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Patterns of Abundance and Diversity of Fishes in Iraqi Estuarine and Marine Waters of the Northwestern Arabian Gulf

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ABSTRACT

Scientific study data were collected to determine temporal changes in the patterns and abundance of fish biodiversity and variation in the abundance of fisheries to assess the status of fish populations in Iraqi marine waters. During the study, 159 species of fish were collected, the composition of which included 17 species within eight families belonging to five orders of the cartilaginous fish class, in which the order Myliobatiformes dominated, as well as 142 species, consisting of 56 families, within 17 orders of the class Actinopteri, with the order Acanthuriformes predominating among them. 101 commercial fish species were reached, while 58 species were recorded for non-commercial species. A decrease in the number of individuals, species, and monthly weights was observed during the summer season. Rare species were found to be more abundant than resident and seasonal species, with commercial species predominant over non-commercial species within the Tyler subdivision. The average index of diversity, richness, evenness, and dominance was 3.15, 9.60, 0.77, and 0.41, respectively. A decrease in the average length of the four most abundant species in fishing samples was observed. With the allometric growth of these species in relation to length and weight, relative condition index values indicate good and poor health conditions depending on the sensitivity and tolerance of the species to the environment. In conclusion, estuarine and coastal areas are unique in terms of breeding and feeding migrations, serving as a crucial habitat for young fish. Administrators use this information to make decisions on appropriate management measures to ensure the long-term sustainability of fishery resources.

INTRODUCTION

Estuaries are characterised by their high geomorphological and environmental complexity, which is linked to water cycle patterns, it is usually due to changes in freshwater discharges into the coastal ecosystem. These environmental differences have several responses in the estuarine community **(Potter *et al*., 2015; Teichert *et al*., 2017)**. It is linked to the characteristics of their life cycles, access to shelter and food, physiological characteristics, and structure of the distribution patterns of living organisms, which appear from changes in density and living mass **(Winemiller *et al*., 2015; Molina *et al*., 2020)**. Estuaries are dynamic, transitional, and unstable environments between sea and river, linked to salinity, temperature, currents, and food supplies **(James *et al*., 2013)**. Estuaries are among the most productive ecosystems on earth, and migratory fish, whether marine or riverine, frequently use them for reproduction, providing nursery, and feeding habitats, especially for young fish **(Strydom, 2015; Nashima *et al*., 2021)**. While many fish species lay their eggs in marine waters and enter river estuaries for varying periods, others complete their life cycle inside the river mouth **(Potter *et al*., 2015)**. Studies on the composition and functioning of estuarine and coastal fish assemblages are important for understanding their lifestyle characteristics, and it has become important to classify estuarine fish assemblages as an aid to understanding and managing the impacts of human activities on them **(Whitfield & Elliott, 2002; McLusky & Elliott, 2004)**.

A multitude of scholars have conducted extensive investigations about the makeup of fish species that inhabit the maritime waters of Iraq, including a study by **Mohamed *et al*. (1993)** recorded 86 species belonging to 46 families, and also the study by **Mohamed *et al*. (2002)** reported 116 species belonging to 58 families. In a study by **Mohamed and Mutlak (2008)**, they recorded 53 species and 44 genera. Additionally, in the study of **Al-Shamary *et al*. (2021)**, 91 species are part of forty-seven families of Osteichthyes (bony fish) and thirteen different species of Chondrichthyes (Cartilaginous fish) were gathered. This study provideed an overview of the temporal patterns in fish abundance, diversity, and distribution in the study area.

MATERIALS AND METHODS

1. Description of the study area

Our territorial waters are located at the head of the Arabian Gulf to the north, and the Shatt al-Arab River is the main source of freshwater that flows into it. The coastline is 48 kilometers long. Tides occur twice a day, and tidal currents are a source of movement for water currents, as well as the influence of wind. The Shatt al-Arab estuary consists of shallow water no more than 4m deep, which is an extension of the tidal flats surrounding the estuary and has a slight slope towards open water. Fish samples were taken from two sectors within the coordinates (29°50'46.806''N; 48°40'17.465''E) and (29°48'27.961''N; 48°37'16.77''E). Fig. (1) shows a map of the study area.

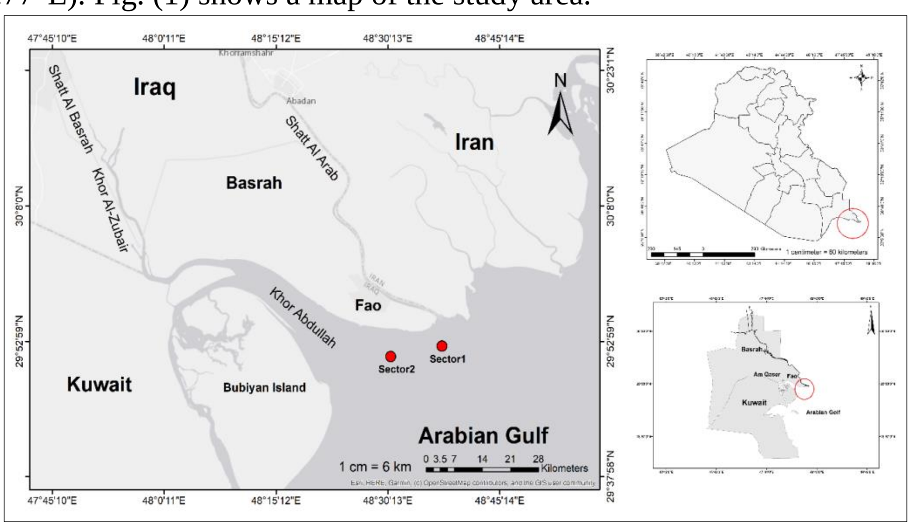

Fig. 1. Sampling sectors

2. Collecting fish samples

Fish samples were collected monthly from January 2022 to December 2022, through sea trips on a fishing boat (small trawler). It is 22.5m long and 7.5m wide and has a capacity of (240H.P.). It is equipped with a bottom trawl net length of 20m and a height of (2m), and the size of the net openings is (2.5cm). The fish samples were kept in refrigerated boxes before arriving at the laboratory.

3. Laboratory work

Fish were classified according to **Carpenter *et al*. (1997)**. Fish samples were measured by weight (kg) and length (cm), and the numbers and weights of individuals for each species were recorded monthly.

1- The monthly weight, number, and species percentages of commercial and non-commercial fish were calculated.

2- Fish species were divided, according to **Tyler (1971)**, rendering to their presence or monthly appearance into: Resident, seasonal, and rare species. These are the species that are present for 9– 12, 6– 8, and 1– 5 months, respectively.

3- Relative abundance was calculated according to **Krebs (1974)**. Relative abundance % = (ni/N) ×100

4- Biological assessment index: The composition of the marine fish community was described using biological assessment indicators to compare monthly changes.

