

## Research Article

# Annual food consumption/biomass ratio of demersal fish resources in the Persian Gulf and Oman Sea

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## Abstract

The consumption/Biomass (Q/B) ratio and aspect ratio are basic inputs to mass-balanced trophic structures that are frequently used by ECOPATH software program. Here, we listed Q/B ratio for 154 fish species of the Persian Gulf and the Gulf of Oman to contribute to mass-balanced trophic model parametrization. Samples were collected using a research vessel bottom trawl from the Persian Gulf and the Gulf of Oman (Hormozgan province) between May and December 2017. All species were classified into six ecological groups (demersal, benthopelagic, reef-associated, pelagic-neritic, pelagic-oceanic, and bathypelagic). The aspect ratio value for all species ranged from 0.59 for *Plotosus lineatus* to 5.16 for *Megalaspis cordyla*. On the other hand, the Q/B ratio varied from 3.94 for *Epinephelus coioides* to 29.47 for *Pentaprion longimanus*. The Q/B index quantifies the proportion of food consumed within the ecosystems of the Persian Gulf and Gulf of Oman, establishing a significant correlation with fish production. It serves as a fundamental parameter in ECOPATH modeling, which is essential for sustainable fishing practices and effective fisheries management.

## Article info

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## Introduction

Advanced fishing technology has led to critical conditions to many marine ecosystems worldwide (Christensen *et al.*, 2003; Froese and Proelß, 2010; Coll *et al.*, 2013). Like other marine ecosystems, the Persian Gulf and Gulf of Oman aquatic resources may face the same difficult situation due to overfishing, loss of habitats and nursery ground, oil pollution, and temperature stress during the past three decades (Nadim *et al.*, 2008). In this case, fisheries statistics have shown a significant reduction of many commercial aquatic resources in these regions (Valinassab *et al.*, 2006). Although it is a notable region in terms of biodiversity in the northwestern Indian Ocean (Randall *et al.*, 1978; Randall, 1996; Assadi and Dehghani, 1997; Carpenter *et al.*, 1997), many of its ecosystems are remarkably changed due to high fishing intensity (Valinassab *et al.*, 2006) and direct anthropogenic stressors (Hamza and Munawar, 2009). Specifically, increasing the fleets and fishing efforts maintain intensive pressure on the Persian Gulf and the Gulf of Oman marine resources (Valinassab *et al.*, 2006). Also, countries around the Persian Gulf and Gulf of Oman have misreported their artisanal and industrial catches, including discards, recreational, subsistence, and illegal fishing sectors (Al-Abdulrazzak *et al.*, 2015).

Ecosystem modeling operating Ecopath with Ecosim (EwE) software presents a new approach to fisheries management, sustainable fisheries, and fisheries models (Christensen and Pauly, 1992; Pauly *et al.*, 2000). These ecosystem models are used to simulate the transfer of energy and mass between and within the different trophic

levels in the ecosystem based on mathematical relationships (Pauly *et al.*, 2000). To contribute to the mass balance model, much information is required from an ecosystem, aquatics and their interactions. Consumption is one of the input parameters necessary for the construction of Ecopath models, which is intake of food by a species/group over a duration of time that is usually represented on an annual basis (Christensen and Pauly, 1993). The annual food consumption/biomass ratio (Q/B ratio) has been explained as the number of times a population consumes its weight in a year (Pauly, 1986). Christensen and Pauly's study on the published Ecopath models shows an extended usage of empirically derived Q/B values in most cases (see Christensen and Pauly, 1993). Also, it is important to understand how consumption and metabolism rates scale with body mass and temperature to know if and how the body growth of large fish within populations is limited by temperature and evaluate the physiological basis of growth models (Lindmark *et al.*, 2022). Such data can be utilized as input values in cases when local Q/B estimates are unavailable for the species and also for comparison intentions.

In comparison with other ecosystems, required input information for mass-balanced trophic structure modeling in the Persian Gulf and Gulf of Oman is very scarce (Tajzadeh Namin *et al.*, 2020). In the present study, we aimed to estimate the Q/B ratio for 154 species divided into six main ecological groups (demersal, benthopelagic, reef-associated, pelagic-neritic, pelagic-oceanic, and bathypelagic)

from the Persian Gulf and Gulf of Oman. Our results provide new insights as basic input parameters for future ecosystem-based fisheries management in this region.

