ISSN: 0001-5113 AADRAY	ACTA ADRIAT., 52(2): 261 - 268, 2011	UDC: 597.556.333.7: 593.1 (262.16)

Investigation of Length-Weight Relationships for 10 commercial fish species as a possible trophic state index of Coastal Lagoons

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Length-weight (L-W) relationships were estimated and compared for 10 commercially important fish species caught during September-December 2004 from two lagoons in the Ionian Sea based on similar length ranges. The median value of the exponent b of the L-W relationships was 3.091 and ranged from 2.444 to 3.536. The larger specimens of the mid-trophic level species (i.e. Sparus aurata*,* Diplodus annularis *and* D. sargus*) were heavier at the same length in the less eutrophic lagoon. In contrast, most of the low-trophic level species (i.e. Mugilidae) did not show significant (P>0.05) differences of the L-W parameters between the studied lagoons. The estimated parameters of the L-W relationships for each species between the two lagoons in relation to their trophic state are also discussed. Our findings indicated that the L-W relationships of the mid-trophic level species may be possibly used as an index of the trophic state in lagoons.*

Key words: Length-weight relationship, trophic state index, lagoon, Ionian Sea

INTRODUCTION

Coastal lagoons are organically enriched areas where high biomass and productivity is attained as they are influenced by both marine and terrestrial environments (BARNES, 1980). Given that, lagoons play an important role as nurseries, offering food and shelter to numerous fish species that spawn in the open sea (COSTA *et al.,* 2002). However, these environments are fragile and sensitive to both natural and anthropogenic changes in their abiotic and biotic parameters (CLOERN, 2001), a fact that increases their vulnerability to sustaining a balanced food-web structure (REIZOPOULOU *et al*., 1996). The intermediate role between the open sea and inland waters makes lagoons important ecosystems that are usually protected under international conventions (i.e. Ramsar: www.ramsar.org; or as a part of Natura 2000 network: http://ec.europa.eu/environment/ nature/natura2000/index_en.htm). Coastal lagoons are also key ecosystems for fisheries exploitation operated by local fishing communities (KAPETSKY, 1984). In Greece, fishery exploitation in lagoons is traditionally based on the species-specific inshore-offshore seasonal or ontogenic fish migrations using a variety of fishing gears and methods (i.e. barrier traps, beam trawls, fyke nets, trammel nets and longlines) (ANONYMOUS, 2001).

The importance of Length-Weight (L-W) relationships has been extensively documented elsewhere (FROESE, 2006). Among others, L-W relationships are used for between-habitat comparisons of growth of a specific species (HANIFFA *et al.*, 2006; TSOUMANI *et al*., 2006) considering L-W estimates as an index of habitat trophic state. In Greek waters, L-W relationships were

extensively studied (STERGIOU & MOUTOPOULOS, 2001; KOUTRAKIS & TSIKLIRAS, 2003) and were originally used to provide estimates for the conversion of length to weight and vice versa and for determining the condition of fish. The aim of the present study was to present the L-W relationships for 10 commercially important fish species caught in two lagoons of the Ionian Sea and to explore for possible between-lagoon differences of L-W parameters estimated for these species.

MATERIAL AND METHODS

The Klisova (38°20'26''N, 21°27'10''E) and Papas lagoons (38°11'37''N, 21°23'39''E) are located in the Patraikos gulf (western Greece). These are typical closed type coastal lagoons (ANONYMOUS, 2001), with differences in their trophic state. Papas is more eutrophic than Klisova (Table 1) and has occasionally exhibited dystrophic crises (NIKOLAIDOU *et al*., 2005). Species composition (%) of the lagoon landings was comprised in great part by typical species of Greek lagoons; five species of Mugilidae (*Chelon labrosus*, *Liza aurata*, *Liza saliens*, *Liza ramada* and *Mugil cephalus*) (50-55%), *Sparus aurata* (9-15%), *Anguilla anguilla* (eel) (7-16%), *Dicentrarchus labrax* (1-2%) and *Diplodus* species (i.e., *Diplodus annularis*, *D. sargus*, *D. puntazzo*) (5-15%) (ANONYMOUS, 2001).