- Diversity index: **Shannon and Weaver (1949)**. (H = - ∑ pi ln pi)
- Evenness index: **Pielou (1977)**. (J = H / ln S)
- Richness index: **Margalefe (1968)**. D= (S-1) / Ln N
- Dominants Index (D3): **Kwak and Peterson (2007)**. D3=[∑i=1pi] *100

5- Biological characteristics:

- Frequency distribution of lengths: The data on fish length groups was distributed with an interval of 1cm between each length group, and the frequency of their total lengths and weights was recorded.
- Length-weight relationship: The relationship between the length and weight of the fish and the condition factor was calculated using the following equations, according to **Le Cren (1951)**: $W = a.\ L^b$; **Fulton (1911)**: $K= 100\times W/L^3$, respectively.

RESULTS

1. Compositions of fishes' population

The composition of the fish catch included two main classes: The Chondrichthyes (Class: Elasmobranchii) and the Osteichthyes (Class: Actinopteri). The first class included five orders; these orders included eight fish families and seventeen species, among them there are six species of sharks belonging to three families and two orders, while (rays and skates) dominated the rest of the species in their class, with eleven species and five families belonging to three orders. The number of species in the Osteichthyes class reached (142) species belonging to (56) families and (17) orders.

In general, three orders were distinguished by the abundance of families and species from the rest of the orders of this class, where the order, named Acanthuriformes, prevailed than the rest of the orders of this class, comprising 16 fish families with 47 species. Followed by the Carangiformes order, which included ten fish families with thirty species. The number of families of the order Clupeiformes reached five families, which included 14 fish species, bringing the total of the study samples to 159. Table (1) shows a description of the composition of the Iraqi marine fish community in the Arabian Gulf.

Table 1. Orders, families, and species of fish caught in Iraqi territorial waters.

Seq.	Scientific Name	Common Name
	Phylum: Chordata	
	Class: Elasmobranchii	
	Order: Orectolobiformes	
	Family: Rhincodontidae	
1	*Rhincodon typus* Smith, 1828	Whale shark
	Family: Hemiscylliidae	
2	*Chiloscyllium arabicum* Gubanov, 1980	Arabian carpetshark
	Order: Carcharhiniformes	
	Family: Carcharhinidae	
3	*Carcharhinus dussumieri* (Valenciennes, 1839)	Whitecheek shark
4	*Carcharhinus leucas* (Valenciennes, 1839)	Bull shark
5	*Rhizoprionodon acutus* (Rüppell, 1837)	Milk shark
6	*Rhizoprionodon oligolinx* Springer, 1964	Grey sharpnose shark
	Order: Torpediniformes	
	Family: Torpedinidae	
7	*Torpedo sinuspersici* Olfers, 1831	Variable torpedo ray
	Order: Rhinopristiformes	
	Family: Glaucostegidae	
8	*Glaucostegus granulatus* (Cuvier, 1829)	Granulated guitarfish
	Order: Myliobatiformes	
	Family: Dasyatidae	
9	*Brevitrygon imbricata* (Bloch & Schneider, 1801)	Bengal whipray
10	*Brevitrygon walga* (Müller & Henle, 1841)	Scaly whipray
11	*Himantura bleekeri* (Blyth, 1800)	Bleeker's whipray
12	*Himantura uarnak* (Gmelin, 1789)	Honeycomb stingray
13	*Maculabatis arabica* Manjaji-Matsumoto & Last, 2016	Arabic whipray
14	*Maculabatis randalli* (Last, Manjaji-Matsumoto, 2012)	Arabian banded whipray
15	*Pastinachus sephen* (Forsskål, 1775)	Cowtail stingray
	Family: Gymnuridae	
16	*Gymnura poecilura* (Shaw, 1804)	Long-tailed butterfly ray
	Family: Aetobatidae	
17	*Aetobatus flagellum* (Bloch & Schneider, 1801)	Longheaded eagle ray
	Class: Actinopteri	
	Order: Anguilliformes	
	Family: Muraenesocidae	
18	*Muraenesox cinereus* (Forsskål, 1775)	Daggertooth pike conger
	Order: Clupeiformes	
	Family: Engraulidae	
19	*Thryssa hamiltonii* (Gray, 1835)	Hamilton's thryssa
20	*Thryssa vitrirostris* (Gilchrist & Thompson, 1908)	Orangemouth anchovy
21	*Thryssa whiteheadi* Wongratana, 1983	Whitehead's thryssa
	Family: Clupeidae	

22	*Anodontostoma chacunda* (Hamilton-Buchanan, 1822)	Chacunda gizzard shad
23	*Herklotsichthys lossei* Wongratana, 1983	Gulf herring
24	*Nematalosa nasus* (Bloch, 1795)	Bloch's gizzard shad
25	*Sardinella albella* (Valenciennes, 1847)	White sardinella
26	*Sardinella longiceps* Valenciennes, 1847	Indian oil sardine
27	*Tenualosa ilisha* (Hamilton, 1822)	Hilsa shad
	Family: Chirocentridae	
28	*Chirocentrus nudus* Swainson, 1839	Whitefin wolf-herring
	Family: Dussumieriidae	
29	*Dussumieria elopsoides* Bleeker, 1849	Slender rainbow sardine
	Family: Pristigasteridae	
30	*Ilisha compressa* Randall, 1994	Compressed ilisha
31	*Ilisha melastoma* (Bloch & Schneider, 1801)	Indian ilisha
32	*Ilisha sirishae* Seshagiri Rao, 1975	Lobejaw ilisha
	Order: Siluriformes	
	Family: Plotosidae	
33	*Plotosus lineatus* (Thunberg, 1787)	Striped eel catfish
	Family: Ariidae	
34	*Netuma bilineata* (Valenciennes, 1840)	Bronze catfish
35	*Netuma thalassina* (Rüppell, 1837)	Giant catfish
36	*Plicofollis layardi* (Günther, 1866)	Thinspine sea catfish
	Order: Aulopiformes	
	Family: Synodontidae	
37	*Saurida tumbil* (Bloch, 1795)	Greater lizardfish
	Order: Batrachoidiformes	
	Family: Batrachoididae	
38	*Colletteichthys dussumieri* (Valenciennes, 1837)	Flat toadfish
	Order: Scombriformes	
	Family: Ariommatidae	
39	*Ariomma indica* (Day, 1870)	Indian driftfish
	Family: Stromateidae	
40	*Pampus argenteus* (Euphrasen, 1788)	Silver pomfret
	Family: Scombridae	
41	*Scomber australasicus* Cuvier, 1832	Blue mackerel
42	*Scomberomorus commerson* (Lacepède, 1800)	Barred Spanish mackerel
43	*Scomberomorus guttatus* (Bloch & Schneider, 1801)	Indo-Pacific king mackerel
	Family: Trichiuridae	
44	*Eupleurogrammus glossodon* (Bleeker, 1860)	Longtooth hairtail
45	*Eupleurogrammus muticus* (Gray, 1831)	Smallhead hairtail
46	*Trichiurus lepturus* Linnaeus, 1758	Largehead hairtail
	Order: Syngnathiformes	
	Family: Mullidae	
47	*Upeneus doriae* (Günther, 1869)	Gilded goatfish
48	*Upeneus tragula Richardson, 1846*	Freckled goatfish
	Order: Kurtiformes	
	Family: Apogonidae	
49	*Apogonichthyoides taeniatus* (Cuvier, 1828)	Twobelt cardinal
	Order: Gobiiformes	
	Family: Gobiidae	

