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*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.

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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)

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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 25º 23′ and 28º 57′ North and 52º 41′ and 58º 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$^{-1}$) 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$^2$). 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).

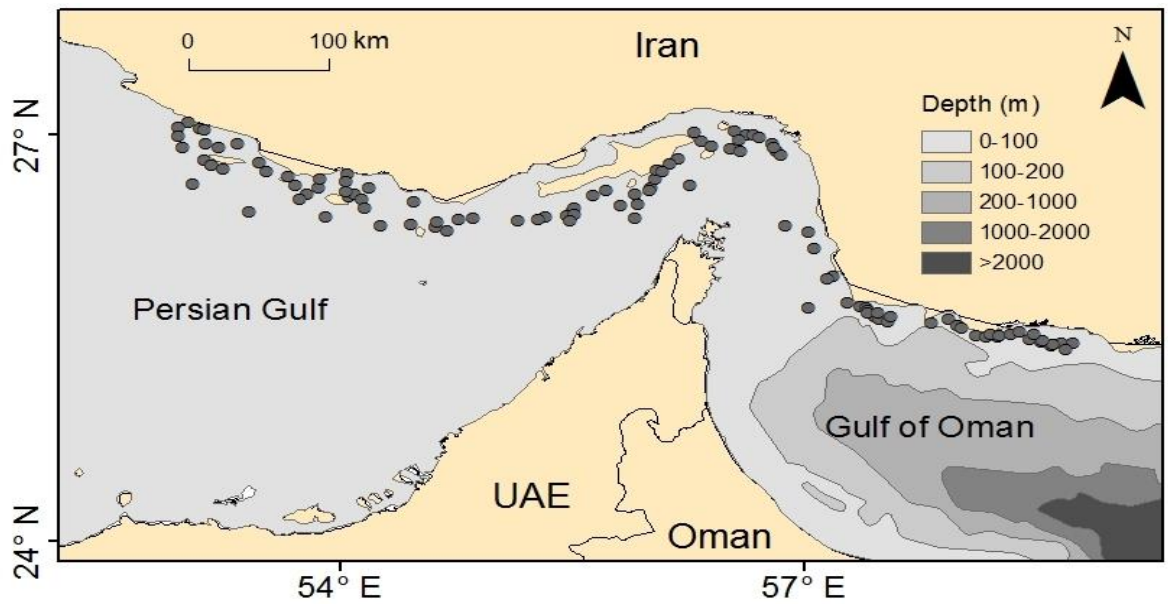



**Figure 1: Map of the study area where samples were collected in the Persian Gulf and Oman Sea.**

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)

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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).

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

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

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/(°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).

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 annul 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).

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

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**Table 1 (continued):**

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

[a] 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, $W_{max}$: 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 |
|---|---|---|---|---|---|---|---|
| **Ariommatidae** | | | | | | | |
| *Ariomma indica* | 159 | 23.7 | 70.49 | 295 | 343.0 | 2.1 | 11.37 |
| **Carangidae** | | | | | | | |
| *Decapterus russelli* | 195 | 23.3 | 112.38 | 235 | 273.3 | 3.4 | 15.27 |
| **Carcharhinidae** | | | | | | | |
| *Rhizoprionodon acutus* | 41 | 23.2 | 74.80 | 2650 | 3081.4 | 7[a] | 18.53 |
| **Aetobatidae** | | | | | | | |
| *Aetobatus ocellatus* | 65 | 23.0 | 43.40 | 4850 | 5639.5 | 7[a] | 16.38 |
| *Aetobatus flagellum* | 11 | 22.9 | 102.00 | 5250 | 6104.7 | 7[a] | 16.12 |
| **Myliobatidae** | | | | | | | |
| *Aetomylaeus milvus* | 32 | 22.7 | 86.93 | 6950 | 8081.4 | 7[a] | 15.22 |
| **Sciaenidae** | | | | | | | |
| *Johnius borneensis* | 61 | 22.6 | 0.47 | 274 | 318.6 | 1.15 | 9.63 |
| *Otolithes ruber* | 46 | 22.6 | 336.08 | 2350 | 2732.6 | 0.99 | 6.02 |
| **Stromateidae** | | | | | | | |
| *Pampus argenteus* | 46 | 22.6 | 1176.34 | 1158 | 1346.5 | 4.63 | 13.95 |

[a] 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).

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

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**Table 3 (continued):**

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

[a] In general, indication of aspect ratio of elasmobranch species from literature (Optiz, 1996)

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

[a] 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.*,

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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 atropos* 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

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for ecosystem-based fisheries management in the future.

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