*Table 1. Morphological and environmental parameters for the studied lagoons (from Nicolaidou et al., 2005; * unpubl. data*

Lagoon characteristics	Klisova	Papas
Size (km^2)	18	3
Depth (m)	0.2-2.0	0.2-1.5
Salinity (psu)	23.0-41.0	20.0-42.5
T°C	5.0-30.0*	10.0-32.0
O_2 (mg/l)	5.0-6.7	1.2-9.3
Coarse %	19.9-35.6	23.0-98.0
Organic C %	1.6-3.6	2.9-5.6

Bi-monthly samples were derived from landings caught by barrier traps in the studied lagoons during the September-December 2004 period. The samples were preserved frozen (-20°C). Using a random sub-sample, sex was determined from gonad examination and gonad maturity stage was determined visually following the KESTEVEN scale (1960). The individuals with gonad maturity stage higher than stage II of KESTEVEN's scale were considered as mature while the rest as immature. In order to examine for significant differences of sex ratio and maturity stage of the same species between the studied lagoons a χ^2–test (p=0.05) was applied (ZAR, 1999).

Fork length (FL) to the nearest mm, and total weight (W) to the nearest 0.1 g were measured. L-W relationships per species-lagoon combination were estimated by the exponential equation $W = aFL^b$, where a and b are the parameters determined by the method of least squares on the logarithmic form of the above equation. In order to minimize the effects of season, age and maturity stage on L-W relationships per species and lagoon, similar length ranges and sampling periods were used. To examine for significant differences on L-W relationships between lagoons an analysis of covariance (ANCOVA; P=0.05) was applied (ZAR, 1999).

To visualize the differences in growth on weight with respect to species length between the studied lagoons the following index (IW) was used:

$$IW(FL) = \frac{W_1(FL)}{W_2(FL)} = \frac{a_1}{a_2} \times \frac{FL^{b_1}}{FL^{b_2}},$$

where a_1, b_1, a_2 and b_2 are the parameters of the L-W relationship of Klisova (i=1) and Papas (i=2), respectively. The index represented the ratio of theoretical weight of each FL in Klisova to the corresponding theoretical weight in Papas. Hence, when $IW(FL)>1$ the weight at same length of each species was greater in Klisova lagoon while the inverse was true when the weight at same length was greater in Papas lagoon.

RESULTS AND DISCUSSION

No significant differences of both average maturity stage and sex ratio in the same species between the studied lagoons (χ^2; $p<0.05$) were recorded (Table 2). L-W relationships were estimated for 10 fish species (n=5756) belonging to three families (Table 3). All relationships were highly significant ($P < 0.001$), with all R^2 values being greater than 0.867. The median value of *b* was 3.091 and 50% of the values ranged between 3.011 and 3.296. Minimum (2.444 for *D. puntazzo*) and maximum (3.536 for *L. aurata*) *b* values were recorded in Papas lagoon.

Comparisons of *b* values between lagoons showed that for *L. aurata b* values were significantly (ANCOVA; $P<0.05$) greater in Papas lagoon, whereas for *D. puntazzo*, *D. sargus* and *S. aurata* were significantly (ANCOVA; $P<0.05$) greater in Klisova lagoon. For the remaining species (i.e. *D. labrax*, *C. labrosus*, *L. ramada*, *L. saliens*, *M. cephalus* and *D. annularis*) *b* values did not significantly (ANCOVA; $P>0.05$) differ between the studied lagoons.

The estimation of the *IW*(FL) index showed that the larger individuals of *D. sargus*, *D. puntazzo*, *S. aurata* and all sampled individuals of *D. annularis* were heavier at the same length in Klisova than in Papas (*IW*(FL) > 1), whereas the inverse was true for the larger individuals of *L. aurata.* For the remaining Mugilidae species (i.e. *C. labrosus*, *L. ramada*, *M. cephalus* and *L. saliens*) the *IW(FL)* values were less than one. All sampled individuals of *D. labrax* recorded *IW(FL)* values greater than one (Fig. 1).