50	*Bathygobius fuscus* (Rüppell, 1830)	Dusky frillgoby
51	*Boleophthalmus dussumieri* Valenciennes, 1837	There is no common name
52	*Cryptocentrus lutheri* Klausewitz, 1960	Luther's prawn-goby
53	*Trypauchen vagina* (Bloch & Schneider, 1801)	There is no common name
	Order: Carangiformes	
	Family: Sphyraenidae	
54	*Sphyraena obtusata* Cuvier, 1829	Obtuse barracuda
55	*Sphyraena putnamae* Jordan & Seale, 1905	Sawtooth barracuda
56	*Sphyraena qenie* Klunzinger, 1870	Blackfin barracuda
	Family: Polynemidae	
57	*Eleutheronema tetradactylum* (Shaw, 1804)	Fourfinger threadfin
58	*Polydactylus sextarius* (Bloch & Schneider, 1801)	Blackspot threadfin
	Family: Psettodidae	
59	*Psettodes erumei (Bloch & Schneider, 1801)*	Indian halibut
	Family: Paralichthyidae	
60	*Pseudorhombus arsius* (Hamilton, 1822)	Largetooth flounder
	Family: Soleidae	
61	*Brachirus orientalis* (Bloch & Schneider, 1801)	Oriental sole
62	*Solea stanalandi* Randall & McCarthy, 1989	Stanaland's sole
	Family: Cynoglossidae	
63	*Cynoglossus arel* (Bloch & Schneider, 1801)	Largescale tonguesole
64	*Cynoglossus bilineatus*) Lacepède, 1802(	Fourlined tonguesole
	Family: Menidae	
65	*Mene maculata* (Bloch & Schneider, 1801)	Moonfish
	Family: Carangidae	
66	*Alepes djedaba* (Forsskål, 1775)	Shrimp scad
67	*Alepes kleinii* (Bloch, 1793)	Razorbelly scad
68	*Alepes melanoptera* (Swainson, 1839)	Blackfin scad
69	*Atropus atropos* (Bloch & Schneider, 1801)	Cleftbelly trevally
70	*Carangoides bajad* (Forsskål, 1775)	Orangespotted trevally
71	*Carangoides coeruleopinnatus* (Rüppell, 1830)	Coastal trevally
72	*Carangoides malabaricus* (Bloch & Schneider, 1801)	Malabar trevally
73	*Gnathanodon speciosus* (Forsskål, 1775)	Golden trevally
74	*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad
75	*Parastromateus niger* (Bloch, 1795)	Black pomfret
76	*Rastrelliger kanagurta* (Cuvier, 1816)	Indian mackerel
77	*Scomberoides commersonnianus* Lacepède, 1801	Talang queenfish
78	*Selaroides leptolepis* (Cuvier, 1833)	Yellowstripe scad
79	*Seriolina nigrofasciata* (Rüppell, 1829)	Blackbanded trevally
80	*Trachinotus blochii* (Lacepede, 1801)	Snubnose pompano
81	*Trachurus indicus* Nekrasov, 1966	Arabian scad
82	*Uraspis helvola* (Forster, 1801)	Whitetongue jack
	Family: Echeneidae	
83	*Echeneis naucrates* Linnaeus, 1758	Live sharksucker
	Family: Rachycentridae	
84	*Lutjanus sanguineus* (Cuvier, 1828)	Humphead snapper
	Order: Cichliformes	
	Family: Cichlidae	
85	*Oreochromis aureus* (Steindachner, 1864)	Blue tilapia

	Order: Beloniformes	
	Family: Belonidae	
86	*Strongylura leiura* (Bleeker, 1850)	Banded needlefish
87	*Strongylura strongylura* (van Hasselt, 1823)	Spottail needlefish
	Family: Hemiramphidae	
88	*Rhynchorhamphus georgii* (Valenciennes, 1847)	Long billed half beak
	Order: Mugiliformes	
	Family: Mugilidae	
89	*Osteomugil speigleri* (Bleeker, 1858)	Speigler's mullet
90	*Planiliza abu* (Heckel, 1843)	Abu mullet
91	*Planiliza klunzingeri* (Day, 1888)	Klunzinger's mullet
92	*Planiliza subviridis* (Valenciennes, 1836)	Greenback mullet
	Order: Perciformes	
	Family: Epinephelidae	
93	*Cephalopholis hemistiktos* (Rüppell, 1830)	Yellowfin hind
94	*Epinephelus areolatus* (Forsskål, 1775)	Areolate grouper
95	*Epinephelus bleekeri* (Vaillant, 1878)	Duskytail grouper
96	*Epinephelus diacanthus* (Valenciennes, 1828)	Spinycheek grouper
97	*Epinephelus epistictus* (Temminck & Schlegel, 1842)	Dotted grouper
98	*Epinephelus latifasciatus* (Temminck & Schlegel, 1842)	Striped grouper
	Family: Labridae	
99	*Choerodon robustus* (Günther, 1862)	Robust tuskfish
100	*Scarus ghobban* Forsskål, 1775	Blue-barred parrotfish
	Family: Platycephalidae	
101	*Platycephalus indicus* (Linnaeus, 1758)	Bartail flathead
	Family: Synanceiidae	
102	*Pseudosynanceia melanostigma Day, 1875*	Blackfin stonefish
	Order: Centrarchiformes	
	Family: Terapontidae	
103	*Terapon jarbua* (Forsskål, 1775)	Jarbua terapon
104	*Terapon puta Cuvier, 1829*	Small-scaled terapon
105	*Pelates quadrilineatus* (Bloch, 1790)	Fourlined terapon
106	*Terapon theraps* Cuvier, 1829	Largescaled terapon
	Order Acanthuriformes	
	Family: Priacanthidae	
107	*Priacanthus tayenus* Richardson, 1846	Purple-spotted bigeye
	Family: Sillaginidae	
108	*Sillago sihama* (Forsskal, 1775)	Silver sillago
	Family: Lutjanidae	
109	*Lutjanus ehrenbergii* (Peters, 1869)	Blackspot snapper
110	*Lutjanus indicus* Allen, White & Erdmann, 2013	There is no common name
111	*Lutjanus johnii* (Bloch, 1792)	John's snapper
112	*Lutjanus lutjanus* Bloch, 1790	Bigeye snapper
113	*Lutjanus sanguineus* (Cuvier, 1828)	Humphead snapper
	Family: Gerreidae	
114	*Gerres infasciatus* Iwatsuki & Kimura, 1998	Nonbanded whipfin mojarra
115	*Gerres longirostris*) Lacepède, 1801(	Strongspine silver-biddy
116	*Gerres oyena* (Forsskål, 1775)	Common silver-biddy
	Family: Haemulidae	