### Materials and methods

The study area was located in Iranian waters of the Persian Gulf and Gulf of Oman (Hormozgan province), with coordinates 25° 23' and 28° 57' North and 52° 41' and 58° 00' East (Fig. 1). Specimens were captured during two cruises using commercial bottom trawler (with headline of 72 m and 60 min of duration) with “FERDOWS-1” between October and December 2017, included sampling at 109 randomly stations over the coastal and continental shelf areas and the upper slopes from 0 to 50 m in the Persian Gulf, and from 0 to 100 m in the Gulf of Oman. The biomass of each species was estimated

based on Sparre and Venema (1998). The towing distance ( $d$ ) at each station was measured using the formula  $d=vt$ , where;  $d$  is the towing distance in each station in nautical miles (n. m.);  $v$  is the speed of the vessel during towing (n. m. hours<sup>-1</sup>) and  $t$  towing duration (hours) at each sampling station. The swept area at each station was then estimated using the equation  $a = dhx$ , where  $d$  is towing distance (n.m.);  $h$  is headline height and  $x$  is wing spread coefficient. The catch per unit area (CPUA) for each species is given by:  $CPUA=C/a$ , where:  $C$  is a catch (kg) and  $a$  is swept area (n.m<sup>2</sup>). Finally, the total biomass ( $B$ ) for each species in the study area was estimated by using the formula  $B=CPUA/N*0.54A$ , where  $N$  is; 0.54 is the escape coefficient proposed by Sparre and Venema (1998).

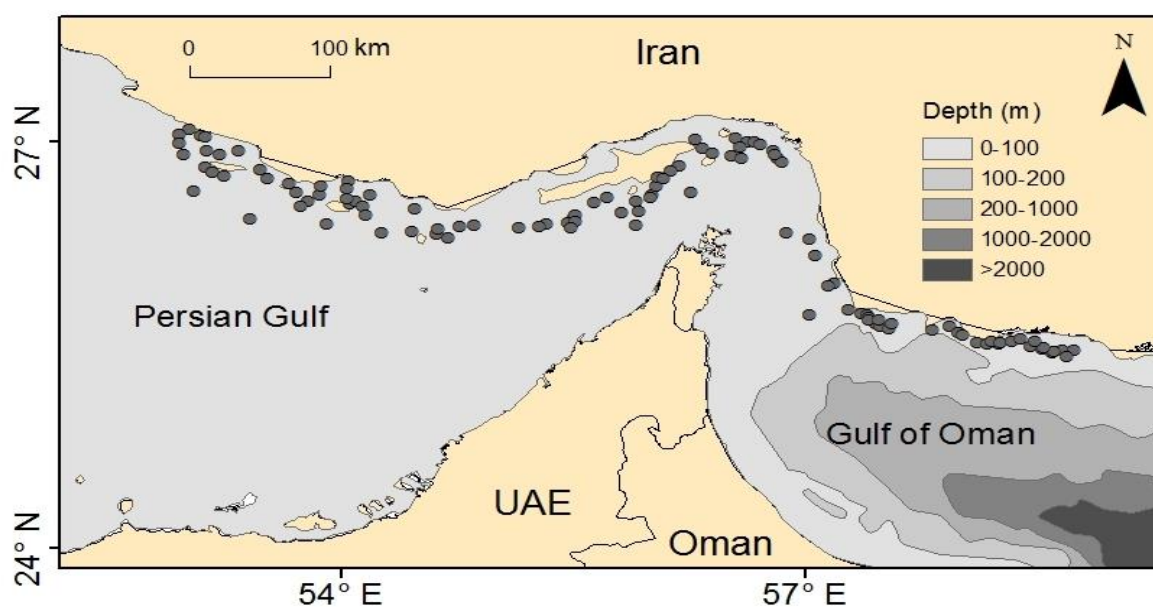


Figure 1: Map of the study area where samples were collected in the Persian Gulf and Oman Sea.

Before the towing, the water temperature was attained with conductivity, temperature, and depth profiler (CTD) in

each sampling station. In addition, samples were taken from the landing areas and fishing tools (Traps, Gill nets and Set nets)

that were used by traditional fishermen in order to collect the rare species. Species were identified on board based on literature (Randall *et al.*, 1978; Fischer and Bianchi, 1984; Randall, 1996; Assadi and Dehghani, 1997; Jabado *et al.*, 2017).

$$Q/B = 10^{(7,9640 - 0,204 \log W_{\infty} - 1,965T + 0,083A + 0,532h + 0,398d)}$$

Where  $Q/B$  is the annual food consumption/biomass ratio of each fish population;  $W_{\infty}$  is the asymptotic weight of the population (wet weight, in g);  $T$  is the mean habitat temperature for the fish population expressed as  $1,000/(\text{°C} + 273.1)$ ;  $A$  is the aspect ratio of the caudal fin; and  $h$  and  $d$  are binary variables for types of food consumed ( $h=1$ ,  $d=0$  for herbivores;  $h=0$ ,  $d=1$  for detritivores;  $h=0$ ,  $d=0$  for carnivores).

