



Review Article

A Review of Length-Weight Relationship, Condition Factors and Fisheries Status of Flatfishes from Different Geographical Areas

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Abstract | The length-weight relationship (LWR) of flatfishes from various coasts worldwide was reviewed. Descriptive statistics, condition factors, and fisheries data were analyzed and compared across regions. Additionally, their growth patterns were discussed in relation to Geographical variations. Published research suggests diverse range of flatfishes over the globe. Highest estimated $R^2=99$ found from many species which expresses positive growth however the lowest was obtain $R^2=49$ in *Cynoglossus puncticeps* from Pakistan and the highest b value was found 3.648 in *Buglossidium luteum* from Spain and lowest b value was 1.041 in *Citharichthys stampflii* from Africa. The highest condition factor (3.557) was observed in *Citharichthys stampflii* from Africa, while the lowest condition factor (0.05) was recorded in *Cynoglossus lingua* from Bangladesh. Fish length-weight variations are influenced by plenty biological factors such as regional bases, genetics, age, food availability, salinity, water quality and temperature, as well as environmental factors. Some other important factors including habitat conditions, health status. Moreover, human activities like overfishing and aquaculture practices can impact growth patterns.

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Introduction

Flatfishes are particularly abundant on the open continental shelf where they are frequently of commercial importance (Topp *et al.*, 1972). Researchers have been examining the length-weight correlations (LWRs) of fish species since the late 1800s, and the technique under consideration has

long been recognized as an invaluable resource for describing a wide range of biological traits (Le Cren, 1951; Froese, 2006; Freitas *et al.*, 2017). In fisheries science, fish length-weight correlations are essential tools for determining the average weight of several fish species in an assemblage of a certain length (Ali *et al.*, 2021). The length-weight relationship (LWR) makes precise calculations of fish population

dynamics, growth, gonad maturation and feeding rates possible, is essential to fish biological research and stock assessment. Fish growth patterns are a vital tool for managing the sustainably harvested population of fish (Ali *et al* 2023). *Platichthys flesus* (Linnaeus, 1758) is one of the most significant flatfish for commercial purposes in Black Sea coastal waters of Turkey which is widely dispersed in the Marmara, Black and Azov seas in addition to the Atlantic, western Mediterranean, Adriatic and Aegean seas (Borsa *et al.*, 1997). Research on length-weight relationships is essential for stock assessment models and has significant implications for fisheries science (Mendes *et al.*, 2004).

Length-weight relationships are useful for determining a fish's weight at a specific length and can be applied to research on the development of gonads, feeding rate, metamorphosis, maturity and condition (Richter *et al.*, 2000). The average weight at a certain length group and the relative health of a fish population can both be estimated using this relationship (Oscoz *et al.*, 2005; Abowei *et al.*, 2009). Fish length-weight relationships are typically used to convert growth-in-length equations to growth-in-weight and estimate biomass from length observations (Pauly, 1993; Goncalves *et al.*, 1997; Binohlan and Pauly, 1998). Researchers studying fish biology regularly employ length-weight relationships (LWRs) as valuable resources (Ferreira *et al.*, 2008; Parsa *et al.*, 2017).

Overview of flatfish

Flatfish family is a much-diversified group of fish. Taxonomists claim that 1820 species have been found (Cerim and Ateş, 2020). Flatfishes order Pleuronectiformes are divided into two suborders, Psettidoidei with one family and one genus, Pleuronectoidei contains 13 families and 132 genera. The eyes of these flatfishes are exclusively located on one side of the body (Nelson *et al.*, 2016). The directive Linnaeus gave the Pleuronectiformes its original name in 1758. The words necto and pleuro, respectively indicate swim and on side. Since they are the only group of fish that lacks bilateral symmetry, flatfish are simple to identify. The dorsal side of the body is dark and has both eyes, but the ventral side is white and eyeless. They typically stay towards the bottom of the continental shelf and swim in accordance with the body's curves (Aung *et al.*, 2019).

Description and role of flat fishes

The majority of flatfish are deep-bodied, laterally compressed that are easily identified physically by the presence of both eyes on the same side of the head in both juvenile and adult postmetamorphic animals (Figure 1). Every flatfish was once a bilaterally symmetrical, pelagic fish, but flatfish experience a remarkable ontogenetic metamorphosis during larval growth where one eye moves from one side of the head to the other (Brewster, 1987; Inui and Miwa, 2012; Schreiber, 2013). In all but a few species of recent flatfishes, either the right or left eye migrates (Hubbs and Hubbs, 1944). They are the only vertebrates to diverge from a bilaterally symmetrical body design to such an extent. The process of eye migration helps flatfishes make the switch from pelagic to benthic lifestyle (Schreiber, 2013). According to geological data, orbital migration was one of the first distinguishing pleuronectiform traits to arise (Friedman, 2012).

The flatfishes inhabit characteristically in shallow habitat of temperate water, warm water and are categorized by anal fin confluent pointed to caudal fin and pectoral fin with lack of swim bladder. These fishes are carnivorous by nature. Living species of Pleuronectiformes comprise of 772 species, pertaining to 14 families and 129 genera (Nelson *et al.*, 2016).

