PHYSICAL PROPERTIES OF THREE SONGKHLA LAGOON FISH SPECIES IN THE LOWER GULF OF THAILAND DURING AND AFTER THE MONSOON SEASON

HUE, H. T. T.[1,2,3*] – PRADIT, S.[1,3*] – JARUNEE, C.[1,3] – LIM, A.[4] – NITIRATSUWAN, T.[5] – GONCALO, C.[6]

[1]*Marine and Coastal Resources Institute (MACORIN), Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand*

[2]*Central Institute for Natural Resources and Environmental Studies, Vietnam National University, Ha Noi, Vietnam*

[3]*Coastal Oceanography and Climate Change Research Center, Prince of Songkla University, Hatyai, Thailand*

[4]*Faculty of Science and Technology, Prince of Songkla University, Pattani, Thailand*

[5]*Rajamangala University of Technology, Srivijaya, Trang, Thailand*

[6]*Swedish Agency for Marine and Water Management, Stockholm, Sweden*

**Corresponding authors*
e-mail: hathithuhue2001@yahoo.com; spradit22@gmail.com; phone: +66-910-495-786; +84-98-726-1294

(Received 3rd Jul 2018; accepted 31st Aug 2018)

Abstract. Length–weight relationships (LWR) were estimated for three main Songkhla Lagoon fish species occurring in the lower gulf of Thailand. Samples were collected monthly during monsoon and after monsoon season (September 2017 to April 2018). Fishes were captured by three methods: fishing gear, crab gear and shrimp gear. This study is the first reference on LWR equation parameters of *Pellona ditchella* (Valenciennes, 1847), *Sardinella gibbosa* (Bleeker, 1849) and *Alepes vari* (G. Cuvier, 1833) in the lower gulf of Thailand, this good document would be used to compare these fish condition with many coastal areas in the world. This work provides the important information of fish migration between lagoon and lower gulf of Thailand as well as for two species from which we present a wider size range in FishBase, *Pellona ditchella* (Valenciennes, 1847) and *Sardinella gibbosa* (Bleeker, 1849).
Keywords: *length–weight relationship, Pellona ditchella, Sardinella gibbosa, Alepes vari, fish migration, fish well-being*

Introduction

Songkhla Lagoon is one of the two lagoons in the world that has Irrawaddy dolphins (*Orcaella brevirostris*), which are endangered species. The lagoon is located in the southern part of Thailand and is divided into three distinct parts. The southern part of the lagoon is connected to the Gulf of Thailand through a 380 m wide strait Songkhla Lagoon. It is very rich regarding biodiversity and provides resources and livelihoods for local fishermen all year around. The livelihood of more than 1.9 million people of the 25 districts located in the three provinces of Southern Thailand rely on the lagoon's fishery resources. However, as in many other similar ecosystems elsewhere (Martínez et al., 2007; Satumanatpan and Pollnac, 2017), those resources have been declining sharply over recent decades. Many fishermen of Songkhla Lagoon are wondering

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

whether they can sustain themselves through fishing or if they must convert to another occupation. Many of them have already moved to other fishing areas or changed profession.

As part of the efforts to create policies for sustainable fishing in Songkhla Lagoon and improve the livelihoods of fishing communities dependent on the lagoon's resources, numerous studies were conducted in the past two decades on Songkhla Lagoon, focusing mostly on models of fish catch landing (e.g. Chesoh and Lim, 2008; Chesoh, 2009; Chesoh and Choonpradub, 2011; Hue et al., 2018) or the effects of chemical contamination (e.g. Pradit et al., 2013). Other research has dealt with the government-led shrimp restocking program (Xu et al., 1997; Davenport et al., 1999; Wang et al., 2006; Hamasaki and Kitada, 2013; Niamaimandi and Zarshenas, 2015).

Fish condition can be a very important parameter to the managers of fisheries. Plump fish may be an indicator of favorable environmental conditions (e.g., habitat, food availability), whereas thin fish may indicate a less favorable environment. Thus, monitoring fish well-being can be extremely useful for the biologists of fisheries to make management recommendations concerning fish populations and their management. There is evidence that length–weight relationships (LWR) plays an important role in estimating fish biomass based on length. These parameters can be compared between seasons, years or different areas using standardized sampling procedures (Correia et al., 2017), and data on the length and weight of fish are currently two of the most common and standardized parameters about the biology of fish (Le Cren, 1951).