Many approaches exist to estimate  $Q/B$  ratio (Palomares and Pauly, 1989). In this study, the following equation was used (Christensen and Pauly, 1992):

The aspect ratio of the caudal fin ( $A$ ) was measured in at least 50 percent of the samples from each fish species, that estimated by using the following equation: Aspect ratio =  $h^2/S$ , where  $h$  is caudal fin height, and  $S$  is caudal fin surface area (measured using Image J software). The aspect ratio for elasmobranch species was assumed 7.0 (Optiz, 1996) and we excluded them from analyses. When the aspect ratio was not available, Pauly (1986) proposed the following formula:

$$Q/B = 106.37 * 0.0313(1000/T) * W_{\infty}^{-0.168} * 1.38 Pf * 1.89 hd$$

Where,  $W_{\infty}$ ,  $T$  and  $hd$  are as defined above; and  $Pf$  is 1 for apex and pelagic predators and zooplankton feeders, and 0 for other feeding types (Pauly, 1986).

For calculating  $Q/B$  most of the components of the equation were derived directly from field studies and in the absence of any of the components of the equation, the fish base database and library studies were used.

## Results

A total of 9228 specimens included 55 families and 154 species were classified into six ecological groups: demersal ( $n=49$ ), benthopelagic ( $n=9$ ), reef-associated ( $n=77$ ), pelagic-neritic ( $n=17$ ),

pelagic-oceanic ( $n=1$ ) and bathypelagic ( $n=1$ ). Among the demersal group, the caudal fin aspect ratio values ranged from 0.89 for *Johnius belangerii* to 4.17 for *Trachinotus mookalee*. In addition, the annual food consumption/biomass ( $Q/B$ ) ratio values ranged from 4.64 for *Argyrosomus hololepidotus* to 29.47 for *Pentaprion longimanus* (Table 1). On the other hand, among benthopelagic ecological group, *Otolithes ruber* showed the lowest both caudal fin aspect ratio (0.99) and  $Q/B$  rate (6.02). Moreover, the maximum aspect ratio of caudal fin and  $Q/B$  rate were obtained for *Pampus argenteus* (4.63) and *Rhizoprionodon acutus* (18.53), respectively (Table 2).

**Table 1: Estimated the annual food consumption/biomass ratio (Q/B) ratio of demersal fishes from the Persian Gulf and the Gulf of Oman (N: sample size; T: temperature; B: biomass,  $W_{max}$ : maximum weight,  $W_{\infty}$ : infinitive weight, AR: aspect ratio of the caudal fin).**

Family/Species	N	T (°C)	B (t)	$W_{max}$ (g)	$W_{\infty}$ (g)	AR	Q/B
<b>Ariidae</b>							
<i>Plicofollis tenuispinis</i>	521	28.3	3538.46	1890	2197.7	2.04	19.24
<i>Plicofollis dussumieri</i>	279	28.0	103.08	5120	5953.5	1.25	13.50
<i>Netuma thalassina</i>	311	27.5	156.02	7120	8279.1	1.32	12.79
<b>Carangidae</b>							
<i>Trachinotus mookalee</i>	9	26.8	10.07	3650	4244.2	4.17	10.11
<b>Dasyatidae</b>							
<i>Maculabatis randalli</i>	88	25.3	3796.14	5950	6918.6	7 <sup>a</sup>	15.72
<i>Brevitrygon walga</i>	329	25.0	162.54	459	533.7	7 <sup>a</sup>	26.50
<b>Epinephelidae</b>							
<i>Epinephelus bleekeri</i>	39	23.1	11.39	5430	6314.0	1.273	5.36
<i>Epinephelus diacanthus</i>	16	23.0	4.85	2345.78	2727.7	1.14	6.20
<i>Epinephelus latifasciatus</i>	9	22.9	24.77	1850	2151.2	1.41	6.85
<i>Epinephelus epistictus</i>	7	22.8	23.12	1450	1686.0	1.48	7.30
<b>Gerreidae</b>							
<i>Pentaprion longimanus</i>	32	24.2	60.29	23	26.7	4.36	29.47
<i>Gerres filamentosus</i>	23	23.7	118.88	285	331.4	2.14	11.54
<b>Gymnuridae</b>							
<i>Gymnura poecilura</i>	75	23.1	1404.827533	9550	11104.65116	7 <sup>a</sup>	14.26
<b>Hemiscylliidae</b>							
<i>Chiloscyllium arabicum</i>	16	22.9	11.76	2940	3418.6	7 <sup>a</sup>	18.15
<b>Leiognathidae</b>							
<i>Aurigequula fasciata</i>	258	22.7	784.55	210	244.2	1.99	11.93
<i>Leiognathus lineolatus</i>	326	22.6	151.66	15	17.4	2.19	21.24
<i>Photopectoralis bindus</i>	309	22.5	322.47	14.5	16.9	2.48	22.61
<b>Myliobatidae</b>							
<i>Aetomylaeus nichofii</i>	47	22.4	67.85	985	1145.3	7 <sup>a</sup>	22.68
<b>Monacanthidae</b>							
<i>Stephanolepis diaspros</i>	4	22.4	1.14	425	494.2	1.56	23.80
<b>Mullidae</b>							
<i>Upeneus doriae</i>	109	22.4	1405.91	168	195.3	2.19	12.98
<b>Muraenesocidae</b>							
<i>Muraenesox cinereus</i>	16	22.4	261.00	6580	7651.2	7 <sup>a</sup>	15.40
<b>Narcinidae</b>							
<i>Narcine atzi</i>	3	22.4	0.21	2650	3081.4	7 <sup>a</sup>	18.53
<b>Nemipteridae</b>							
<i>Nemipterus japonicas</i>	185	22.4	2613.09	354	411.6	3.21	13.54
<i>Nemipterus randalli</i>	19	22.4	2.10	135	157.0	1.48	11.85
<i>Nemipterus peronii</i>	65	22.4	121.63	286	332.6	2.98	13.54
<b>Paralichthyidae</b>							
<i>Pseudorhobus arsius</i>	12	22.3	195.44	650	755.8	1.14	8.06
<b>Platycephalidae</b>							
<i>Grammoplites scaber</i>	62	22.3	10.45	365	424.4	1.62	9.93
<i>Grammoplites suppositus</i>	39	22.3	252.30	345	401.2	1.12	9.13
<b>Polynemidae</b>							
<i>Polydactylus plebeius</i>	16	22.3	1.04	359	417.4	1.98	10.68
<i>Polydactylus sextarius</i>	23	22.2	71.70	320	372.1	1.8	10.56
<b>Psettodidae</b>							
<i>Psettodes eruemi</i>	76	22.2	174.38	3100	3604.7	0.95	5.65
<i>Cynoglossus arel</i>	23	28.3	3.38	459	533.7	1.32	8.95
<b>Rhinidae</b>							
<i>Rhynchobatus laevis</i>	3	27.5	18.11	15450	17965.1	7 <sup>a</sup>	12.94