117	*Diagramma pictum* (Thunberg, 1792)	Painted sweetlips
118	*Plectorhinchus pictus* (Tortonese, 1936)	Trout sweetlips
119	*Pomadasys kaakan* (Cuvier, 1830)	Javelin grunter
120	*Pomadasys maculatus* (Bloch,1793)	Saddle grunt
121	*Pomadasys stridens* (Forsskål, 1775)	Striped piggy
	Family: Sparidae	
122	*Acanthopagrus arabicus* Iwatsuki, 2013	Arabian seabream
123	*Acanthopagrus bifasciatus* (Forsskål, 1775)	Twobar seabream
124	*Acanthopagrus sheim Iwatsuki, 2013*	Spotted yellowfin seabream
125	*Argyrops spinifer* (Forsskal, 1775)	King soldierbream
126	*Crenidens crenidens* (Forsskål, 1775)	Karanteen seabream
127	*Crenidens indicus* Day, 1873	There is no common name
128	*Diplodus kotschyi* (Steindachner, 1876)	One spot seabream
129	*Pagellus affinis* Boulenger, 1888	Arabian pandora
130	*Rhabdosargus haffara* (Forsskål, 1775)	Haffara seabream
131	*Sparidentex hasta* (Valenciennes, 1830)	Sobaity seabream
	Family: Lethrinidae	
132	*Lethrinus lentjan* (Lacepede, 1802)	Pink ear emperor
133	*Lethrinus microdon* Valenciennes, 1830	Smalltooth emperor
134	*Lethrinus nebulosus (Forsskal, 1775)*	Spangled emperor
	Family: Nemipteridae	
135	*Nemipterus japonicus* (Bloch, 1791)	Japanese threadfin bream
136	*Nemipterus zysron* (Bleeker, 1856)	Slender threadfin bream
137	*Scolopsis ghanam* (Forsskål, 1775)	Arabian monocle bream
138	*Scolopsis taeniata* (Cuvier, 1830)	Black-streaked monocle bream
139	*Scolopsis vosmeri* (Bloch, 1792)	Whitecheek monocle bream
	Family: Sciaenidae	
140	*Johnius belangerii* (Cuvier, 1830)	Belanger's croaker
141	*Nibea maculata* (Bloch & Schneider, 1801)	Blotched croaker
142	*Otolithes ruber* (Bloch & Schneider, 1801)	Tigertooth croaker
143	*Pennahia anea* (Bloch, 1793)	Donkey croaker
144	*Protonibea diacantha* (Lacepede, 1802)	Blackspotted croaker
	Family: Pomacanthidae	
145	*Pomacanthus maculosus* (Forsskål, 1775)	Yellowbar angelfish
	Family: Drepaneidae	
146	*Drepane longimana* (Bloch & Schneider, 1801)	Concertina fish
	Family: Chaetodontidae	
147	*Heniochus acuminatus* (Linnaeus, 1758)	Pennant coralfish
	Family: Ephippidae	
148	*Ephippus orbis* (Bloch, 1787)	Orbfish
149	*Platax teira* (Forsskål, 1775)	Longfin batfish
	Family: Leiognathidae	
150	*Equulites oblongus* (Valenciennes, 1835)	Oblong ponyfish
151	*Photopectoralis bindus* (Valenciennes, 1835)	Orangefin ponyfish
	Family: Scatophagidae	
152	*Scatophagus argus* (Linnaeus, 1766)	Spotted scat
	Family: Siganidae	
153	*Siganus canaliculatus* (Park, 1797)	White-spotted spinefoot

154	*Siganus javus* (Linnaeus, 1766)	Streaked spinefoot
	Order: Tetraodontiformes	
	Family: Triacanthidae	
155	*Triacanthus biaculeatus* (Bloch, 1786)	Short-nosed tripodfish
	Family: Tetraodontidae	
156	*Lagocephalus guentheri* Miranda Ribeiro, 1915	Diamondback puffer
157	*Lagocephalus lunaris* (Bloch and Schneider,1801)	Lunartail puffer
	Family: Monacanthidae	
158	*Paramonacanthus choirocephalus* (Bleeker, 1851)	Pig faced leather jacket
	Family: Balistidae	
159	*Abalistes stellatus* (Anonymous, 1798)	Starry triggerfish

1.1. Changes in the composition of the fish community

The number of fish samples caught during the study period was 7836. Fig. (2) shows the monthly changes in the number of species, individuals, and monthly fish weights. The figure exhibits that the lowest number of individuals was recorded in August and amounted to (147) individuals, and the highest was in May (1657) individuals, with an average number of individuals reaching (653) individuals. The lowest diversity was caught during August, amounting to 29 species, and June witnessed the highest diversity, amounting to 76 species, with a monthly average of 62 species. The results of the monthly catch weights showed that the lowest weights appeared in August and amounted to 15.487kg, while the highest values were recorded in February and were 111.487kg, with a monthly catch rate of 63.97kg and a total annual catch of 767.620kg.

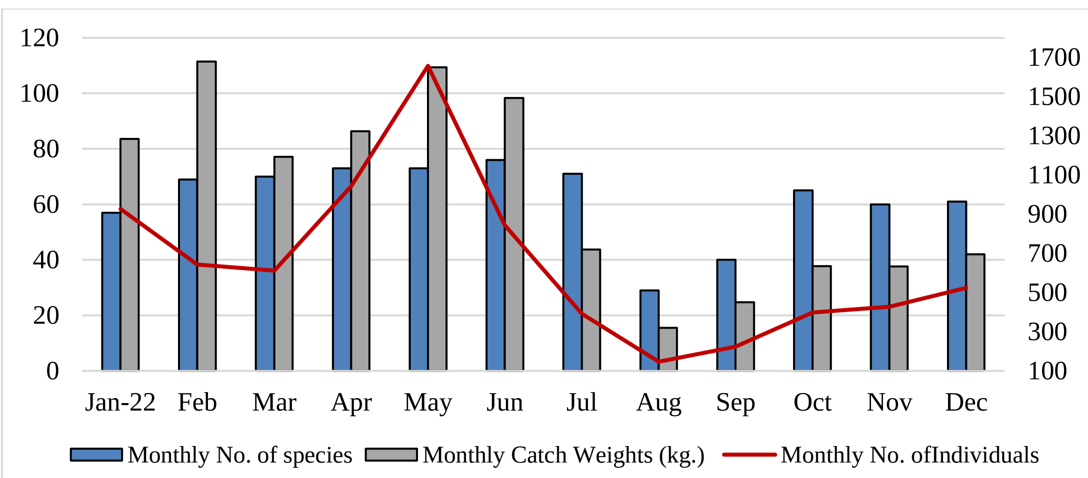

Fig. 2. Number of individuals, species, and monthly weights during the study

1.2 Changes in the composition of commercial and non-commercial fish

Fig. (3) shows the monthly numbers of individuals for the composition of commercial and non-commercial fish, the total number of individuals of commercial species reached 5967, which is equivalent to 76.14 percent of the total number of individuals of caught fish. The lowest numbers were recorded in August and reached 115 individuals, while the highest numbers reached (1075) individuals in May, with a monthly average of (497.25) individuals. The number of individuals of non-commercial species constituted (23.86%) of the total number of individuals, and the lowest numbers were (32) individuals in August, while the highest numbers were recorded in May and amounted to (582) individuals, with a monthly average of (155.75) individuals.