A number of factors are known to influence the L-W relationship in fish (i.e. habitat, growth phase, season, degree of stomach fullness, gonad maturity, sex, size range, health, fish condition and preservation techniques) (FROESE, 2006). During this study an attempt was made to reduce the influence of certain of these factors affecting the L-W estimates in order to focus on the effect of habitat. Indeed, the sampling protocol (i.e. sampling during the same period, selection of samples with similar length ranges and using the same preservation technique for all species caught in both studied lagoons) reduced

Table 2. Number of individuals per maturity stage category and per sex of the studied species in Klisova and Papas lagoons (MT: mature individuals, IM: immature individuals, N: total number of species, ML: males, FM: females and P: probability from χ^2-test)

	Number of individuals per maturity stage category							Number of individuals per sex						
	Klisova			Papas				Klisova			Papas			
Species	MT	IM	N	MT	IM	N	P	ML	FM	IM	ML	FM	IM	P
Dicentrarchus labrax	132	183	315	61	101	162	0.33	71	61	183	28	33	101	0.32
Chelon labrosus	69	113	182	49	66	115	0.49	34	35	113	26	23	66	0.61
Liza aurata	54	126	180	52	102	154	0.43	29	25	126	27	25	102	0.73
Liza ramada	37	82	119	26	67	93	0.63	18	19	82	14	12	67	0.81
Liza saliens	14	45	59	13	61	74	0.39	8	6	45	7	6	61	0.65
Mugil cephalus	26	30	56	17	27	44	0.48	15	11	30	11	6	27	0.82
Diplodus annularis	8	152	160	2	66	68	0.51	8	0	152	2	0	66	0.78
Diplodus puntazzo	0	65	65	2	120	122	0.31	0	0	65	2	0	120	0.58
Diplodus sargus	3	77	80	6	116	122	0.74	3	0	77	6	0	116	0.92
Sparus aurata	89	40	129	151	59	210	0.55	77	12	40	130	21	59	0.58

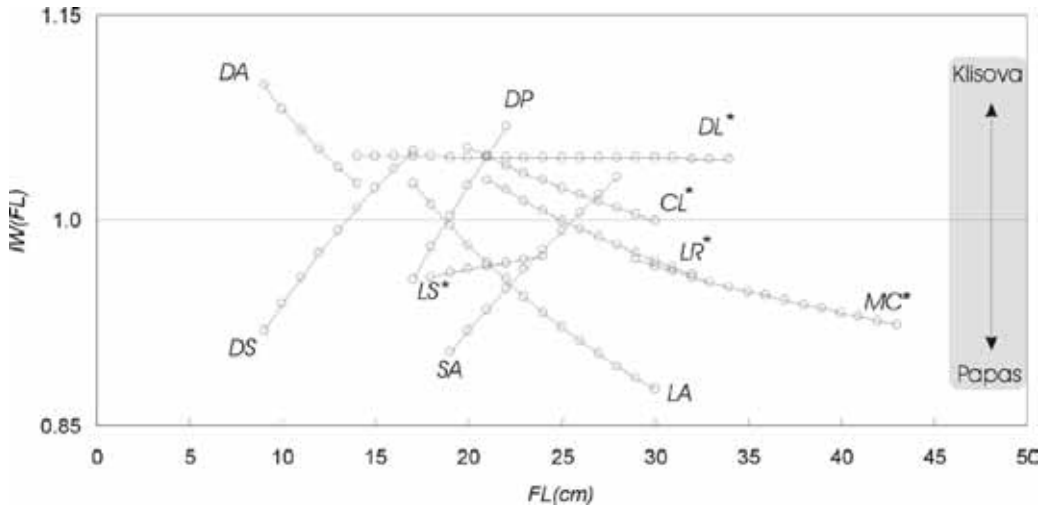

*Fig. 1. The weight to length index (IW(FL)) of the study species (DA: Diplodus annularis, DS: D. sargus, DP: D. puntazzo, SA: Sparus aurata, LA: Liza aurata, LR: L. ramada, LS: L. saliens, MC: Mugil cephalus, CL: Chelon labrosus and DL: Dicentrarchus labrax) for Papas and Klisova lagoons according to Fork Length (in cm). * indicates the species with non significant statistical differences in the L-W parameters between the two lagoons*

the effect attributed to different growth stage, season, preservation techniques and the degree of stomach fullness. With respect to the latter, it has been observed that most seaward migrated fish caught by barrier fish traps (KATSELIS *et al.,* 2002) have empty stomachs (MINOS, 1996; HOTOS, 1999; ROGDAKIS, 2004; DIMITRIOU, 2007). In addition, maturity stage and sex ratio did not differ significantly among the same species caught in the studied lagoons indicating that the effects of gonad maturity and sex on L-W relationships are very low.