**Table 1 (continued):**

Family/Species	N	T (°C)	B (t)	W <sub>max</sub> (g)	W <sub>∞</sub> (g)	AR	Q/B
<b>Rhynobatidae</b>							
<i>Glaucostegus granulatus</i>	13	26.8	26.50	5430	6314.0	7 <sup>a</sup>	16.01
<i>Rhinobatos annandalei</i>	34	25.9	109.56	2760	3209.3	7 <sup>a</sup>	18.38
<b>Sciaenidae</b>							
<i>Johnius belangerii</i>	53	25.0	0.24	289	336.0	0.89	9.06
<i>Pennahia anea</i>	38	24.5	12.25	541	629.1	1.24	8.52
<i>Argyrosomus hololepidotus</i>	19	24.2	0.19	12580	14627.9	1.42	4.64
<i>Protonibea diacanthus</i>	21	23.7	80.44	13250	15407.0	1.6	4.76
<b>Serranidae</b>							
<i>Epinephelus bleekeri</i>	39	23.1	11.39	5430	6314.0	1.273	5.36
<i>Epinephelus diacanthus</i>	16	23.0	4.85	2345.78	2727.7	1.14	6.20
<i>Epinephelus latifasciatus</i>	9	22.9	24.77	1850	2151.2	1.41	6.85
<i>Epinephelus epistictus</i>	7	22.8	23.12	1450	1686.0	1.48	7.30
<b>Sparidae</b>							
<i>Argyrops spinifer</i>	42	22.6	754.34	4200	4883.7	2.11	6.63
<b>Terapontidae</b>							
<i>Terapon jarbua</i>	75	22.5	81.90	365	424.4	2.01	10.70
<b>Tetraodontidae</b>							
<i>Lagocephalus inermis</i>	19	22.4	34.08	3250	3779.1	1.96	6.79
<i>Lagocephalus guentheri</i>	13	22.4	51.16	450	523.3	2.11	10.45
<i>Lagocephalus lunaris</i>	9	22.4	4.28	560	651.2	0.99	8.07
<b>Triacanthidae</b>							
<i>Triacanthus biaculeatus</i>	35	22.4	5.59	255	296.5	1.11	24.24
<b>Triglidae</b>							
<i>Lepidotrigla omanensis</i>	21	22.4	0.33	134	155.8	1.54	12.00
<i>Lepidotrigla bispinosa</i>	9	22.4	1.22	124	144.2	1.63	12.40

<sup>a</sup> In general, indication of the aspect ratio of elasmobranch species from literature (Optiz, 1996).