The weights of commercial and non-commercial species were measured, and the data for commercial species shows that their total weights reached 665.481kg, representing 86.69% of the total catch. The highest catch values were in February (108.427kg) and the lowest were in August (9.545kg), with an average monthly weight of 55.457kg. The total weight of non-commercial species reached 102.139kg, which is equivalent to 13.31% of the total weight, the lowest weights were in November (1,236kg) and the highest were in June (19.481kg), with an annual average of 8.512kg. The number of commercial fish species reached 101 species, while the number of non-commercial fish species reached 58 species.

Fig. (3) shows the monthly variation between the composition of commercial and non-commercial fish diversity. The lowest types of commercial fish collected in August were 19 species, and the highest species in March were 52 species, with a monthly average of 40 species. In August, the lowest number of non-commercial species was 10, and the highest number of species was recorded in June, which reached 33 species with a monthly average of 22 species. The percentage of commercial species was 63.5% of the total number caught, while the percentage of non-commercial species was 36.5%.

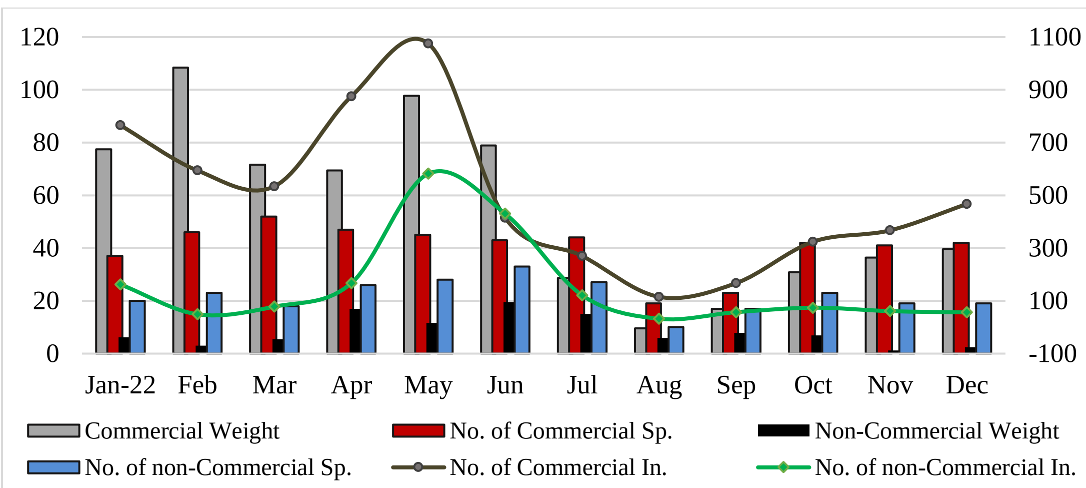

Fig. 3. Monthly changes in the composition of commercial and non-commercial fish

2. Species occurrence

Fish species were divided according to **Tyler (1971)** into three groups, as shown in Fig. (4), which shows the fish species included in each group, The first group (resident species), which repeatedly appeared in catch samples from 9– 12 months ago, included 28 species and constituted 17.6% of the total number of species caught. The members of this group contained 18 species of commercial fish and 10 species of non-commercial fish, i.e., 64.3% and 35.7% for each of them, respectively. The second group (seasonal species), which appeared repeatedly over 6– 8 months, consisted of 23 species and constituted 14.5% of the total number of species caught. The members of this group consisted of 12 species of commercial fish and 11 species of non-commercial fish (52% and 48%), respectively. The third group (rare species) represented the largest number of species during the study, and its presence was repeated from 1– 5 months, which included

108 species and constituted (67.9%) of the total number of species caught. The species members of this group contained 68 species of commercial fish and 40 non-commercial species, with a percentage of 63 and 37% for each of them, respectively.

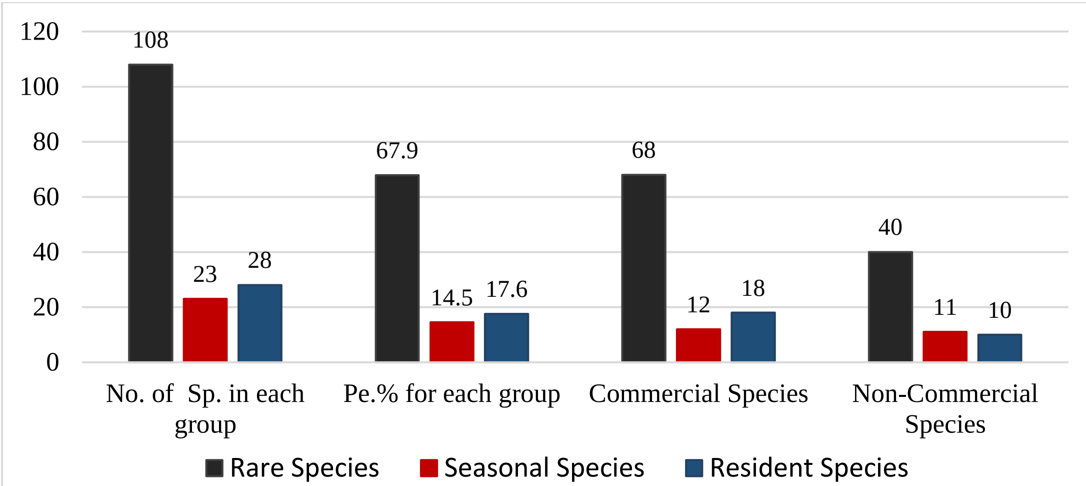

Fig. 4. Occurrence of resident, seasonal, and rare species

3. Environmental evidence

Fig. (5) shows the values of the diversity and richness indexes, along with the evenness index and the dominance index for the study samples. The lowest values of the biodiversity index were (2.78) in August, and the highest values were recorded in July (3.64), with a monthly average of (3.15). The values of the richness index were recorded at the lowest levels in August (5.61), while the highest values were in July (11.73), with a monthly average of 9.60, and the lowest values of the evenness index were (0.66) in June, while the highest values were recorded in September (0.89) at a monthly rate of 0.77. The dominance index (0.29) reached its lowest levels during July and September, and its highest value was recorded in June (0.49) at a monthly rate of 0.41.