Pellona ditchella (Valenciennes, 1847), *Sardinella gibbosa* (Bleeker, 1849) and *Alepes vari* (G. Cuvier, 1833) are present in most of the markets in Southeast Asia. Their current known distribution extends across the Indo-West Pacific: from Madagascar, and Durban, South Africa to the Gulf of Oman and the coasts of India; from the Andaman Sea to Indonesia and the Philippines, southeast to the Arafura Sea, northern and western Australia and Papua New Guinea (Russell et al., 1989). During the period 2003-2017, they were found frequently in the lower Gulf of Thailand, including Songkhla Lagoon. *P. ditchella* is found most often in coastal, marine waters, but also enters mangroves and river estuaries, and tolerates brackish water and freshwater. *S. gibbosa* is commonly found in marine, pelagic-neritic habitats, and forms schools in coastal waters. Alepes scads are marine, coastal predatory fish not found in the open oceans (Pauly et al., 1996; Riede, 2004; Fricke et al., 2011).

Information about the health of these fishes is important in all countries along their range of distribution where they are fished commercially. Previous research on these fishes focuses on *S. gibbosa* and includes a study on the genetics and morphology of cryptic species of *S. gibbosa* (Thomas et al., 2014); the confirmation of presence of *S. gibbosa* in the Red sea and documenting its introduction into the Eastern Mediterranean Sea (Stern et al., 2015); heavy metal contamination in *S. gibbosa* in the coast of Balochistan, Pakistan (Ahmed et al., 2015); and stock assessment of *S. gibbosa* in the Gulf of Thailand (Boonjorn et al., 2012). No studies are known of the ecology or the living conditions of these fishes, let alone of monthly or seasonal changes in those two aspects. This paper addresses this gap by studying monthly and seasonal changes in the length–weight relationship of the two species and one genus of fish. It provides an account of investigations carried out in both Songkhla Lagoon and Sathing Pra, in a context of sharp decline in fish catches in Songkhla Lagoon. This study concentrates primarily on the populations and general biology of those fishes, in particular growth

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

and related aspects, thereby providing early findings to inform further research on measures to enhance fish populations in Songkhla Lagoon.

Material and methods

Study site

This study was conducted in the lower Gulf of Thailand, in the coastal area of Sathing Pra District, Thailand (*Fig. 1*). The climate of the lower Gulf of Thailand is governed by two monsoons the southwest monsoon from May to September, and the northeast monsoon between October and March. There are two seasons: (a) the rainy season, usually covering the period May to January, with the heaviest rains typically in November; and (b) the dry season, from February to April. April is normally the hottest month (ONEP, 2005).

