 72	Cynoglossidae (7) n = 86	Paralichthyidae (8) n = 121	Bothidae (9) n = 71	Paralichthyidae (11) n = 143	Soleidae (12) n = 38	Psettodidae (13) n = 72	Bothidae (14) n = 35
Weight (g)	352.5±58.9	361.3±186.68	393.3±195.3	650.8±772.6	1452±626	696.3±282.0	288.1±56.3	189.5±30.4	154.9±1.4	2100.4±394.3	1135.7±748.2	1803±687.7	—
Total length (mm)	226.6±184.4	262.5±54.7	235.2±51.4	326.2±92.4	276.6±45.6	235.8±26.1	215.7±200.7	215.7±85.8	235±25.5	295.5±151.9	307.3±51.1	266.6±31.8	200.6±28.9
Standard length (mm)	193.7±43.7	227±39	205.3±39.4	285.1±81.3	215.0±53.3	216.7±24.4	216.7±24.4	215.7±85.8	235±25.5	261.3±136.3	293.7±45	200.6±28.9	—
Head length (mm)	48.4±19.6	65.3±39.9	48.4±23.7	60.1±7	124.6±30.4	44.4±13.9	49.1±5.8	75.7±85.8	66.9±8.1	67.8±16.9	92.2±28.7	79.3±8.8	60.3±13
Head height (mm)	47.3±8.5	78.2±60	58.3±29.6	15.7±3.1	14.5±4.8	85.6±29.2	41.5±8.6	77.6±25.2	97.4±9.2	81±24.4	99.7±28.7	13.5±3.4	60.3±13
Snout length (mm)	11.7±4.8	10.6±8.7	26.1±19.7	16.6±0.89	18.8±0.9	12.7±7.3	20.7±4.2	9.9±7.0	15.5±2.3	10.1±8	22.5±0.7	13.5±3.4	22.5±0.7
Inter orbital length (mm)	2.4±0.8	3.2±2.57	9.43±5.6	14.8±6.3	7.1±3.1	4.3±4.2	3.2±1.0	3.6±2.0	3.2±1.0	3.7±2.4	21±19.8	11.5±5.6	8±3.4
Caudal fin length (mm)	13.8±7.7	38.6±20.9	37.23±16.5	57.7±11.1	57.0±19.6	27.6±8	18.9±18	39.9±20.4	43.4±4.6	38.2±16.3	56.5±13	68.6±9.5	—
Peduncle length (mm)	13.2±5.8	18±5.8	22.1±7	49.7±7.6	21.2±8.8	16.0±6.0	12.5±5.3	16.0±4.0	26.9±2.9	18.9±5.3	20.3±8.3	42.3±11.3	68.6±9.5
Pectoral fin length (mm)	7.4±3.1	34.7±16	25.8±8.9	31.1±6.6	34.4±11.1	15.5±4	—	34.4±17.1	41.7±4.9	35±18.2	24.8±16.2	43.9±11.8	57±9
Ventral fin length (mm)	14.2±8.9	23.5±19.9	18±15.5	28.0±6.4	28.6±9.7	13.3±3.6	—	20.8±5.4	22.8±2.5	23.1±4.8	18.8±10.2	28.9±7.4	43.3±7.4
Dorsal fin length (mm)	8.7±3.2	15.3±12.5	24±8.6	26.7±7	23.9±7.4	17.2±4.4	11.1±2.4	21.9±5.2	24.1±2.9	22.5±19.5	21.2±6.1	30.8±8.7	23±5.8
Body height (mm)	72±32.8	101±52.2	100.2±24.9	125±57	168.3±46.9	106.1±28.5	51.0±7.3	116.2±23.6	111.6±22.1	104.2±43.7	124.3±40	152.3±38.5	—

1. *Cynoglossus durbanensis*, *C. ared*, *C. lachneri*, *C. puncticeps*.
2. *Pseudorhombus javanicus*, *Paralichthioides oligolepsis*, *Pseudorhombus malayanus*.
3. *Parachirus marmoratus*, *Monochirus luteus*, *Solea elongata*, *Brachirus orientalis*.
4,5,13. *Psettodes erumei*.
6. *Cynoglossus marmoratus*, *Solea elongata*, *Brachirus orientalis*, *Zebria synaptruroides*.
7. *Cynoglossus ared*, *C. kopsii*, *C. bilineatus*, *C. capensis*, *C. puncticeps*.
8. *P. javanicus*, *Pseudorhombus malayanus*, *P. elevatus*, *P. arsius*.
9. *Engyprosopon grandisquama*, *Laeops guentheri*, *Arnoglossus aspilos*.
10. *Cynoglossus ared*, *C.lachneri*, *C.bilineatus*, *C. puncticeps*.
11. *Pseudorhombus malayanus*, *P. elevatus*, *P. arsius*, *P. javanicus*.
12. *Parachirus marmoratus*, *Brachirus orientalis*.
14. *Arnoglossus arabicus*, *A. aspilos*, *Laeops guentheri*.