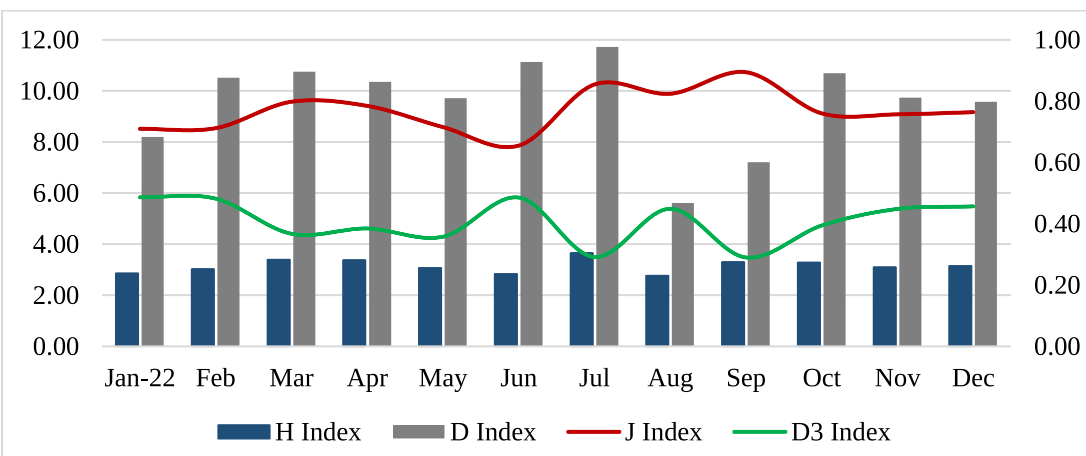

Fig. 5. The value of environmental evidence

4. Biological characteristics

4.1. Frequency distribution of lengths

Four species predominated among the total number of commercial fish species, and they stood out for their numerical abundance: *Sillago sihama*, *Johnius belangerii*, *Cynoglossus arel*, *Pennahia anea*. Fig. (6) displays the frequency distribution of annual length totals for these species. The total lengths of *S. sihama* fish were divided into two length categories, starting at 10– 12cm and ending at 26– 28cm. The highest number of individuals was in the category (14– 16cm), amounting to 313 individuals at a rate of 33.02%, and the lowest number of individuals was in the two height categories (10– 12, 26– 28cm), which amounted to only four individuals at a rate of 0.42%. The lowest length for this species was 11.5cm for two individuals, and the largest length was 27cm for only one individual, with an average length of 16.5cm. The total number of individuals for this species reached 948.

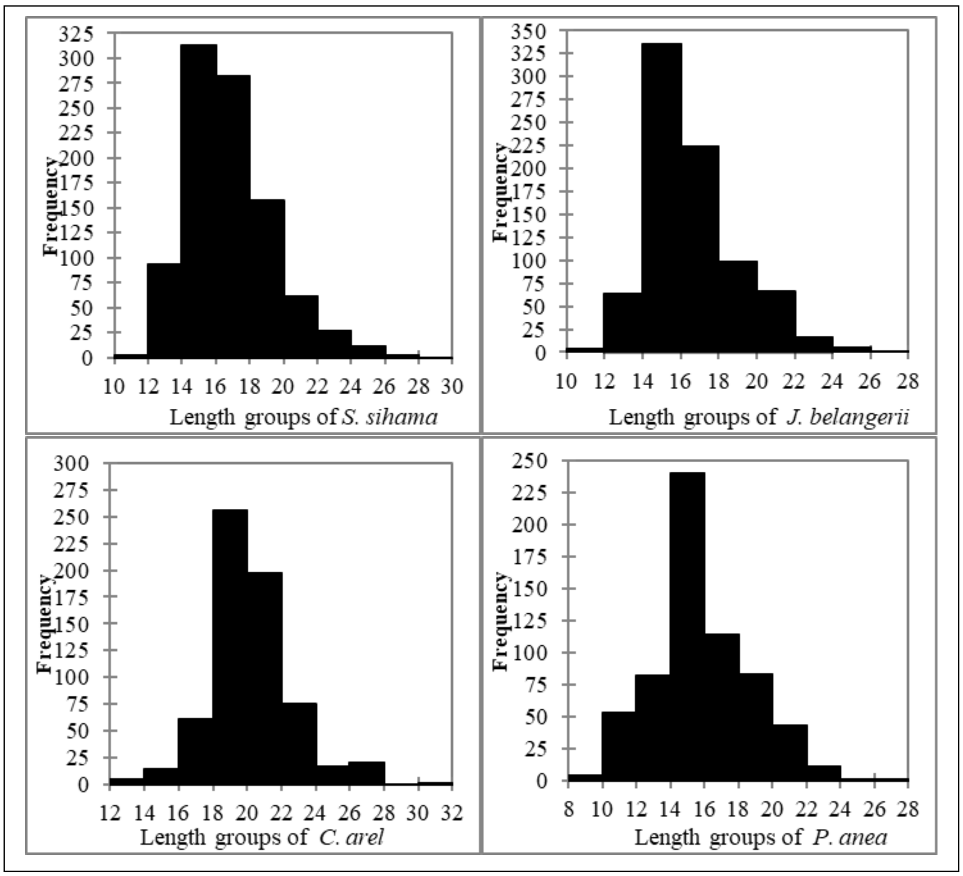

Fig. 6. The frequency distribution of lengths for some fish species

The length categories for *J. belangerii* fish started from 10–12cm and ended at 26–28cm. The highest number of individuals was in the 14–16cm category, reaching 335 individuals (41%), and the lowest number of individuals was in the two length categories (26–28cm). There was only one individual, at a rate of 0.12%. The minimum length of this species was 10cm for only one specimen, and the largest length was 27cm for only one individual, with an average length of 16cm. The total number of individuals for this species reached 832.

The ranges of length categories for *C. arel* fish ranged from 12–14cm to 30–32cm. The highest number of individuals within the (18–20cm) category reached 256 individuals, at a rate of 40%, and the lowest number of individuals was within the two length categories (30– 32cm). Only one individual, with a rate of 0.15%, caught the smallest length of this species (13cm) for only five samples of fish of this species, and the largest length (31cm) belonged to only one individual, with an average length of 20cm. The total number of individuals for this species reached 681 individuals. During the study period, it was noticed that there were no individual fish within the length category (28–30). The length categories started from 8–10cm and ended at 26–28cm for *P. anea* fish. The highest number of individuals in the (14–16cm) category was 240, at a rate of 38%, and the lowest number of individuals was in the two length categories (24–26, 26–28cm), and only two individuals reached a rate of 0.0015%. The smallest length of this species (9.5cm) was caught for only four specimens, and the largest length (27cm) belonged to one individual, with an average length of 15.5cm. The total number of individuals reached 632.

4.2. The relationship of length to weight and the condition factor

The relationship between length and weight was extracted for the four most abundant species in the total catch samples, and Fig. (7) represents the form of the exponential relationship between length and weight for the four species. Table (2) shows the formula for the exponential relationship between the length and total weight of the four species with the coefficient of determination (R^2) and the total number of individuals during the study period.