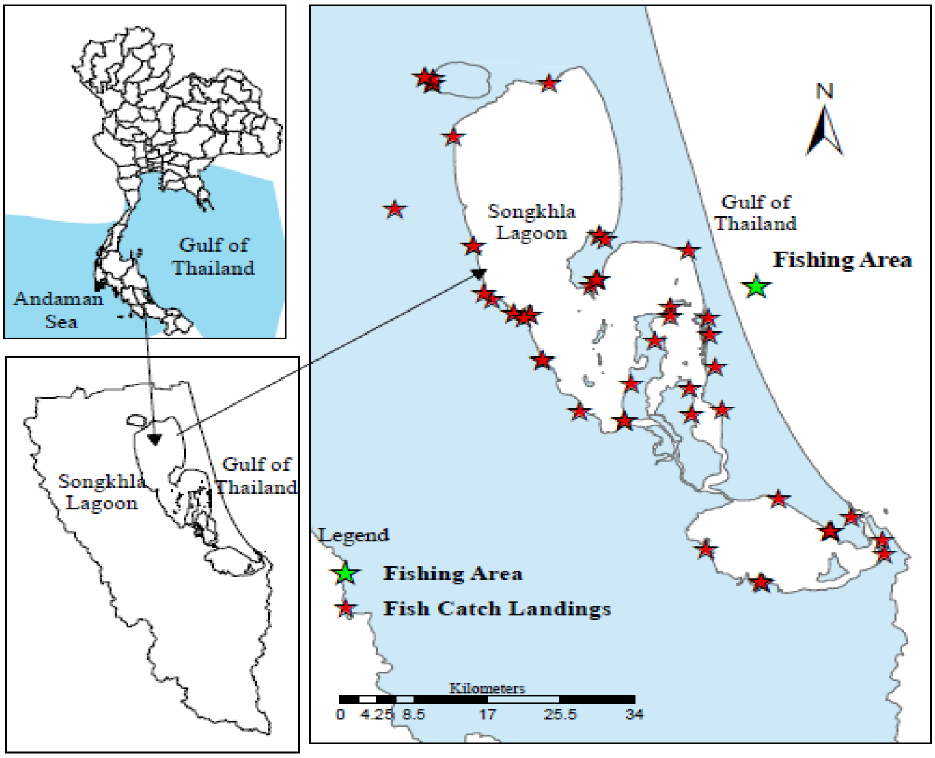

Figure 1. *The locations of sampling*

Data collection

Specimens used in this study were collected on a monthly basis from fishermen fishing in the coastal district of Sathing Pra during the period of September 2017 to April 2018, at the sampling sites indicated in *Figure 1* (07°31’24” N; 100°27’46” E). A list of 185 fish species found in Songkhla Lagoon during 2003-2017 issued by the Thai National Institute of Coastal Aquaculture (NICA) was used to identify the caught fish species. The list was first given to the head of Fisherman Association in Sathing Pra, through whom it was distributed to the fishermen contributing to the study, who did the first species identification themselves.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

The fishing grounds where the specimens were caught are located approximately 3 km from the shores of the lagoon. Number Fish specimens were captured with two main fishing gears: fish nets (length: 180 m, mesh size: 4.5 × 4.5 cm) and shrimp nets (length: 30 m, mesh size: 3 × 3 cm), the only one fish specimen Sardinella gibbosa was caught with crab nets (length: 180 m, mesh size: 11 × 11 cm), at depths of approximately 80, 15 and 20 m, respectively. Fishing usually took place between 3 and 6 am, with some variation between months and seasons. The fishing boats in this coastal area are usually small boats with a length of 7-10 m length and a width of 1.8-2 m.

All specimens were bought from the fishermen, iced and transferred to the laboratory of the Marine and Coastal Resources Institute, Prince of Songkla University (MACORIN), where a verification of the species was carried out, followed by the measurement of the total length and weight. Total length of fish was measured from the tip of the premaxilla to the tip of the longest caudal fin ray stretched out posteriorly. Millimeter was used to be length measurements (Society, 2017). The total weight of fish specimens was recorded with an accuracy of 0.1 g using an Ohaus digital weighing balance (Ajani et al., 2013).

Data analysis

The purpose of this study is to assess the condition of commercially important fish found in Songhkla Lagoon by investigating their length–weight relationship, and monthly and seasonal changes in this parameter. The monthly data on length and weight was separated into two periods: the monsoon season (from September 2017 to January 2018) and after the monsoon season (dry season) (from February to April 2018).

Length–weight relationship analysis

Linear transformation of fish length and weight was made by using natural logarithm at the observed lengths and weights. The length–weight relationship (LWR) was calculated following Pauly (1983) and used to calculate the regression coefficient (slope of regression line of weight and length). The parameter “β” of the LWR was estimated using *Equation 1:*

$$W = aL^{\beta} \qquad \text{(Eq.1)}$$

Here: W = the weight of the fish in grams, L = the total length of the fish in millimeters, a = constant, β = growth exponent.

A logarithmic transformation was used to make the relationship linear (*Eq. 2;* Le Cren, 1951):

$$\text{Log } W = \beta \log L + \log a \qquad \text{(Eq.2)}$$

The LWR parameters *a* and β as well as the coefficient of determination (R^2) were derived by least squares regression (Ricker, 1973). The slope (β) also known as the allometry coefficient, has an important biological meaning, indicating the rate of weight gain relative to growth in length or the rate at which weight increases for a given increase in length.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

Inferences about slope (β)

If a fish grows without changing its shape or density, then it is said to exhibit isometric growth. In this case, the volume of the fish is proportional to any linear measure of its size and β = 3. Isometric growth in fish is rare (Bolger and Connolly, 1989; McGurk, 1985). If β > 3 the fish tends to become “plumper” with an increase in length, a situation called positive allometric growth (Blackwell et al., 2000). If β < 3 the fish tends to become “thinner” with a decrease in length, a situation called negative allometric growth (Froese, 2006).