**Table 2: Estimated the Q/B ratio of benthopelagic fishes from the Persian Gulf and the Gulf of Oman (N: sample size; T: temperature; B: biomass, W<sub>max</sub>: maximum weight, W<sub>∞</sub>: infinitive weight, AR: aspect ratio of the caudal fin).**

Family/Species	N	T (°C)	B (t)	W <sub>max</sub> (g)	W <sub>∞</sub> (g)	AR	Q/B
<b>Ariommatidae</b>							
<i>Ariomma indica</i>	159	23.7	70.49	295	343.0	2.1	11.37
<b>Carangidae</b>							
<i>Decapterus russelli</i>	195	23.3	112.38	235	273.3	3.4	15.27
<b>Carcharhinidae</b>							
<i>Rhizoprionodon acutus</i>	41	23.2	74.80	2650	3081.4	7 <sup>a</sup>	18.53
<b>Aetobatidae</b>							
<i>Aetobatus ocellatus</i>	65	23.0	43.40	4850	5639.5	7 <sup>a</sup>	16.38
<i>Aetobatus flagellum</i>	11	22.9	102.00	5250	6104.7	7 <sup>a</sup>	16.12
<b>Myliobatidae</b>							
<i>Aetomylaeus milvus</i>	32	22.7	86.93	6950	8081.4	7 <sup>a</sup>	15.22
<b>Sciaenidae</b>							
<i>Johnius borneensis</i>	61	22.6	0.47	274	318.6	1.15	9.63
<i>Otolithes ruber</i>	46	22.6	336.08	2350	2732.6	0.99	6.02
<b>Stromateidae</b>							
<i>Pampus argenteus</i>	46	22.6	1176.34	1158	1346.5	4.63	13.95

<sup>a</sup> In general, indication of the aspect ratio of elasmobranch species from literature (Optiz, 1996).

Among reef-associated ecological group, in particular, the caudal fin aspect ratio values ranged from 0.59 for *Plotosus lineatus* to 5.16 for *Megalaspis cordyla*. In addition,

Q/B ratio values varied from 3.94 for *Epinephelus coioides* to 24.43 for *Cyclichthys orbicularis* (Table 3).

**Table 3: Estimated the Q/B ratio of reef-associated fishes from the Persian Gulf and the Gulf of Oman (N: sample size; T: temperature; B: biomass,  $W_{\max}$ : maximum weight,  $W_{\infty}$ : infinitive weight, AR: aspect ratio of the caudal fin).**

Family/Species	N	T (°C)	B (t)	$W_{\max}$ (g)	$W_{\infty}$ (g)	AR	Q/B
<b>Apogonidae</b>							
<i>Ostorhinchus fasciatus</i>	58	24.9	1.14	25	29.1	1.94	18.25
<i>Verulux cypselurus</i>	95	25.0	0.08	22	25.6	2.43	20.57
<b>Carangidae</b>							
<i>Carangoides malabaricus</i>	369	25.0	1881.39	560	651.2	3.87	13.99
<i>Carangoides hedlandensis</i>	87	25.1	18.41	1100	1279.1	3.85	12.15
<i>Carangoides bajad</i>	39	25.1	12.89	890	1034.9	4.35	13.95
<i>Alepes djedaba</i>	311	25.1	13.22	354	411.6	3.14	13.36
<i>Atule mate</i>	236	25.2	5.51	265	308.1	4.59	18.70
<i>Alectis ciliaris</i>	21	25.2	42.69	4850	5639.5	4.41	9.99
<i>Alectis indicus</i>	96	25.2	335.07	4760	5534.9	4.31	9.84
<i>Megalaspis cordyla</i>	142	25.2	382.47	1750	2034.9	5.16	14.19
<i>Carangoides chrysophrys</i>	135	25.2	1272.20	4590	5337.2	3.98	9.30
<i>Ulua mentalis</i>	68	25.2	101.15	5840	6790.7	2.97	7.30
<i>Selar crumenophthalmus</i>	206	25.2	3152.97	350	407.0	1.90	10.57
<i>Uraspis helvola</i>	41	27.7	3.66	365	424.4	3.92	15.42
<i>Carangoides armatus</i>	53	27.8	30.46	715	831.4	3.27	11.87
<i>Gnathanodon speciosus</i>	11	27.7	4.19	6350	7383.7	3.07	7.32
<i>Selaroides leptolepis</i>	12	28.2	4.90	125	145.3	2.48	14.57
<i>Caranx sexfasciatus</i>	12	28.3	19.33	5365	6238.4	4.21	9.42
<i>Caranx ignobilis</i>	9	28.3	49.66	6150	7151.2	3.47	7.95
<i>Parastromateus niger</i>	35	28.3	763.74	1450	1686.0	2.75	9.30
<i>Seriolina nigrofasciata</i>	1	28.3	0.85	1950	2267.4	1.97	7.55
<i>Scomberoides commersoniannus</i>	38	28.3	239.57	4580	5325.6	1.89	6.24
<b>Carcharhinidae</b>							
<i>Carcharhinus sorrah</i>	32	28.3	13.73	5955	6924.4	7 <sup>a</sup>	15.71
<i>Carcharhinus dussumieri</i>	56	28.3	365.16	5850	6802.3	7 <sup>a</sup>	15.77
<b>Chaetodontidae</b>							
<i>Heniochus acuminatus</i>	39	28.3	4.10	235	273.3	2.06	11.82
<b>Dasyatidae</b>							
<i>Urogymnus asperrimus</i>	1	27.9	0.40	25850	30058.1	7 <sup>a</sup>	11.65
<i>Himantura uarnak</i>	11	27.7	409.76	45850	53314.0	7 <sup>a</sup>	10.36
<i>Pastinachus sephen</i>	69	27.6	1795.47	6580	7651.2	7 <sup>a</sup>	15.40
<b>Derpaneidae</b>							
<i>Drepane punctata</i>	45	27.0	1175.15	2650	3081.4	2.98	8.60
<i>Drepane longimana</i>	35	24.9	397.91	1100	1279.1	2.07	8.64
<b>Diodontidae</b>							
<i>Cyclichthys spilostylus</i>	6	25.0	14.56	1985	2308.1	1.32	16.60
<i>Cyclichthys orbicularis</i>	8	25.0	1.39	250	290.7	1.129	24.43
<b>Ephippidae</b>							
<i>Ephippus orbis</i>	39	25.1	103.33	302	351.2	2.31	11.78
<i>Platax orbicularis</i>	8	25.1	47.57	3950	4593.0	2.97	7.91
<b>Engraulidae</b>							
<i>Encrasicholina punctifer</i>	26	25.2	1.42	13	15.1	1.81	20.34
<b>Fistulariidae</b>							
<i>Fistularia petimba</i>	2	25.2	14.38	3580	4162.8	1.32	5.89
<b>Gerreidae</b>							
<i>Gerres acinaces</i>	16	25.2	279.91	112	130.2	2.63	15.33
<b>Haemulidae</b>							
<i>Pomadasyd comersonni</i>	3	25.2	0.13	2568	2986.0	1.83	6.94
<i>P. kaakan</i>	193	27.7	2221.46	3750	4360.5	1.26	5.76
<i>P. maculatum</i>	112	27.8	7.60	235	273.3	1.53	10.68
<i>P. stridens</i>	97	27.7	474.22	215	250.0	1.61	11.04