Table 2. Values of the exponential equation for the length-weight relationship

Species	No. of individuals	Length weight relationship	Coefficient of determination (R^2)
S. sihama	948	$W=0.0047*L^{3.1476}$	$R^2=0.957$
J. belangerii	832	$W=0.0052*L^{3.2804}$	$R^2=0.939$
C. arel	681	$W=0.0055*L^{2.9089}$	$R^2=0.858$
P. anea	632	$W=0.0049*L^{3.3052}$	$R^2=0.961$

Table (3) shows the values of the relative condition factor according to the length categories for each species. The values show a difference in the health condition of each species, since the relative condition factor of S. sihama fish is low and that of C. arel fish is steeper, meaning their growth is weak. Both species *J. belangerii* and *P. anea*, exhibited a good condition index, despite inhabiting the same environment and exposed to the same conditions.

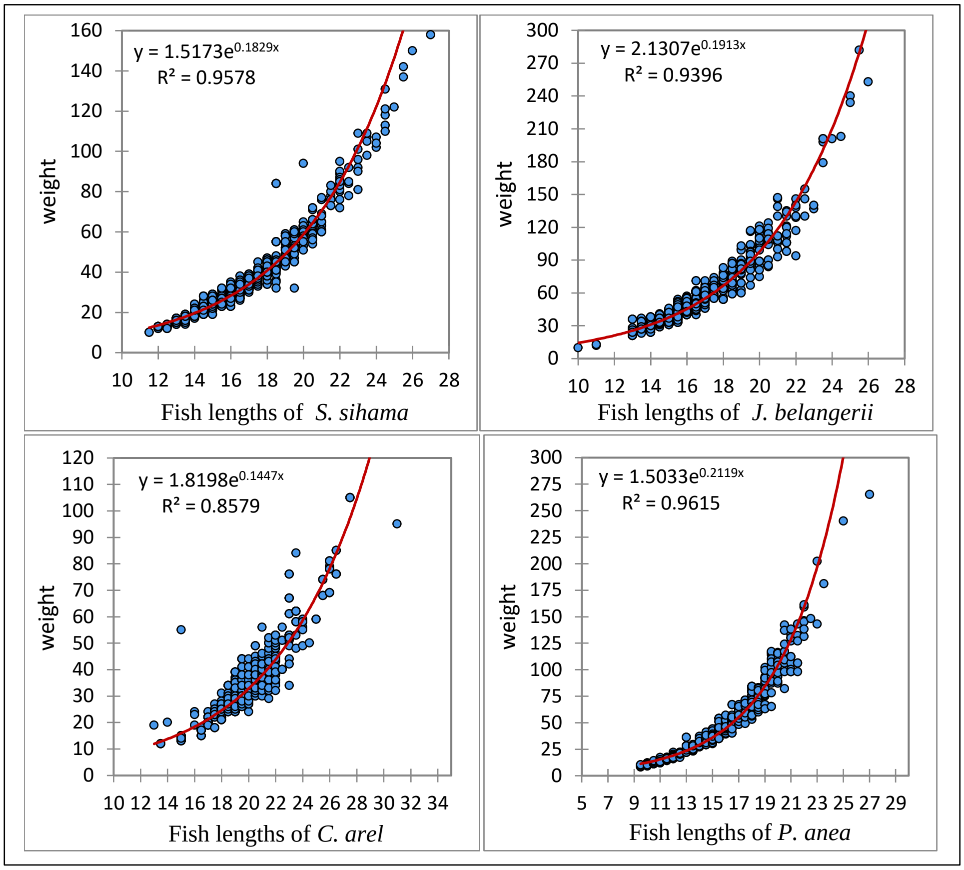

Fig. 7. The relationship of length - weight for some species of fish

Table 3. Relative condition factor values for some types of fish

Length range		No. of ind. for each category	Percentage of individuals	Percentage for each category	Condition factor (K)
S. sihama					
10	12	2	0.2%	0.1%	0.66
12	14	93	9.8%	4.9%	0.70
14	16	313	33.0%	16.5%	0.71
16	18	282	29.8%	14.9%	0.71
18	20	157	16.6%	8.3%	0.73
20	22	61	6.4%	3.2%	0.74
22	24	27	2.9%	1.4%	0.78
24	26	11	1.2%	0.6%	0.80
26	28	2	0.2%	0.1%	0.83
J. belangerii					

Length range		No. of ind. for each category	Percentage of individuals	Percentage for each category	Condition factor (K)
10	12	4	0.5%	0.2%	0.96
12	14	64	7.9%	3.9%	1.15
14	16	335	41.3%	20.6%	1.11
16	18	223	27.5%	13.7%	1.16
18	20	98	12.1%	6.0%	1.19
20	22	66	8.1%	4.1%	1.24
22	24	16	2.0%	1.0%	1.28
24	26	5	0.6%	0.3%	1.51
26	28	1	0.1%	0.1%	1.44
C. arel					
Length range		No. of ind. for each category	Percentage of individuals	Percentage for each category	Condition factor (K)
12	14	5	0.8%	0.4%	0.56
14	16	14	2.2%	1.1%	0.52
16	18	61	9.4%	4.7%	0.42
18	20	256	39.6%	19.8%	0.42
20	22	197	30.5%	15.2%	0.41
22	24	75	11.6%	5.8%	0.43
24	26	17	2.6%	1.3%	0.41
26	28	20	3.1%	1.5%	0.44
30	32	1	0.2%	0.1%	0.32
P. anea					
Length range		No. of ind. for each category	Percentage of individuals	Percentage for each category	Condition factor (K)
8	10	4	0.6%	0.3%	1.08
10	12	53	8.4%	4.2%	1.04
12	14	82	13.0%	6.5%	1.09
14	16	240	38.0%	19.0%	1.11
16	18	114	18.0%	9.0%	1.15
18	20	83	13.1%	6.6%	1.22
20	22	43	6.8%	3.4%	1.27
22	24	11	1.7%	0.9%	1.38
24	26	1	0.2%	0.1%	1.54
26	28	1	0.2%	0.1%	1.35

DISCUSSION

The numerical abundance was represented by the dominance of four species over the rest of the marine fish composition during the study period with a 50.71%, and these four species constituted a percentage not exceeding 2.5% of the total number of species. This percentage indicates the low quality of the ecosystem, and this situation is inversely related to the balance of the fish community **(Kwak & Peterson, 2007)**. Fish numbers vary due to density-dependent processes that determine supply, growth, natural mortality, and fishing response, and most natural (non-fishing-related) fluctuations are related to supply and are assumed to indicate the independent effect of density due to fluctuating environmental factors **(Rose *et al*., 2001; Matte *et al*., 2020)**.