A test of whether the fish from the lower Gulf of Thailand exhibits allometric growth or not and confidence interval for β can be obtained by fitting the transformed length–weight model. The slope is generically labeled with beta (β) such that the test for allometry can be translated into the following statistical hypotheses:

$$H_0 : \beta = 3 \text{ ("Isometric growth")}$$

$$H_1 : \beta \neq 3 \text{ ("Allometric growth")}$$

Regarding model parameters can be obtained with a t-test using *Equation 3:*

$$t = \frac{\hat{\beta} - \beta_0}{SE_{\hat{\beta}}} \quad \text{(Eq.3)}$$

where β, SE_β are from the linear regression result and β_0 is the specified value in the H_0. In this study, the hypothesis test that a linear model parameter is equal to a specific value. To test a parameter is equal to a value other than 0, hoCoef meets all the requires and was used to efficiently compute the t and corresponding P-value for non-default hypothesis (for H_0: $\beta = 0$ by default).

Predictions of fish original scale

The study used the result from the length–weight regression to predict the weight of the fishes at the mean length. The result was back – transformed to the original scale by exponentiation. Due to the fact that the geometric mean is always less than the arithmetic means and, thus, the back-transformed mean always underestimates the arithmetic mean from the original scale (Ogle and College, 2013), the final original scale was multiplied with a correction factor derived from analysis of normal and log – normal distribution theory, using *Equation 4:*

$$e^{\frac{(\delta_{Y/X})^2}{2}} \quad \text{(Eq.4)}$$

where $\delta_{Y/X}$ is calculated from summarizing model length–weight regression of fish.

Comparing length–weight regressions (between seasons)

Inter-seasonal variation in the LWR of the fish included in this study was assessed by means of an analysis of variance (ANOVA) of the regression models using the factor season. The statistical significance for the study was set at a P value < 0.05. The full

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

model with indicator and interaction terms was then fit and stored in an object with the ANOVA table. All statistical analysis was performed using the FSA package (Ogle, 2018) from the R software (R Core Team, 2018).

Results

During the study period, 20 different Songkhla Lagoon species were captured in the coastal area of Sathing Pra, of which two species were crabs, three species were shrimps and 15 species were fish. The number of species varied markedly between months, but the fish species Indian pellona (*Pellona ditchella*), goldstripe sardinella (*Sardinella gibbosa*) and genus alepes (*Alepes vari*) appeared regularly, with sample sizes of 537, 162 and 49, respectively *(Table 1)*. Among the samples, the total length of *P. ditchella* ranged from 103 to 183 mm, *S. gibbosa* from 102 to 175 mm, and *Alepes vari* from 122 to 216 (*Table 1*), whereas the ranges of the total body weight were 9 to 59 g, 6 to 43 g, and 11 to 93 g, respectively (*Table 1*).

Table 1. *Total length and weight for Pellona ditchella, Alepes vari and Sardineela gibbosa*

Common name	Scientific name	Sample size	Total length (mm)		Total weight (g)	
			Range	Mean	Range	Mean
Pellona ditchella	*Pellona ditchella* (Valenciennes, 1847)	537	103-187	143.9	9-59	30.81
Alepes vari	*Alepes vari* (G. Cuvier, 1833)	49	112-216	162.9	11-93	47.71
Sardinella gibbosa	*Sardinella gibbosa* (Bleeker, 1849)	162	102-175	130.8	6-43	19.93

Length–weight model

Figure 2 depicts the natural log-transformed total length and weight of *P. ditchella*, Alepes and *S. gibbosa* captured in the lower gulf of Thailand between September 2017 and April 2018, with the best fit regression line superimposed. *Table 2* gives the equations and other parameters of the length weight models for the three fish included in the study by using *Equation 2*, derived from those regression lines.