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Table 2: The identified species of Pleuronectiformes along the Persian Gulf coastline of Khuzestan, Bushehr and Hormozgan using checklist method

Province / Family	Hormozgan	n*	Bushehr	n*	Khuzestan	n*
Soleidae	*Barchirus orientalis* *Solea stanalandi* *Parachirus marmoratus*	92	*Barchirus orientalis* *Solea elongata* *Zebrias synapturoides* *Zebrias quaggta* *Parachirus marmoratus*	84	*Barchirus orientalis* *Solea elongata* *Monochirus luteus* *Parachirus marmorats*	117
Cynoglossidae	*Cynoglossus arel* *C. bilineatus* *C. puncticeps* *C. lachneri*	104	*Cynoglossus arel* *C. bilineatus* *C. puncticeps* *Cynoglossus kopsii* *Cynoglossus capenis*	121	*Cynoglossus arel* *C. bilineatus* *C. punctices* *C. durbanensis* *C. lachneri*	218
Paralichtidae	*Pseudorhombus arsius* *P. elevatus* *P. malayanus* *P. javanicus*	105	*Pseudorhombus arsius·* *P. elevatus* *P. malayanus* *P. javanicus*	82	*Pseudorhombus annulatus* *P.natalensis* *P. arsius* *P. elevatus* *P. malayanus* *P. algoensis* *P. javanicus*	166
Bothidae	*Arnoglossus aspilos* *A . arabicus* *Laeopes guentheri*	54	*Arnoglossus aspilos* *Engyprosopon grandisquama* *Laeops guentheri*	60	*Arnoglossus aspilos* *A . arabicus* *Engyprosopon grandisquama* *Laeops guentheri* *L. natalensis* *L. pectoralis*	146
Psettodidae	*Psettodes erumei*	73	*Psettodes erumei*	44	*Psettodes erumei*	80
Citharidae	*Citharoides macrolepis*	16	-	-	*Citharoides macrolepis*	14

*n = Morphometric and meristic traits

Discussion

Pleuronectiformes are the most important flat fishes in waters near beaches. Some species live in 1-45m depth (*Pseudorhombus orbignyanus*) and some in wide and deep limitations between 6-120m (*Pseudorhombus patagonicus*). However, young fishes choose estuary regions with less than 3m depth for nursery (Diaz de Astarloa & Munroe, 1998).

The studied fishes in the Persian Gulf coastlines of Khuzestan, Bushehr and Hormozgan and their adults live in the depths at 35m while Manickchand-Heileman (1994) reported that young fishes prefer estuary regions and low depth estuary.

The morphometric traits of these fishes are obtained from measurement of different body parts which are influenced by environment and its changes in a long period, finally, change the fish morphology. Therefore it could be mentioned that environmental changes affect the inheritance (Turan, 1999; Ismen, 2001). The meristic characteristics in populations are more dependent on genetic differentiations which are not influenced by environment and even these characteristics are constant in fishes with different sizes (Winfeild & Nelson, 1991).

Valinassab *et al.* (2000) suggested that the main factor for the size and morphological differences in cuttlefishes of Persian Gulf and Oman Sea is ecological conditions.

Important morphometric traits especially in the type of anal fin and eyes situation after metamorphosis clearly showed the environmental effects on fish morphology. This fact has been confirmed about the meristic traits such as lateral line and fin rays which have genetic origin and it has been determined that there are no differences between adults and young populations.

Pleuronectiformes which live in estuaries due to high temperature of these regions have higher growth compared to the waters far from the beach (Kramer, 1991).

In the present study, the mean weight of different families in different provinces showed various results. This could clearly show that weight and morphological

indices of this order are related to ecological conditions specially temperature, depth and food abundance. In a way that the species of Cynoglossidae and Paralichthyidae families, which are captured relatively away from the beach, had lower weights and they had complete oval morphology.

Hermida *et al.* (2005) in a study for identification of triple spine orientations in different regions of northwest of Spain reported that morphometic characters were more useful for identifications of species compared to meristic traits.

Statistical analysis of morphometric characteristics in this study show the existence of 4 families and 17 species in Khuzestan, 5 families and 17 species in Bushehr, and 5 families containing 14 species in Hormozgan.

Valinassab *et al.* (2000) used hierarchical cluster analysis for differentiation of cuttle fish populations in the Persian Gulf and Oman Sea and showed that the genera in these two regions are two separate populations. In the study of Pleuronectiformes, the results obtained from hierarchical cluster analysis and designing the dendrogram showed that waters of Khuzestan had 5 dendrogram clusters while Bushehr and Hormozgan each have three clusters. Some researches have focused on morphometric and meristic characteristics for identification of species, subspecies and different populations of fishes such as *Mallotus villorus* (Sharp *et al.*, 1978), *Micromesistius poutassa*   (Gamble, 1959,1960), *Chanos chanos* (Villaluz & Maccrimon, 1988), *Centropristis striata* (Shepherd, 1991), *Acipenser medirostris* (North & Farr, 2002), *Engraulis encrasicolus* (Bembo *et al*, 1996), *Salvelinus alpinus* (Doherty & Mccarthy, 2004).