**Table 3 (continued):**

Family/Species	N	T (°C)	B (t)	W <sub>max</sub> (g)	W <sub>∞</sub> (g)	AR	Q/B
<i>Plectorhinchus pictus</i>	4	28.2	0.92	2450	2848.8	1.51	6.60
<i>Diagramma pictum</i>	15	28.3	148.64	5120	5953.5	0.79	4.95
<b>Lethrinidae</b>							
<i>Lethrinus lentjan</i>	13	28.3	27.92	980	1139.5	2.41	9.44
<i>Lethrinus nebulosus</i>	29	28.3	194.23	3256	3786.0	1.92	6.73
<i>L.microdon</i>	11	28.3	35.18	1650	1918.6	2.61	8.82
<b>Lutjanidae</b>							
<i>Lutjanus johni</i>	32	28.3	61.63	4859	5650.0	3.76	8.82
<i>Lutjanus lutjanus</i>	39	28.3	22.08	362	420.9	2.57	11.93
<i>Lutjanus quinquelineatus</i>	88	28.3	23.15	356	414.0	2.37	11.52
<i>Lutjanus malabaricus</i>	39	28.3	125.46	3985	4633.7	1.54	6.01
<i>Lutjanus erythropterus</i>	4	28.2	0.85	3850	4476.7	1.76	6.31
<i>Lutjanus argentimaculatus</i>	2	27.9	0.14	1510	1755.8	1.56	7.35
<i>Pinjalo pinjalo</i>	21	27.7	0.35	4350	5058.1	1.73	6.12
<b>Menidae</b>							
<i>Mene maculate</i>	21	27.5	208.00	254	295.3	4.89	19.98
<b>Monacanthidae</b>							
<i>Aluterus monoceros</i>	21	24.9	7.40	1960	2279.1	1.41	16.93
<b>Nemipteridae</b>							
<i>Scolopsis vosmeri</i>	14	25.0	9.49	165	191.9	4.11	18.80
<i>Scolopsis ghanam</i>	6	25.0	0.41	320	372.1	3.11	13.56
<b>Platycephalidae</b>							
<i>Platycephalus indicus</i>	49	25.1	1.40	1150	1337.2	1.87	8.24
<i>Cociella crocodilla</i>	2	25.1	6.08	2540	2953.5	1.35	6.35
<b>Plotosidae</b>							
<i>Plotosus lineatus</i>	29	25.2	9.80	245	284.9	0.59	8.85
<b>Pomacanthidae</b>							
<i>Pomacanthus maculosus</i>	26	25.2	1.17	895	1040.7	1.29	7.77
<b>Rachycentridae</b>							
<i>Rachycentron canadum</i>	16	25.2	70.09	29800	34651.2	3.102	5.37
<b>Rhinidae</b>							
<i>Rhina ancylostoma</i>	3	25.2	8.75	25600	29767.4	7 <sup>a</sup>	11.67
<b>Rhinopteridae</b>							
<i>Rhinoptera javanica</i>	43	27.8	617.18	12540	14581.4	7 <sup>a</sup>	13.50
<b>Scorpaenidae</b>							
<i>Pterois russelli</i>	16	28.2	9.41	401	466.3	1.39	9.32
<b>Serranidae</b>							
<i>Epinephelus coioides</i>	46	28.3	193.10	16530	19220.9	0.85	3.94
<i>Epinephelus areolatus</i>	21	28.3	5.84	450	523.3	1.57	9.43
<i>Cephalopholis hemistiktos</i>	19	28.3	0.84	352	409.3	1.39	9.58
<b>Sparidae</b>							
<i>Rhabdosargus haffara</i>	64	28.3	20.41	780	907.0	3.66	12.56
<i>Acanthopagrus bifasciatus</i>	11	28.3	12.84	1850	2151.2	1.93	7.57
<b>Sphyraenidae</b>							
<i>Sphyraena putnamiae</i>	53	28.3	810.12	4855	5645.3	2.11	4.30
<i>Sphyraena jello</i>	28	28.3	611.69	8450	9825.6	1.90	5.52
<b>Synodontidae</b>							
<i>Saurida tumbil</i>	77	27.9	3603.30	1350	1569.8	2.01	8.20
<i>S. undosquamis</i>	23	27.7	56.54	211	245.3	1.99	11.92
<b>Tetraodontidae</b>							
<i>Chelonodon patoca</i>	10	27.5	0.78	980	1139.5	1.38	7.76
<b>Terapontidae</b>							
<i>Terapon theraps</i>	65	24.9	38.48	284	330.2	1.93	11.09
<b>Torpedinidae</b>							
<i>Torpedo sinuspersici</i>	36	25.0	129.37	3850	4476.7	7 <sup>a</sup>	17.17