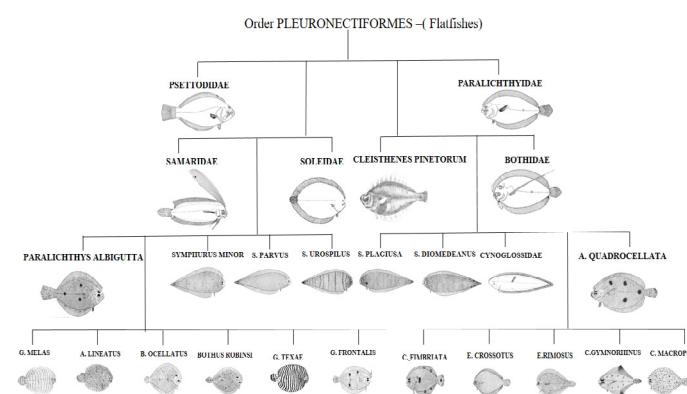


Figure 1: The fishes of Order pleuronectiformes.

Cynoglossidae

Flatfish from Cynoglossidae family are medium to small-sized benthic fishes which can be found in marine environments from tidal pools to the continental shelf and upper slope to depths of 1,500 meters (Munroe, 2001). An extensive family of specialized freshwater, marine and estuary flatfishes with over 164 primary small and sinistral species mostly grouped into three genera. Their eyes are present from the left side of the body which are nearly

together and mouth is very small and sub terminal and rostral hook is present mostly below the mouth (Nair, 2017).

Paralichthyidae

Flatfishes comprising roughly 108 species and 11 genera. Size of these fishes can be 45 cm and they inhabit in marine water with depth of 200 m benthic (Psomadakis *et al.*, 2015).

Soleidae

Flatfishes are primarily tiny to medium-sized, can be found in anywhere of the world including marine and estuarine surroundings. There are currently 29 genera and 192 species recognized; however, little is known about the taxonomic status of many of these species and genera, as well as how they relate to one another. The taxonomy and systematics of these flatfishes have recently seen significant advancements (Desoutter, 1987, 1994; Chapleau and Desoutter, 1996; Desoutter and Chapleau, 1997; Vachon *et al.*, 2005; Randall, 2005; Randall and Gon, 2005; Randall and Desoutter-Meniger, 2007; Vachon *et al.*, 2007; Johnson and Randall, 2008). Body length of these fishes range from 32 cm approximately. However, they inhabit in shallow coastal water, some of them in estuaries and benthic (Psomadakis *et al.*, 2015).

Bothidae

This large diverse family of sinistral flatfishes comprises approximately 20 genera and 164 species (Hensley and Ahlstrom, 1984). These fishes are also known as Left eye flounder, size can be 30 cm around and inhabits to the marine coastline with the depth of 600 m benthic (Psomadakis *et al.*, 2015).

Citharidae

Citharidae family consists of four genera and six small to medium size species (Hubbs, 1945). Morphometrically their body seem to elliptical and moderately compressed, size varies to 36 cm. Caudal fin have 13 to 15 and 21 to 23 branched rays, pectoral fin is present from both side of the body (Hensley and Ahlstrom, 1984).

Pleuronectidae

The Pleuronectidae family is comprised of five subfamilies: Pleuronectinae, Paralichthodinae, Rhombosoleinae, Samarinae, and Poecilopsettinae were the five subfamilies that made up the Pleuronectidae (Chapleau and Keast, 1988; Chapleau,

1993). Based on multiple plesiomorphic features, Sakamoto (1984) identified the Pleuronectidae family through a phenetic examination of 77 species.

Scophthalmidae

This family consist to nine species of small to large sinistral flatfishes in four genera make up this small family. They are distinguished by their large eyes and mouth, two slightly asymmetrical elongate pelvic fin bases that extend anteriorly to the urohyal, an elongated supra-occipital process that forms a bridge with the dorsal margin of the blind-side frontal bone and caudal vertebrae with asymmetric transverse apophyses (Hensley and Ahlstrom, 1984; Chapleau, 1993; Chanet, 1998).

Psettodidae

The morphological and molecular classifications of the psettodids, also known as toothed flounders, suggest that they are the sister group to Pleuronectoidei. The family Psettodidae includes three Psettodes species. Size of these fishes range approximately 64 cm (Psomadakis *et al.*, 2015).

Samaridae

A flatfish inhabits relatively deep tropical and subtropical marine waters of the Indo-Pacific. This family composed of three genera and approximately twenty-nine nominal species. Size of these fishes range 22 cm (Psomadakis *et al.*, 2015).

Phylogeny of flatfish

Biological diversity of flatfishes are presented with family based which communicate hypothesized evolutionary relationships among mentioned families and shows how a family of flatfish evolve from the other ancestor. Current study presented the phylogenetic tree of nine flatfish families which reflects how other groups evolve (Figure 2).