The comparison of Pleuronectiformes samples in Khuzestan, Bushehr and Hormozgan with the table of identification index of species and its checklist, which includes morphometric and meristic characteristics and their relations, showed that Khuzestan province (n=741) had 6 families containing 25 species, in which Bothidae and Paralichthyidae with 7 species had the maximum and Citharidae and Psettodidae with one species had the minimum number of species. Also Soleidae with 4 species and Cynoglossidae with 5 species were identified. Ten species from 5 families of this order had higher abundance and distribution in Khuzestan waters compared to others; these species were *Psettodes erumei, Brachirus orientalis,*

Arnoglossus aspilos, Pseudorhombus elevatus, Pseudorhombus arsius, Arnoglossus arabicus, Pseudorhombus javanicus, Cynoglossus arel, Cynoglossus bilineatus and Cynoglossus puncticeps.

The morphometric and meristic traits and their relation with the table of identification index of species checklist demonstrated in the waters of Bushehr province (n=391) determined 5 families and 19 species, in which Cynoglossidae with 5 species had the highest number of species while Psettodidae with one species had the lowest number. Also from Soleidae 5 species, Paralichthyidae 4 species and Bothidae 3 species were identified. Eight species from 5 families of this order including : *Psettodes erumei, Brachirus orientalis, Arnoglossus aspilos, Pseudorhombus elevatus, Pseudorhombus javanicus, Cynoglossus arel, Cynoglossus bilineatus* and *Cynoglossus puncticeps* had the highest abundance and distribution in Bushehr waters.

In the Persian coastline of Hormozgan province (n=419), the comparison on the basis of morphometric and meristic traits and their relation with the table of identification index of species checklist demonstrated that there were 6 families and 16 species in this province. Cynoglossidae and Paralichthyidae each with 4 species had the highest number of species while Psettodidae and Citharidae with one species had the lowest number. Also Soleidae and Bothidae each had 3 species. Seven species from 5 families of this order had the highest abundance and distribution in Hormozgan waters including: *Psettodes erumei, Brachirus orientalis, Arnoglossus aspilos, Solea stanalandi, Pseudorhombus elevatus, Pseudorhombus arsius* and *Cynoglossus lachneri.*

Previous studies reported the following number of families and species from all the Arabian waters of the Persian Gulf (UAE, Saudi Arabia, Kuwait, Qatar and Bahrain), including Belgvad and Loppenthin (1942) 4 families and 14 species, Asadi and Dehghani (1996) 4 families and 9 species, Fischer and Bianchi (1983) 2 families and 10 species, and Carpenter *et al.* (1997) 6 families and 22 species. In this study, the Persian Gulf coastline in Khuzestan province 6 families and 25 species, in Bushehr 5 families and 19 species and in Hormozgan 6 families and 16 species were found, which shows this research is the most complete one which has

been conducted on the Persian coastline of Iran. Thirteen species from 5 families Persian Gulf (Khuzestan, Bushehr and Hormozgan) that have not been reported so far are identified and reported in this research.

Distribution of a species is dependent on multiple physicochemical factors such as condition of water, regional climatology, water flows and as a whole to environmental conditions (Manickchand & Heileman, 1994). The annual changes of weather in different regions, layers of water, the type of sediments, salt concentration changes, water flows etc. result in changes of the distribution and species diversity of Pleuronectiformes in the Persian Gulf. Therefore the distribution of more species is evident in Khuzestan. This is because different species are adaptable with different conditions and high biodiversity in this region. The floor of the northern parts of the Persian Gulf specially in Khuzestan province are covered with small grain sediments (muddy and sandy muddy) (ROPME, 2000), which makes a better bottom compared to southern regions (Arabian coastlines) with large grain sediments (sandy muddy, sandy). Therefore one of the effective factors in distribution and diversity of these fishes in Khuzestan is the bottom conditions. In this study, 25 species from 6 families were identified which showed some of the species are specific to Khuzestan area and thus responsible exploitation must be taken. In Bushehr province due to the lower compatibility with ecological conditions, the number of species decreases to 19 in 5 families.

Incompatibility in Hormozgan has reached its maximum and 16 species from 6 families have been reported. Some of the species (3) were specific to Hormozgan area.

Considering these facts, it could be concluded that it is essential to study the biology of Pleuronectiformes and take in account all the aspects. With respect to the sensitivity of Persian Gulf region, taking care of all the facilities, time and location limitations Pleuronectiformes capturing seems crucial. Also due to the high diversity of species in Persian Gulf especially in Khuzestan, the management of resources and specific exploitation of these species must be taken into account. Because of high capture of these fishes in these regions, it could be mentioned that

they have a very important commercial role in the life of people who live near the beach and this shows the value of this research.

Acknowledgment

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