<sup>a</sup> In general, indication of aspect ratio of elasmobranch species from literature (Optiz, 1996)



Also, among the pelagic-neritic ecological group, the caudal fin aspect ratio values ranged from 1.31 for *Thryssa malabarica* to 4.64 for *Atropus atropos*. Indeed, the Q/B ratio values ranged from 6.44 for *Elops machnata* to 17.84 for *Atropus atropos*.

*Mobula kuhlii* and *Acropoma japonicum* are the only species in the pelagic-oceanic and bathypelagic ecological group, respectively. The Q/B ratio values were estimated 14.18 and 17.84 for these two species, respectively (Table 4).

**Table 4: Estimated the Q/B ratio of pelagic-neritic, pelagic-oceanic and bathypelagic fishes from the Persian Gulf and the Gulf of Oman (N: sample size; T: temperature; B: biomass,  $W_{\max}$ : maximum weight,  $W_{\infty}$ : infinitive weight, AR: aspect ratio of the caudal fin).**

Family/Species	N	T (°C)	B (t)	$W_{\max}$ (g)	$W_{\infty}$ (g)	AR	Q/B
<b>Pelagic-neritic</b>							
<b>Carangidae</b>							
<i>Atropus atropos</i>	129	26.2	270.52	350	407.0	4.64	17.84
<b>Clupeidae</b>							
<i>Nematalosa nasus</i>	21	26.1	0.12	115	133.7	1.9	13.26
<b>Chirocentridae</b>							
<i>Chirocentrus nudus</i>	7	25.8	53.25	1100	1279.1	4.34	13.34
<b>Dorosomatidae</b>							
<i>Sardinella sinesis</i>	23	26.0	7.23	64	74.4	1.48	13.79
<i>Anodontostoma chacunda</i>	8	26.0	0.19	105	122.1	2.73	15.83
<b>Elopidae</b>							
<i>Elops machnata</i>	1	25.7	0.10	3520	4093.0	1.77	6.44
<b>Engraulidae</b>							
<i>Thryssa mystax</i>	109	25.7	3.06	197	229.1	2.42	13.13
<i>Thryssa setirostris</i>	43	25.6	0.16	168	195.3	2.32	13.30
<i>Thryssa malabarica</i>	91	25.6	0.92	156	181.4	1.31	11.13
<b>Lactariidae</b>							
<i>Lactarius lactarius</i>	86	25.5	119.37	358	416.3	2.13	10.99
<b>Polynemidae</b>							
<i>Eleutheronema tetradactylum</i>	7	25.5	15.41	2540	2953.5	2.34	7.67
<b>Pristigasteridae</b>							
<i>Ilisha megaloptera</i>	17	25.5	0.85	254	295.3	1.43	10.31
<i>Ilishia compresa</i>	42	25.5	1.55	211	245.3	2.11	12.20
<b>Scombridae</b>							
<i>Scomberomorus guttatus</i>	18	26.2	338.93	1750	2034.9	4.63	12.82
<i>Rastrelliger kanagurta</i>	28	26.2	207.47	395	459.3	3.99	15.37
<i>Scomberomorus commerson</i>	12	26.1	360.45	11500	13372.1	4.11	7.91
<b>Sparidae</b>							
<i>Acanthopagrus arabicus</i>	63	26.0	338.28	1150	1337.2	2.1	8.61
<b>Pelagic-oceanic</b>							
<b>Mobulidae</b>							
<i>Mobula kuhlii</i>	1	25.8	12.54	9850	11453.5	7 <sup>a</sup>	14.18
<b>Bathypelagic</b>							
<b>Acropomatidae</b>							
<i>Acropoma japonicum</i>	182	25.7	1.97	29	33.7	1.98	17.84