Geographical distribution of flatfish

The continental seas off Antarctica and southern Arctic Ocean are known as niche of flatfish thus plenty of them can be collected boreal region of the northern Hemisphere (Munroe, 2014). Diverse global patterns of flatfish species diversity are seen in their geographic and ecological ranges. Marine waters in the Indo-West Pacific are home to the highest species diversity. Less abundant in tropical seas and gradually declines from the western Atlantic to the tropical Eastern Pacific and Eastern Atlantic. Flatfishes

can be found almost anywhere in the world from the southern Arctic Ocean to the continental seas off Antarctica. They are prominent components of most fish assemblages in estuaries and marine waters that stretch from shorelines to the outer margins of the continental shelf and upper continental slope. They inhabit a variety of bathymetric environments, ranging from shallow marine and freshwater areas to deep-water habitats (to roughly 2000 m). Only in bathyal depths (below about 1500 m) (Muroe, 2014).

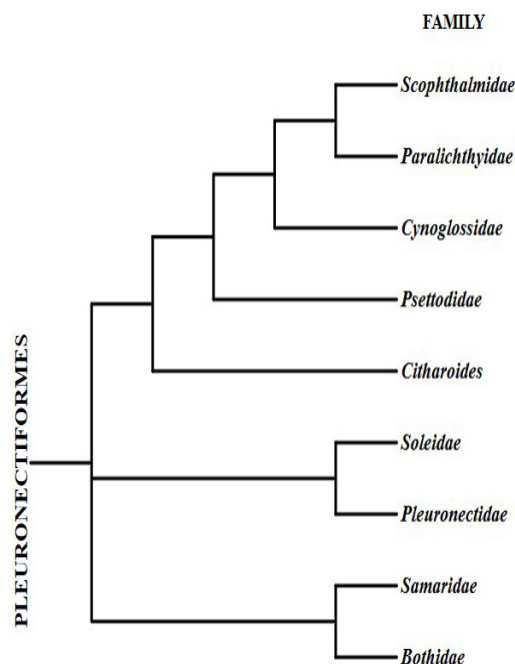


Figure 2: A phylogenetic tree depicting the relationships among the flatfish families studied in the present study.

Materials and Methods

The length-weight relationship (LWR) characteristics are frequently employed to depict several facets of the biology of fish species (Froese, 2006; Le Cren, 1951). The LWR allows predicting fish weight based on length and vice versa (Freitas *et al.*, 2017). The current review is based on length-weight relationship, condition factors and fisheries status of flatfishes worldwide. Data gathered from different published literatures including review and research articles. Length-weight relationship and condition factors data conducted during (2002-2022) with different coastal areas worldwide. However, nine families of flatfish were studied in this current study including eighty-five different flatfish from different regions of the world (Figure 3). Majority of data were presented as $W=aL^b$ and some studies were presented a and b Values to obtain the descriptive statistical not with full equation and some studies with this equation

$CF = \text{Final weight (g)} / \text{Final length 3 (cm)} \times 100$ to calculate the condition factors of flatfishes.

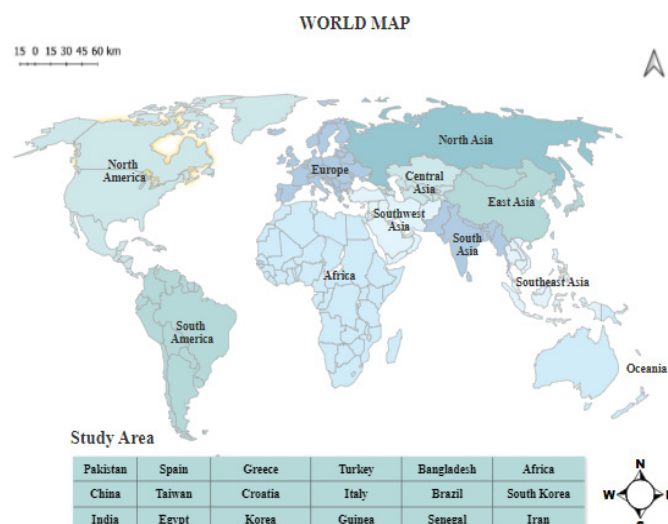


Figure 3: Study map showing data conducted from countries.

Results and Discussion

Length-weight relationship (LWR) data of 85 flatfish species belonging 9 families gathered from different review of literatures. Descriptive statistics such as (N), (a) and (b) values coefficient of (R^2) assessed, the value of (R^2) ranges from 0.49-0.99, estimated b values ranges from 1.041-3.648, estimated condition factors in some flatfish range 0.05-1.94 in some flatfishes. These descriptive statistics were observed from different species and regions (Tables 1, 2 and 3).

Table 1: Landing data of Flatfishes and its value at Baluchistan coast from 2009-2022.