Thus, it is clear that the L-W relationships determined in this study represented the growth in weight according to length under a priori conditions and could not be used for between-species growth comparisons. Nevertheless, most of the estimated *b* and $CL_{95\%}$ values were within the values recorded worldwide (FROESE & PAULY, 2011). Five of six outliers of *b* values, apart from *D. puntazzo* in Papas (*b*=2.444), were found on the right side of the *b* distribution. Also, the *b* values calculated from previous studies for *L. aurata* (HOTOS, 1999), *L. ramada* (MINOS, 1996), *L. saliens* (KATSELIS *et al.*, 2002), *D. labrax* (ROGDAKIS, 2004) and *S. aurata* (DIMITRIOU, 2007) in the Mesolonghi Etoliko lagoon complex (including Klisova) were close to those calculated in the present study.

Previous studies on the mid-trophic level species *Carassius gibelio* from Greek (TSOUMANI *et al*., 2006) and Danish lakes (JEPPESEN *et al.*, 2000) demonstrate that the body weight of species declined with the increase of phosphorus concentration that contributed to food availability according to the trophic state of each lake (TSOUMANI *et al*., 2006). In the present study, for those species that differed in the estimated L-W relationships between lagoons (Table 2), *IW(FL)* values tended to be higher at the same length in Klisova than in Papas lagoon for mid-trophic level species (i.e. *D. annularis*, *D. sargus* and *S. aurata*) (STERGIOU & KARPOUZI, 2002), whereas the inverse was true for the low-trophic level species *L. aurata* (BRUSLE, 1981) (Fig. 1).

Mid-trophic level species feeding mostly on macrozoobenthic organisms (STERGIOU & KARPOUZI, 2002), have a mean size that is negatively related to the trophic state of lagoons (REIZOPOULOU *et al*., 1996). Taking into account also that prey size is positively related to predator size (KARPOUZI & STERGIOU, 2003) and its nutritive value, it was likely that the largest specimens of the above-mentioned mid-trophic level species maximized their energy intake by increasing the consumption of the largest macrozoobenthic organisms (WOOTTON, 1998). Hence, Papas, as a

*Table 3. Estimated parameters of the length-weight relationships [Ln(W) = Ln(a) + b x Ln (FL)] (W in g and FL in cm) for 10 fish species from two lagoons of western Greece (Ionian Sea). N is the sample size; a and b are the parameters of the relationship; SE_a and SE_b are the standard errors for the two parameters; R^2 is the coefficient of determination; and * indicates significant (ANCOVA; P<0.05) difference in L-W parameters between the two lagoons*

Family	Species	Klisova lagoon							Papas lagoon							ANCOVA	
		N	Range FL	Ln(*a*)	SE_a	*b*	SE_b	R^2	N	Range FL	Ln(*a*)	SE_a	*b*	SE_b	R^2	*a*	*b*
Moronidae	*Dicentrarchus labrax*	316	14.0-34.3	-4.81	0.055	3.074	0.017	0.983	171	14.0-34.3	-4.861	0.049	3.076	0.017	0.993		
Mugilidae	*Chelon labrosus*	183	20.9-32.1	-5.15	0.240	3.242	0.076	0.920	114	21.1-32.1	-5.683	0.192	3.407	0.059	0.967		
	Liza aurata	530	17.7-31.2	-5.32	0.122	3.255	0.039	0.930	404	17.7-31.1	-6.143	0.072	3.536	0.023	0.978	*	*
	Liza ramada	124	20.9-30.7	-5.78	0.153	3.376	0.048	0.971	180	20.9-30.7	-6.215	0.208	3.504	0.064	0.940		
	Liza saliens	84	18.0-24.4	-4.85	0.237	3.086	0.078	0.950	101	18.0-24.4	-4.649	0.282	3.031	0.092	0.915		
	Mugil cephalus	73	29.7-43.2	-3.97	0.293	2.955	0.084	0.947	48	29.3-43.1	-4.364	0.573	3.081	0.157	0.950		
Sparidae	*Diplodus annularis*	376	8.9-14.4	-4.09	0.102	3.102	0.043	0.960	110	8.9-14.4	-4.525	0.107	3.257	0.053	0.980	*	
	Diplodus puntazzo	92	17.1-21.2	-3.38	0.338	2.870	0.117	0.867	190	17.1-21.2	-2.129	0.203	2.444	0.068	0.870	*	*
	Diplodus sargus	169	9.6-16.5	-3.96	0.121	3.097	0.047	0.983	1048	9.5-16.5	-3.409	0.071	2.885	0.027	0.910	*	*
	Sparus aurata	396	18.1-28.3	-5.04	0.079	3.334	0.026	0.975	1047	18.1-28.3	-3.925	0.089	2.990	0.029	0.910	*	*