Patterns of species occurrence may be due to various factors that influence how species are distributed across an area and at what time. Through monthly net fishing, at least three groups of species were distinguished: The resident species, which ranked second among the rest of the groups, while the second group was the seasonal species, which was the lowest among the rest of the groups, and the third group, which had the highest specific abundance, was the rare species. This indicates that the latter enters the territorial waters for several purposes, either for both reproduction and laying eggs in the downstream area, or enter the Shatt al-Arab River for the same purpose or for a short period feeding. Seasonal species may enter the area to reproduce, return from other breeding areas to their original habitat, or enter to feed until they reach the size of juveniles or adults, and then they go to the open sea to complete their life cycle. While resident species live, reproduce and have all of its life stages in the same region. Except for a short period of its life that they may enter the Shatt al-Arab River or into open waters at sea.

Species occurrence patterns at spatial and temporal scales can provide insight into how fish species distribution and community composition are determined. Identifying temporal shifts in occurrence patterns and influencing factors is important for conserving the biodiversity of fish species. However, species occurrence patterns in the estuary are not well understood in terms of temporal dynamics, especially monthly changes, and migratory fish species can contribute to the formation of large species pairs and structured patterns in the estuary **(Wang *et al*., 2022; Cheng *et al*., 2023)**.

Three indices of diversity are widely used in ecology: The Shannon index, species richness, and the Simpson index. Developing any measure for diversity is difficult since the variables that analysis by ecologists cannot estimate the diversity of a community unbiasedly based on a random sample of it **(Roswell *et al*., 2021)**. Species diversity is one of the most frequently and quantitatively measured things in ecology. However, how to measure it is complex and sometimes controversial. The past decade had seen a major advance in comparing and standardising different measures of diversity and in developing of methods for standardising samples before measuring diversity **(Chao *et al*., 2020)**.

Our results show that the diversity index values are good, even at their annual average level, but the negative effect appears after the temperature rise during August, with driping of the index values below the half of its ranges. The observed diversity index values ranged between 1.5 and 3.5 and rarely reached its highest level of 4, and in communities containing a very large number of species, this number exceeded 4 **(Ortiz-Burgos, 2016)**. The richness index was affected and followed the same path as the diversity index by the rise in temperature during August. The dominance index is complementary to the evenness index; this can be seen in Fig. (5). It is also observed that the values of the two indexes were almost homogeneous during the study year, except in summer for the period of June to September; this may be due to the lack of homogeneity between the number of species and the number of individuals during the mentioned season.

The study by **Al-Shamary *et al*. (2021)** found the highest value of the diversity index to be 3.3 in the third station and the lowest value to be 1.73 in the first station. The ranges of the richness index were 2.7– 6, 3.1– 7.8, and 4– 9.3 in the three stations, respectively, and the average range of the evenness index values was 0.89– 0.7. Their study revealed declining biodiversity, richness, and evenness. **Al-Hassan and Hussain (1985)** collected sixteen species of marine fish in the central and northern Shatt al-Arab, most of which are pelagic species, and they are widely spread in the Arabian Gulf.

Hussain *et al*. (1988) compiled a checklist of fish in Khor Al-Zubair, recording 80 fish species within 46 families, with the Clupeidae family predominating at 8.7%. The study by **Mohamed *et al*. (2002)** recorded the composition of the fish community and recorded 116 species of marine fish belonging to 58 families, including 16 species belonging to 9 families of cartilaginous fish, the Clupeidae family prevailed with 10 species. A study by **Mohamed and Abood (2020)** was conducted to analyze the quantities of artisanal fisheries over three years. Monthly data were collected from the landing site in the city of Al-Fao. The total species presented reached 35 species within 18 families. The study by **Al-Faisal and Mutlak (2018)** included a list of 214 species of marine fish belonging to seventy-five families. The Carangidae family was the most dominant and represented by twenty-four species, followed by Haemulidae with eleven species, then Serranidae and Sparidae with six species, and finally, thirty-four families included only one species. **Ali *et al*. (2018)** indicate in a review of the literature related to marine fish, that there were catch in the regional marine waters of Iraq or brackish waters, fresh waters, and marshes from 1874 until mid-2018, there were 322 species belonging to 193 genera, 94 families, and 26 orders. In the study of **Al-Shamary and Younis (2023)**, thirteen species of the cartilaginous fish class Chondrichthyes, belonging to 8 families, 12 genera, and 6 orders, were collected. It was observed from data on the lengths of the four species of fish that the most frequent occurrence of lengths for those species ranged between 14 and 16cm for three of them, except for *C. arel*, where the length of 18– 20cm prevailed, and the maximum length of *S. sihama* fish reached 27cm.

The study by **Muchlis and Restiangsih (2021)** recorded the average length of *S. sihama* is 18.13cm, and the length at first maturity is 22.66cm. This observation shows that individuals of this species are unable to preserve their stocks due to hunting them before their first maturity, and the peak season is expected for the period of laying eggs in this area in August. The results of the previous researcher's study were consistent with the Fish Base database, since it determined the total length at sexual maturity to be 22.5cm for *S. sihama* fish.

Relationships between fish length and weight are used as important biological information for fisheries management. This relationship helps determine the growth pattern and biomass from the estimated weight and is useful for obtaining information on the growth status of the fish to estimate whether growth is isometric or allometric. Fish generally increase in size (length and weight) during growth, and the main factors that affect their growth are the amount of food available, the number of fish using the same food source, temperature, oxygen, and other water quality factors, along with the size, age, and sexual maturity of the fish **(Froese, 2006; Giarrizzo, 2015; Das *et al*., 2022)**.

It is noted from Table (2) that all four studied species have similar positive growth because the value of (b) is close to 3. This indicates the high quality of the environment as a result of supplying the Shatt al-Arab mouth with nutrients that support primary productivity in the environment of the study area. The relationship between length weight and condition factors is of great importance in fishery assessment studies since they provide information on the assessment of the general health status of fish, provide information on quality and environmental suitability, as indicators, reflect the interaction between biotic and abiotic factors and the physiological conditions of fish. Condition factors are used to compare fish fatness, with heavier fish of a specific length being in better condition **(Blackwell *et al*., 2000; Jisr *et al*., 2018; Mehanna & Farouk, 2021; Ragheb, 2023)**.

Table (3) shows the relative condition factor values according to length categories. It shows that the condition factor values are low for the species *S. sihama* and very low for the second species, *C. arel*, which is a benthic species. While the two species (*J. belangerii*; *P. anea*) were in good condition, as the values of the relative condition factor were more than one over the months and according to the height categories. Here, it is essential to point out the sensitivity and tolerance of each species to environmental factors. Another factor that may be affected by these conditions is the tolerance of the species in question, such as food scarcity, the relationship between predator and prey, the possibility of a break in the food chain, the impact of protected habitats, etc.

CONCLUSION

The fish community is unbalanced despite its great diversity, and rare species constitute a large percentage of the community composition. We conclude that it is a migration, breeding, feeding, and sheltering area for the larvae of many fish. The environmental indicators had good values, however the high temperature in summer affected the variation in the number of individuals and species of fish. Growth is negative and allometric for several species due to low quality and environmental suitability.

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