Year	Year total quantity in total value total value in metric tons in		
	Pakistani rupees	US dollars	
Year	Tons	Pak. Rupees	US Dollar
2009	255.845	44772830	268857.44
2010	1430.31	214546500	128844.65
2011	1840.184	404429440	2428568.1
2012	2188.166	412835150	2479043.7
2013	2844.133	441214192	2649457.7
2014	2511.729	389317995	2337825
2015	3063.985	471468925	2831135.1
2016	3429.068	581751560	3493373.9
2017	3550.046	683651678	4105276.4
2018	6120.26	1136019200	682170.9
2019	3357.936	839484000	5041037.7
2020	2806.044	645390120	3875518.64
2021	2034.453	508613250	1790375.1
2022	2284.968	616,941,360	2171702.07

*Source: Directorate of Marine Fisheries, Baluchistan.

Table 2: Gathered statistical description and length-weight parameters, condition factors obtained for two families of flatfish's samples from different regions.

Family	Species	Sampling area	N	Regression parameters			Condition factor	References
				a	b	r ²		
Cynoglossidae	<i>Cynoglossus arel</i>	Pakistan	216	--	2.665	0.68	0.469	Ali <i>et al.</i> , 2021
	<i>Cynoglossus arel</i>	India	142	0.0604	2.869	0.96	--	Samanta <i>et al.</i> , 2020
	<i>Cynoglossus arel</i>	Iran	63	0.0012	3.416	0.95	--	Aghajpour <i>et al.</i> , 2015
	<i>Cynoglossus quadrilineatus</i>	Pakistan	519	--	2.859	0.75	0.6345	Ali <i>et al.</i> , 2021
	<i>Cynoglossus puncticeps</i>	Pakistan	75	--	2.102	0.49	0.7351	Ali <i>et al.</i> , 2021
	<i>Cynoglossus bilineatus</i>	Iran	65	0.0030	3.213	0.98	--	Aghajpour <i>et al.</i> , 2015
	<i>Symphurus nigrescens</i>	Spain	123	0.0077	2.983	0.97	--	Torres <i>et al.</i> , 2012
	<i>Solea elongate</i>	Iran	45	0.0140	2.991	0.96	--	Aghajpour <i>et al.</i> , 2015
	<i>S. nigrescens</i>	Turkey	10	0.0112	3.00	0.95	--	Cengiz, 2022
	<i>Cynoglossus lingua</i>	Bangladesh	414	0.0061	2.873	0.91	0.05	Siddique <i>et al.</i> , 2023
	<i>Cynoglossus cynoglossus</i>	Bangladesh	139	0.0023	3.359	0.92	0.11	Siddique <i>et al.</i> , 2023
	<i>Symphurus tessellatus</i>	Brazil	37	0.0025	3.25	0.98	--	Da Costa <i>et al.</i> , 2014
	<i>Cynoglossus senegalensis</i>	Senegal	82	0.007	2.84	0.98	--	Ndiaye <i>et al.</i> , 2015
	<i>Paraplagusia bilineata</i>	Taiwan	20	0.001	3.01	0.96	--	Chu <i>et al.</i> , 2021
	<i>Cynoglossus senegalensis</i>	Africa	15	0.022	2.845	0.76	2.136	Alain <i>et al.</i> , 2022
	<i>Cynoglossus joyneri</i>	Korea	67	0.0053	2.98	0.96	--	Yu <i>et al.</i> , 2021
	<i>Cynoglossus joyneri</i>	China	33	0.0047	3.057	0.95	--	Wang <i>et al.</i> , 2016
	<i>Cynoglossus lighti</i>	China	18	0.0152	2.602	0.95	--	Wang <i>et al.</i> , 2016
	<i>Cynoglossus macrostomus</i>	India	199	0.027	2.420	0.88	--	Abdurahiman <i>et al.</i> , 2004
	<i>Cynoglossus quadrilineatus</i>	Pakistan	111	--	--	0.76	--	Eido <i>et al.</i> , 204
	<i>Cynoglossus gracilis</i>	China	676	0.0030	3.0834	0.97	--	Che <i>et al.</i> , 2022
Paralichthyidae	<i>Pseudorhombus javanicus</i>	Pakistan	213	--	3.043	0.83	1.1927	Ali <i>et al.</i> , 2021
			5					
	<i>Pseudorhombus elevates</i>	Iran	61	0.0045	3.290	0.98	--	Aghajpour <i>et al.</i> , 2015
	<i>Pseudorhombus triocellatus</i>	India	360	0.0140	2.797	0.95	0.359	Bharadhirajan <i>et al.</i> , 2019
	<i>Paralichthys olivaceus</i>	Korea	281	0.0044	3.243	0.96	--	Kwak <i>et al.</i> , 2016
	<i>C. arenaceus</i>	Brazil	95	0.0075	2.87	0.97	--	Da Costa <i>et al.</i> , 2014
	<i>Citharichthys spilopterus</i>	Brazil	74	0.0061	3.00	0.99	--	Da Costa <i>et al.</i> , 2014
	<i>Citharichthys stampflii</i>	Guinea	55	0.0046	3.26	0.99	--	Correia <i>et al.</i> , 2018
	<i>Pseudorhombus arsius</i>	India	147	0.004	3.256	0.98	--	Abdurahiman <i>et al.</i> , 2004
	<i>Pseudorhombus natelensis</i>	India	28	0.019	2.839	0.93	--	Abdurahiman <i>et al.</i> , 2004

According to Bagenal and Tesch (1978) the predicted b values ranges from 2-4 in length-weight relationships (LWRs) of fishes. Froese (2006) also reported the b value range from 2.5-3.5 in fishes. As this current review article observed some growth parameters such as R², slope b and condition factor in different regions of the world. Minimum R² was observed R²=0.49 which expresses negative growth and the highest R²=0.99 which shows positive growth where length and weight both increases. The lowest b value was observed 1.041 and the highest 3.648 there is significant variance and maximum condition factor

was observed 0.05 and the minimum was 1.94. The variations among the species can be due to the regional based and some other aspects such as environmental factors, temperature and other.