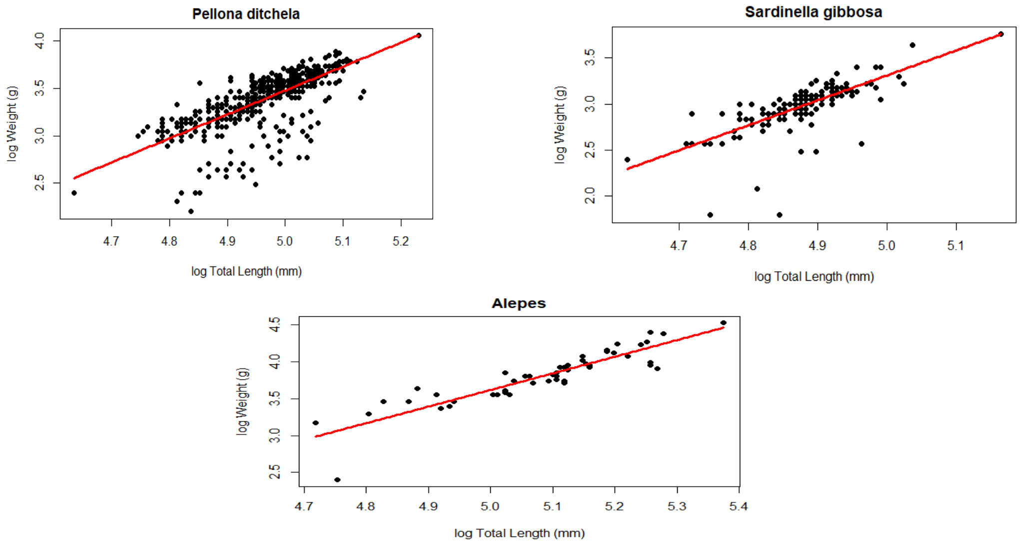

Figure 2. *Plot of natural log total length and weight of the three sampled fish*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

Table 2. *Equation of the length weight models for P. ditchella, Alepes vari. and S. gibbosa*

Fish species	Equation (on the transformed scale)	Equation (on the original scale)	R^2	b range (95% confidence)	P value
P. ditchella	log(W) = -9.19+2.53log(L)	$W = 0.000102*L^{2.53}$	0.51	2.32 - 2.75	P = 0.00002
Alepes vari	Log(W) = -7.64+2.25log(L)	Log(W) = -7.64+2.25log(L)	0.81	1.93 - 1.93	P = 2.538096e-05
S. gibbosa	Log(W) = -10.25 + 2.71*log(L)	$W = 0.000035*L^{2.71}$	0.55	2.33 - 3.1	P = 0.1432605

With a value of R^2 between 0.5 and 0.6 the models for *P. ditchella* and *S. gibbosa* have a weaker fit to the data than the model for Alepes vari, with a value of R^2 of 0.81. The results for the slopes of the equations show that, according to the model, *S. gibbosa* exhibits isometric growth ($p > 0.05$) with an exponent parameter (β) between 2.33 and 3.1, with 95% confidence. The results for the other two fish show that, according to the respective models, both *P. ditchella* and Alepes vari exhibit allometric growth ($p < 0.05$) with values of β between 2.32 and 2.75 for *P. ditchella* and 1.93 and 2.27 for Alepes vari.

Predictions based on original scale

Table 3 presents the results for the predicted mean weight of the three fish included in the study, using the length–weight models presented in *Table 2* and *Equation 4*. With a mean length of 150 mm, *P. ditchella* was estimated to have a weight between 33.4 and 34.6 g. For *Alepes vari*, with the mean length is 160 mm, the weight predicted lies between 18.6 to 19.7, whereas for *S. gibbosa* the figures are 130 mm and 42.2 to 46.3 g.

Table 3. *Prediction of weight of P. ditchella, Alepes vari and S. gibbosa based on the mean length*

Fish species	Bias correction factor	Predicted weight (g)	Mean length (mm)
P. ditchella	1.097	33.4 - 34.6	150
Alepes vari	1.01	18.6 - 19.7	160
S. gibbosa	1.015	42.2 – 46.3	130

Monthly variation of length–weight relationship of the fish

Monthly length–weight relationship of the fish was calculated by using *Equation 1.*, where a = constant, β = slope (or allometry coefficient or growth exponent), n = number of fish sampled, R^2 = Coefficient of determination. The results are shown in *Table 4*.

Table 4 presents the monthly data for the length and weight of the three fish, for the entire study period (September 2017 to April 2018), and the parameters for the respective length–weight relationships. The value of β could not be determined for certain fish in the months of November 2017 and January, March and April 2018 due to the small size of the sample. No sampling was carried out in December 2017, as the heavy weather prevented all fishing activities.