higher primary productivity lagoon than Klisova (Table 1) (NICOLAIDOU *et al*., 2005), possibly offered lower food availability for mid-trophic level species that was accordingly reflected on the L-W parameters.

On the other hand, the adult specimens of Mugilidae exploit mainly the primary productivity, feeding on algae, diatoms and detritus (BRUSLE, 1981). Thus, lagoons provided high food availability for Mugilidae, a fact that might be confirmed by the differences of the L-W parameters and the values of *IW(FL)* index estimated for *L. aurata* (heavier in Papas than in Klisova), while for the other species of Mugilidae, a comparison of the L-W parameters between the two lagoons did not show any significant differences. This could be attributed to the fact that the observed differences of the trophic state between the studied lagoons might affect less, or affect to such a low degree as to be undetectable, the L-W relationships estimated for these species. Also, the opportunistic carnivorous-piscatorious *D. labrax* (PICKETT & PAWSON, 1994; ROGDAKIS *et al*., 2010) might have the ability to maximize its consumption intake and thus, no significant differences in growth as well as in L-W estimates between the studied lagoons may be expected.

In conclusion, our findings indicated that from ten commercial fish species caught in two lagoons, three mid-trophic level species (*D. annularis, D. sargus* and *S. aurata*) showed differences in the L-W relationships between lagoons that might be related to differences in the trophic state between habitats. This prospect is very interesting for evaluating the trophic state of the lagoons as the studied species are among the commonest species of Greek lagoon landings (ANONYMOUS, 2001) and L-W relationships are a very easy and low cost index to determine.

ACKNOWLEDGEMENTS

The authors wish to thank two anonymous reviewers for their useful comments and suggestions.

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Received: 10 May 2010
Accepted 05 July 2011

Istraživanje dužinsko-masenih odnosa za 10 komercijalnih vrsta riba kao mogućih indeksa trofičkih stanja obalnih laguna

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SAŽETAK

Dužinsko-maseni (LW) odnosi su procijenjeni i uspoređeni za 10 komercijalno važnih vrsta riba ulovljenih tijekom razdoblja rujan-prosinac 2004. godine iz dvije lagune u Jonskom moru na temelju raspona sličnih dužina. Medijan vrijednosti eksponenta b dužinsko-masenog odnosa je iznosio 3,091, a kretao se od 2,444 do 3,536. Veće jedinke, srednjeg trofičkog nivoa, vrsta *Sparus aurata, Diplodus annularis* i *D. sargus* su bile teže za istu duljinu ali u manje eutrofnim lagunama. Nasuprot tome, većina vrsta niskog trofičkog nivoa (tj. Mugilidae) nisu pokazali značajne razlike ($P > 0,05$) između parametara dužinsko masenog odnosa u istaživanim lagunama.

Izračunati parametri dužinsko masenog odnosa za svaku vrstu između dviju laguna u odnosu na njihov trofički status se također raspravlja u ovom radu. Naši rezultati pokazuju da dužinsko maseni odnosi vrsta srednjeg trofičkog nivoa mogu eventualno poslužiti kao indeks trofičkog statusa u lagunama.

Ključne riječi: dužinsko-maseni odnos, indeks trofičkog statusa, laguna, Jonsko more