Cynoglossidae

The length-weight relationships (LWR) of 20 species of this family has been studied where highest R²=98 reported in *Cynoglossus bilineatus* from coastal water in the northern Persian Gulf of Iran (Aghajpour *et al.*, 2015), also same values was observed in *Symphurus tessellatus* from Southeastern Brazil (Da Costa *et al.*,

2014) and in *Cynoglossus senegalensis* from the Saloum Delta, Senegal (Ndiaye *et al.*, 2015). However, the lowest $R^2=49$ studied in In Pakistani water by (Ali *et al.*, 2021). The variations among the flatfish species can be due to the regional base or environmental factors. Slope b also discussed, the highest b value form this family found 3.359 in *Cynoglossus cynoglossus* from bay of Bengal, Bangladesh (Siddique *et al.*, 2023) and the lowest was reported 2.102 in *Cynoglossus puncticeps* from Pakistan (Ali *et al.*, 2021).

Paralichthyidae

LWR of 11 flatfish species from this family has been studied in current review article where the highest $R^2= 0.99$ found in *Citharichthys spilopterus* from Southeastern Brazil (Da Costa *et al.*, 2014) and same value also found in *Citharichthys stampflii* from Bijagós Archipelago, Guinea- Bissau (Correia *et al.*, 2018). This similarity of growth parameters expresses the

same environmental conditions in both countries. The lowest $R^2= 0.45$ in *Citharichthys stampflii* species In Azagny National Park, Africa (Alain *et al.*, 2022). The slope b was studied in this family where the highest b was value found 3.256 in *Pseudorhombus arsius* from southern coast of Karnataka, India (Abdurahiman *et al.*, 2004). However lowest b value found 1.019 in *Pseudorhombus elevates* from Pakistani water (Ali *et al.*, 2021). These variations can be due to the different regions temperature and other aspects.

Soleidae

A total of 18 species from this family had been studied where growth parameters were observed and highest reported $R^2=0.99$ in *Solea Solea* from Southern Aegean Sea, Turkey (Cerim and Ates, 2020) and the lowest $R^2=0.64$ in *Solea ovate* from southwestern coast, Taiwan (Chu *et al.*, 2021). Slope b also studied in this family where b value was observed 3.648

Table 3: Gathered statistical description and length-weight parameters, condition factors obtained for two families of flatfishes samples from different regions.

Family	Species	Sampling area	N	Regression parameters			Condition factor	References
				a	b	r ²		
Soleidae	<i>Euryglossa orientalis</i>	Pakistan	156	--	2.943	0.76	1.943	Ali <i>et al.</i> , 2021
	<i>Buglossidium luteum</i>	Spain	110	0.0026	3.648	0.92	--	Torres <i>et al.</i> , 2012
	<i>Dicologlossa cuneata</i>	Spain	400	0.0051	3.142	0.94	--	Torres <i>et al.</i> , 2012
	<i>Synaptura kleinii</i>	Greece	61	0.0075	3.040	0.97	--	Koutrakis <i>et al.</i> , 2003
	<i>Solea solea</i>	Greece	21	0.0098	3.002	0.98	--	Koutrakis <i>et al.</i> , 2003
	<i>Arnoglossus thori</i>	Turkey	16	0.0037	3.41	0.96	--	Cengiz, 2022
	<i>Solea nasuta</i>	Turkey	100	0.016	2.755	0.96	--	Ak <i>et al.</i> , 2009
	<i>Zebrias zebra</i>	China	14	0.0250	2.76	0.95	--	Xiong <i>et al.</i> , 2018
	<i>Solea ovata</i>	Taiwan	96	0.009	2.18	0.64	--	Chu <i>et al.</i> , 2021
	<i>Solea solea</i>	Turkey	1136	0.0079	3.064	0.99	--	Cerim <i>et al.</i> , 2020
	<i>Synapturichthys kleinii</i>	Croatia	117	0.0035	3.255	0.93	--	Dulčić <i>et al.</i> , 2006
	<i>Solea solea</i>	Croatia	2130	0.0019	3.453	0.94	--	Dulčić <i>et al.</i> , 2006
	<i>Solea solea</i>	Italy	5401	0.007	3.057	0.96	--	Bolognini <i>et al.</i> , 2013
	<i>Buglossidium luteum</i>	Croatia	37	0.0175	2.836	0.90	--	Dulčić <i>et al.</i> , 2006
	<i>Pegusa lascaris</i>	Croatia	15	0.0082	3.110	0.97	--	Dulčić <i>et al.</i> , 2006
	<i>Pegusa impar</i>	Croatia	12	0.0834	2.750	0.82	--	Dulčić <i>et al.</i> , 2006
	<i>Pegusa lascaris</i>	Turkey	93	0.0024	3.484	0.95	--	Tsagarakis <i>et al.</i> , 2015
	<i>Solea solea</i>	Turkey	88	0.0088	3.112	0.96	--	Tsagarakis <i>et al.</i> , 2015
Bothidae	<i>Arnoglossus imperialis</i>	Spain	63	0.0074	3.024	0.98	--	Torres <i>et al.</i> , 2012
	<i>Arnoglossus kessler</i>	Turkey	133	0.019	2.74	0.95	--	Ergüden <i>et al.</i> , 2018
	<i>Arnoglossus laterna</i>	Spain	317	0.0069	3.047	0.94	--	Torres <i>et al.</i> , 2012
	<i>Arnoglossus rueppelii</i>	Spain	29	0.0025	3.333	0.99	--	Torres <i>et al.</i> , 2012
	<i>Arnoglossus thori</i>	Spain	110	0.0030	3.489	0.98	--	Torres <i>et al.</i> , 2012
	<i>Engyprosonon macrolepis</i>	India	123	0.0192	2.82	0.96	--	Madhavan <i>et al.</i> , 2020
	<i>Bothus podas</i>	Egypt	155	0.0005	3.2869	0.98	1.20	Akel, 2016
	<i>Arnoglossus kessler</i>	Turkey	60	0.021	2.984	0.72	--	Ak <i>et al.</i> , 2009
	<i>Bothus podas</i>	Egypt	310	0.007	3.20	0.97	--	Abdallah <i>et al.</i> , 2002