There is a slight variation in the value of β (slope) between months for the three fish included in the study, with the majority exhibiting negative allometric growth ($\beta < 3$), and only Alepes vari exhibiting positive allometric growth during the month of October

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

2017 (β = 3.14). This suggests that the majority of the fish sampled experiences poor growth and living conditions. Carlander (1969) showed that the coefficient β in the LWR of fish usually ranged from 2.5 to 3.5. In this study, there were 10 instances in which the value of β was outside this range, as depicted in *Table 4* and *Figure 3*. The same table and figure also show that the lowest value of β was obtained for *S. gibbosa* in October 2017, whereas the highest was for Alepes vari in October 2017 (β = 3.14), followed by that for *S. gibbosa* in January 2018 (b = 2.94).

In the majority of instances (76.9%) the value of the coefficient of determination (R^2) was equal or greater than 0.60, which indicates a moderately significant relationship between length and weight of the fish examined in the period of this study *(Fig. 4)*.

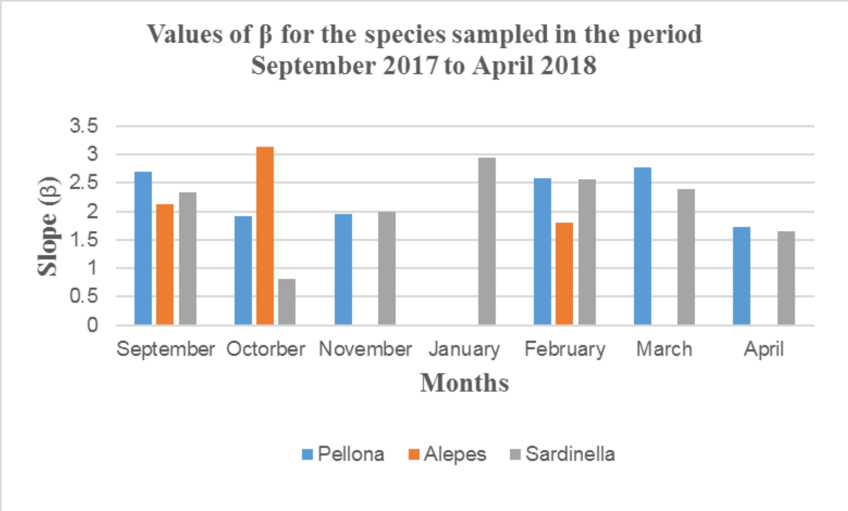

Figure 3. *Values of β for the species sampled in the period September 2017 to April 2018*

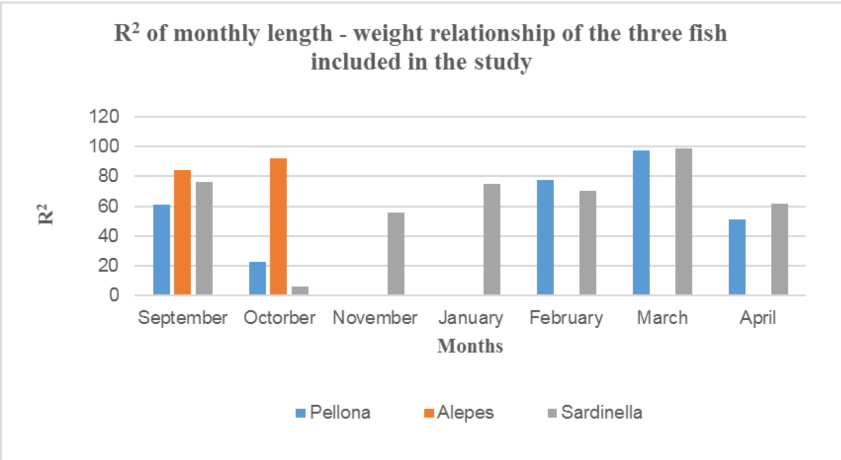

Figure 4. *R^2 of monthly length–weight relationship of the three fish included in the study*

Comparing length–weight regressions during and after the monsoon season

Table 5 presents the values of the ANOVA of the length–weight relationship for the three fish in two distinct periods, namely during and after the monsoon season.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

Table 4. *Monthly values of length and weight for P. ditchella, Alepes vari. and S. gibbosa, and respective length–weight model parameters, September 2017–April 2018*