<sup>a</sup> In general, indication of aspect ratio of elasmobranch species from literature (Optiz, 1996).

## Discussion

Due to the rapid population growth, overexploitation, and mismanagement of fishing, ecosystem-based fisheries management has evolved a more critical role in the conservation of marine ecosystems (Hall and Mainprize, 2004; Long *et al.*, 2015). Since the Persian Gulf

and the Gulf of Oman present different patterns of marine productivity and fishery activities, several studies have been documented to apply the Ecopath modeling approach, a mass-balance model integrated into the Ecopath with Ecosim software to depict the structure and functioning of this marine ecosystem (Tajzadeh-Namin *et al.*,

2020; Taghavimotlagh *et al.*, 2021). However, the present study represents a significant effort to provide baseline information on trophic models in the Persian Gulf and Gulf of Oman, serving as an essential input for Ecopath modeling. In general, all the species studied here were encountered for a large proportion of the species in the sampling area (Valinassab *et al.*, 2006), suggesting it adequately sampled the diversity of sampling which covers the main trophic structure of the ecosystem in the studied area.

There is a close relationship between swimming activity and caudal fins; fish species with high swimming activity have caudal fins with higher aspect ratio values and consequently high metabolic rate (Palomares and Pauly, 1989; García and Duarte, 2002; Sawusdee *et al.*, 2009). For instance, those species that showed maximum aspect ratios, like *Trachinotus mookalee*, *Pampus argenteus*, *Megalaspis cordyla*, and *Atropus atropus* have almost elongated body shapes and sharp caudal fins. All these species have a high swimming activity in their habitat to attack especially soft bottom prey. On the contrary, sedentary fish species have a relatively lower food intake and are characterized by almost rounded caudal fins with low values of aspect ratio. In this study, except *Thryssa malabarica*, all three species with low aspect ratio values have a round caudal fin, indicating that presumably do not require much energy to feed. In most cases, fish caudal fin shape is strongly related to swimming ability and metabolic needs (Giarrizzo *et al.*, 2013).

The annual food Q/B ratio varied from 3.94 for *Epinephelus coioides* to 29.47 for

*Pentaprion longimanus*. In comparison, Giarrizzo *et al.* (2013) reported Q/B rate for 37 fish species collected in a micro-tidal mangrove estuary in Brazil from 2.3 for *Epinephelus itajara* to 67.3 for *Catengraulis edentulus*. These differences could be explained by species (García and Duarte, 2002), and temperature (Giarrizzo *et al.*, 2013). Furthermore, it is revealed that species with a higher proportion of plants in their diet tend to have higher estimated Q/B values (García and Duarte, 2002; Sawusdee *et al.*, 2009). As can be expected, carnivorous frequently occupy the pelagic and soft bottom dwelling, as compared to herbivorous, whose representatives preferentially inhabit seagrasses, benthic algal turfs, and coral reefs.

Studies of Ecosystem-Based Fisheries Management can contribute to our understanding of the community structure of marine ecosystems (Coll *et al.*, 2013). Here, we have listed the aspect ratio and the annual food Q/B ratio that may set up basic information and contribute to mass-balanced trophic model construction for a large proportion of demersal fishes in the Persian Gulf and Gulf of Oman. By combining the Q/B ratio estimates reported here with studies of the prey composition in the fish stomachs from the Persian Gulf and Gulf of Oman and with total fish biomass by species, then integrating these studies with estimates of production and biomass at each trophic level, fisheries managers will be able to summarize the trophic structure of the Persian Gulf and Gulf of Oman ecosystem using ECOPATH model. Thus, the results of the present study may be useful in the formulation of ecological models and for supplying basic information

for ecosystem-based fisheries management in the future.

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