Table 4: Gathered statistical description and length–weight parameters, condition factors obtained for four families' fish species samples from different regions.

Family	Species	Sampling area	N	Regression parameters			Condition factor	References
				a	b	r ²		
Pleuronectidae	<i>Kareius bicoloratus</i>	China	14	0.0154	3.000	--	--	Wang <i>et al.</i> , 2015
	<i>Pleuronichthys cornutus</i>	China	108	0.0067	3.26	0.99	--	Wang <i>et al.</i> , 2013
	<i>Cleisthenes pinetorum</i>	Korea	463	0.0021	3.469	0.97	--	Kwak <i>et al.</i> , 2016
	<i>Glyptocephalus stelleri</i>	Korea	478	0.0017	3.439	0.96	--	Kwak <i>et al.</i> , 2016
	<i>Platichthys stellatus</i>	Korea	250	0.0121	3.081	0.96	--	Kwak <i>et al.</i> , 2016
	<i>Pseudopleuronectes herzensteini</i>	Korea	546	0.0045	3.335	0.96	--	Kwak <i>et al.</i> , 2016
	<i>Pseudopleuronectes yokohamae</i>	Korea	452	0.0100	3.112	0.97	--	Kwak <i>et al.</i> , 2016
	<i>Pleuronectes platessa</i>	Croatia	244	0.0011	3.678	0.94	--	Dulčić <i>et al.</i> , 2006
	<i>Pleuronectes flesus</i>	Croatia	42	0.0070	3.110	--	--	Dulčić <i>et al.</i> , 2006
	<i>Pseudopleuronectes yokohamae</i>	China	20	0.0038	3.411	0.98	--	Wang <i>et al.</i> , 2015
	<i>Pleuronectes flesus</i>	Turkey	122	0.0053	3.230	0.97	--	Tsagarakis <i>et al.</i> , 2015
Scophthalmidae	<i>Scophthalmus maximus</i>	Turkey	68	0.1299	2.477	0.87	--	Bilgin, 2018
	<i>Scophthalmus maximus</i>	Turkey	2953	0.0179	3.020	0.97	--	Froese and Sampang, 2013
	<i>Lepidorhombus boscii</i>	Turkey	420	0.0049	3.146	0.97	--	Tsagarakis <i>et al.</i> , 2015
	<i>Lepidorhombus whiffiagonis</i>	Turkey	26	0.0055	3.036	0.97	--	Tsagarakis <i>et al.</i> , 2015
Citharidae	<i>Citharus linguatula</i>	Greece	72	0.007	3.01	0.96	--	Moutopoulos <i>et al.</i> , 2002
	<i>Citharus linguatula</i>	Turkey	236	0.0047	3.17	0.98	--	Daban <i>et al.</i> , 2021
	<i>Citharus linguatula</i>	Spain	284	0.0056	3.084	0.98	--	Torres <i>et al.</i> , 2012
	<i>Citharus linguatula</i>	Turkey	44	0.0133	2.780	0.92	--	Özvarol, 2014
	<i>Citharus linguatula</i>	Egypt	167	0.0197	2.6673	0.98	1.396	Akel, 2016
Psettodidae and samaridae	<i>Samaris cristatus</i>	India	31	0.0187	2.6037	0.94	--	Madhavan <i>et al.</i> , 2020
	<i>Psettodes belcheri</i>	Guinea	--	0.0043	3.26	0.95	--	Correia <i>et al.</i> , 2018
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Buglossidium luteum from the Gulf of Cadiz, Spain (Torres *et al.*, 2012) and the lowest reported value was 2.18 *Solea ovate* from southwestern coast, Taiwan (Chu *et al.*, 2021).

Bothidae

In this family a total of 9 species were studied from the different coastal waters where we observed different results from the growth parameters. The highest reported R²=0.99 in *Arnoglossus rueppelii* from the Gulf of Cadiz, Spain (Torres *et al.*, 2012) thus the lowest reported R²=0.72 in *Arnoglossus Kessler* from Eastern Black Sea coast of Turkey (Ak *et al.*, 2009). Both species are expressing positive growth but the variation was observed between both species due to many reasons including regional, temperature and other basis. From this family b values also studied where highest b value reported 3.489 in *Arnoglossus*

thori from the Gulf of Cadiz, Spain (Torres *et al.*, 2012) and the lowest b value was observed 2.74 *Arnoglossus Kessler* from Eastern Black Sea coast of Turkey (Ak *et al.*, 2009). Thus, both lowest growth parameters were reported from same study area in same flatfish.

Pleuronectidae

Total 11 species from this family was studied and their growth factors where highest R²= 0.99 found in *Pleuronichthys cornutus* from Haizhou Bay, central Yellow Sea, China (Wang *et al.*, 2013) and the lowest R²=0.94 in *Pleuronectes platessa* eastern Adriatic estuarine systems, Croatia (Dulčić *et al.*, 2006). Both species of flatfishes are expressing very positive growth. Slope b parameter also studied where highest b value was found 3.678 in *Pleuronectes platessa* from Croatia and lowest found 3.000 in *Kareius bicoloratus* from Zhimai River estuary, China (Wang *et al.*, 2015).

Scophthalmidae

Only 4 species found from this family where highest reported $R^2=0.97$ in *Scophthalmus maximus* Turkey (Froese and Sampang, 2013), same value found two different studies in *Lepidorhombus boscii* and *Lepidorhombus whiffiagonis* from the Mediterranean Sea, Turkey (Tsagarakis et al., 2015) and lowest $R^2=0.87$ reported in the Black Sea, Turkey (Bilgin and Kose, 2018). Slope b also studied where the highest b value found 3.146 in *Lepidorhombus boscii* from the Mediterranean Sea, Turkey (Tsagarakis et al., 2015). However lowest reported b value was 2.477 in *Scophthalmus maximus* in the Black Sea, Turkey (Bilgin and Kose, 2018).

Citharidae

Only 5 species were studied from this family and highest $R^2=0.98$ found in *Citharus linguatula* from the Sea of Marmara, Turkey (Daban et al., 2021) and same value also reported in same species from the Gulf of Cadiz, Spain (Torres et al., 2012) and same value found in same species from other region Egyptian Mediterranean Coast, Egypt (Akel, 2016) and lowest $R^2=0.92$ found in *Citharus linguatula* from the Gulf of Antalya northeastern Mediterranean, eastern Mediterranean Sea, Tanean Sea, Turkey (Özvarol, 2014). Highest b value was found 3.17 in *Citharus linguatula* from the Sea of Marmara, Turkey (Daban et al., 2021) and lowest found 2.6673 in *Citharus linguatula* from Egyptian Mediterranean Coast, Egypt (Akel, 2016).

Samaridae

Only one species found from this family and the $R^2=0.94$ in *Samaris cristatus* and b value is 2.6037 the parameter is showing positive growth (Madhavan et al., 2020).

Psettodidae

From this family only one species found *Psettodes belcheri* reported $R^2=0.95$ and b value is 3.26 from the Bijagós Archipelago, Guinea-Bissau (Correia et al., 2018). Thus, it is showing positive growth.

Diversity of flatfish

There are 772 species of Pleuronectiformes in existence belonging to 129 genera and 14 families (Nelson et al., 2016). Length-weight relationship are essential tool for the management of fishery and estimation of fish growth by average weight-length (Sinovcic et al., 2004). There are 133 different species of flatfish

found in the South China Sea, has the most variety. Additionally, there are a variety of flatfish assemblages found in other Indo-West Pacific locations, such as Taiwan, the Indo-Malay Archipelago, the Philippines, north-west Australia, northeastern Australia, southern Japan and the Gulf of Thailand. Many other Indian Ocean locations have also reported high levels of flatfish diversity: The Arabian Sea off the coast of southern India has about 67 different species of flatfish; the Bay of Bengal has 61 different species; Sri Lanka has 56 different species; the Andaman Sea has 49 different species; and the seas off the coast of south-east South Africa have 58 different species of flatfish. Flatfish diversity estimates are noticeably lower in some tropical regions than in adjacent areas. For instance, the Persian Gulf has only 23 species known to science, the northern Arabian Sea has 38 recorded species, the Red Sea has 29 species (Golani and Bogorodsky, 2010), surrounding waters of New Guinea have 63 species and the waters off northern Australia have 54 species. It's possible that there is less diversity of flatfish in these locations, but some of these low values might also point to a lack of sufficient documentation for many of the species that call these places home (Muroe, 2014).

Flatfish fishery worldwide

Flatfish play a significant role in demersal communities worldwide, serving as key predators in many of these populations. Additionally, they are of considerable importance in both the production of demersal fisheries and human consumption (Link et al., 2002). Fisheries constantly fall short of sustainability goals, even though almost all national and international management agencies have made pledges to that end. Significant drops in stock status are typical, and crashes have happened in numerous jurisdictions. What unsustainable practices are so prevalent in fisheries when none of the stakeholders-managers, scientists advising them, or the sector itself have the necessary resources. The role of environmental variability and governance in sustainable fisheries management is tested by examining historical trends in biomass and catch data for flatfish fisheries in New England, the Newfoundland-Labrador Shelf, the west coast of British Columbia, the Bering Sea-Gulf of Alaska, and the North Sea Northern Shelf. The data indicates that achieving sustainability in flatfish fisheries is challenging due to their size. Most stocks have experienced overfishing at some point in their history. Nonetheless, over the whole-time

span under investigation, certain populations in each category sustained sustainable fishing, suggesting that this is feasible under a variety of circumstances. The likelihood of management success varied as predicted throughout different jurisdictional regimes and across significant geopolitical regions. Additionally, there were conflicting variances in stock and by catch sustainability and target fisheries sustainability (Rice and Cooper, 2003).

Flatfish fishery status in Pakistan

Pakistan's coastline, which is separated into two coastal regions, such as the coastal regions of Sindh and Balochistan, stretches more than 990 kilometers along the Arabian Sea (Ali et al., 2024). Flatfish are a prominent feature of Pakistani coast estuarine ecosystems, and certain species have been found to contribute significantly to fisheries catch. The Cynoglossidae family, which includes nine typical species, is known to have a varied range of species along the Pakistani coast. In contrast, the Soleidae family has six species, and the Paralichthyidae and Bothidae families include five species of sole fish. While there is only one species of single fish in the Samaridae and Psettodidae families (FAO, 2015). Fish that are flat in shape are important for the energy route and for maintaining benthic organisms in a state that is fit for human consumption (De-Groot, 1971).

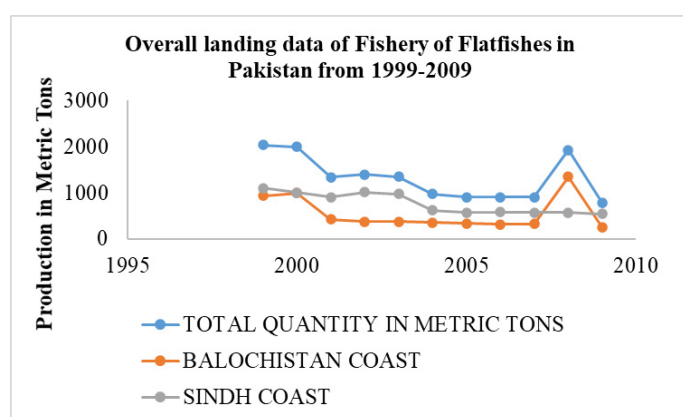


Figure 4: Overall landing data of the Flatfishes fishery (total catch in metric tons) in Pakistan during 1999-2009. (Source: MFD 2015).

Comparative fishery data from Pakistan coast

Figure 4 shows that the total landing of flatfishes has been reduced from 2037 metric tons in 1999 to 795 metric tons in 2009. The lowest landing was recorded in 2009 when only 795 metric tons of flatfishes were landed in Pakistan. The fisheries of flatfishes showed decline trends in the both provinces, while the highest 1355 metric tons in 2008 and lowest landing 255 metric tons in 2009 for flatfishes recorded in the

Baluchistan coast.

Conclusions and Recommendations

This review article presents 80 length-weight relationship data of flatfish belonging to 9 families, gathered from the different literatures worldwide and also compared the data with others regions to check the growth parameters and availability of flatfish stock, flatfish diversity. Growth factors also studied where highest estimated $R^2=99$ found from many species which expresses positive growth however the lowest was obtain $R^2=49$ in *Cynoglossus puncticeps* from Pakistan and the highest b value was found 3.648 in *Buglossidium luteum* from Spain and lowest b value was 1.041 in *Citharichthys stampflii* from Africa. Thus, the highest condition factor was observed 3.557 in *Citharichthys stampflii* from Africa and lowest was 0.05 in *Cynoglossus lingua* from Bangladesh.

Novelty Statement

This review article provides a global synthesis of the length-weight relationship in flatfish, emphasizing species-specific trends, ecological influences and regional variations. It integrates diverse datasets to identify growth patterns, highlights research gaps, and proposes standardized methodologies for future investigations.

Author's Contribution

Wajid Ali and Asadullah Ali Muhammad: Done Ideation, implementation, and text composition.

Ying Chen and Jie Qi: Supervising, write-up and editing.

Conflict of interest

The authors have declared no conflict of interest.

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