Month	P. ditchella							Alepes vari							S. gibbosa						
	n	LWR			Length			n	LWR			Length			n	LWR			Length		
		a	β	R^2	Min	Max	Mean		a	β	R^2	Min	Max	Mean		a	β	R^2	Min	Max	Mean
September	9	0.000099	2.69	61**	147	165	154.8	42	0.000942	2.13	84.15***	122	196	162.4	16	0.000232	2.33	76.53***	117	147	132.4
Octerber	189	0.00197	1.92	23***	115	169	137.4	3	0.0000041	3.14	92.02***	167	216	191.7	18	0.25	0.81	6.12	102	152	120.4
November	2	0.00181	1.96		132	142	137	1				116	116	116	9	0.00119	1.995	55.53**	124	138	132.7
January	1				147	147	147								23	0.0000122	2.94	74.89***	112	154	131.7
February	305	0.0000808	2.59	77.93**	130	170	147.4	2	0.00416	1.802		167	192	179.5	75	0.0000727	2.57	70.4***	119	175	132
March	16	0.0000302	2.78	97.46***											3	0.000169	2.4	99.14*	128	144	137.3
April	15	0.0059	1.72	51.39**	134	160	144.3	1				112	112	112	18	0.0066609	1.65	62.06***	122	146	131.6

*P-value < 0.1; **P-value < 0.05; ***P-value much less than 0.01

Table 5. *ANOVA of fish species in monsoon and after monsoon season*

Variables	Df	SS	MS	F value	P value	Confidence interval (2.5 And 97.5%)		
						Intercept	Log (L)	fSeason Monsoon
				P. ditchella				
Log (L)	1	21.4152	21.4152	576.7773	< 2.2e-16 ***			
fSeason	1	0.8866	0.8866	23.8779	1.36e-06 ***	-3.3-(-2.1)	2.08-2.53	-0.12-(-0.055)
Log(L)$fSeason	1	0.1973	0.1973	5.3127	0.02155 *			
				Alepes vari				
Log (L)	1	5.0864	5.0864	210.0341	<2e-16 ***			
fSeason	1	0.0098	0.0098	0.4032	0.5286	-9.30-(-9.30)	1.92-2.57	-0.13-0.25
Log(L)$fSeason	1	0.1078	0.1078	4.4501	0.0405 *			
				S. gibbosa				
Log (L)	1	5.9244	5.9244	205.2222	< 2e-16 ***			
fSeason	1	0.2904	0.2904	10.0608	0.00182 **	-11.53-(-7.82)	2.22 - 2.98	-0.14- (-0.033)
Log(L)$fSeason	1	0.0110	0.0110	0.3808	0.53806			

*P-value < 0.1; **P-value < 0.05; ***P-value much less than 0.01

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

These results show that for *P. ditchella* the interaction terms are significant ($p = 0.02$), which indicates that there is enough evidence of the difference in the slope in the length–weight relationship between the monsoon and after monsoon seasons. The p-value for the indicator variable also suggests that there is a difference in the intercepts between seasons ($p < 0.05$). There are statistically significant differences between the slopes and intercepts of the regressions for the two different seasons, and there is a constant difference between the log-transformed weights of fish from the two seasons regardless of the log-transformed lengths of the fish. This is confirmed by the plots *(Fig. 5)* and confidence intervals. This result states that, the growth of *P. ditchella* during monsoon and after monsoon seasons is different.

For *S. gibbosa Table 5* shows that the difference in the length–weight regression between seasons is not significant ($p = 0.538$), hence there is not enough evidence to draw any conclusions about inter seasonal differences in the length–weight relationship of this fish species. The p-value for the indicator variable suggests that there is a difference in the intercepts between the two seasons ($p < 0.05$).

The interaction term for Alepes vari is slightly significant ($p = 0.04$), suggesting that there is enough evidence to conclude that there is difference in the slopes in the length–weight relationship between the monsoon and after monsoon seasons. The p-value for the indicator variable suggests that there is no difference in the intercepts of the regressions for each of the two seasons ($p = 0.53$).

These results also show that *P. ditchella* and *S. gibbosa* captured during the monsoon season are smaller than those captured after the monsoon (dry) season, with differences in weight of 0.05 - 0.13 g and 0.03 - 0.14 g, respectively. The opposite was found for Alepes vari, in which case fish captured during the monsoon season was 0.14 to 0.25 g larger than the fish captured during the dry season. *Figure 5* portrays the final models for the length–weight regressions for the monsoon and dry seasons for the three fish, with the respective fit plots.

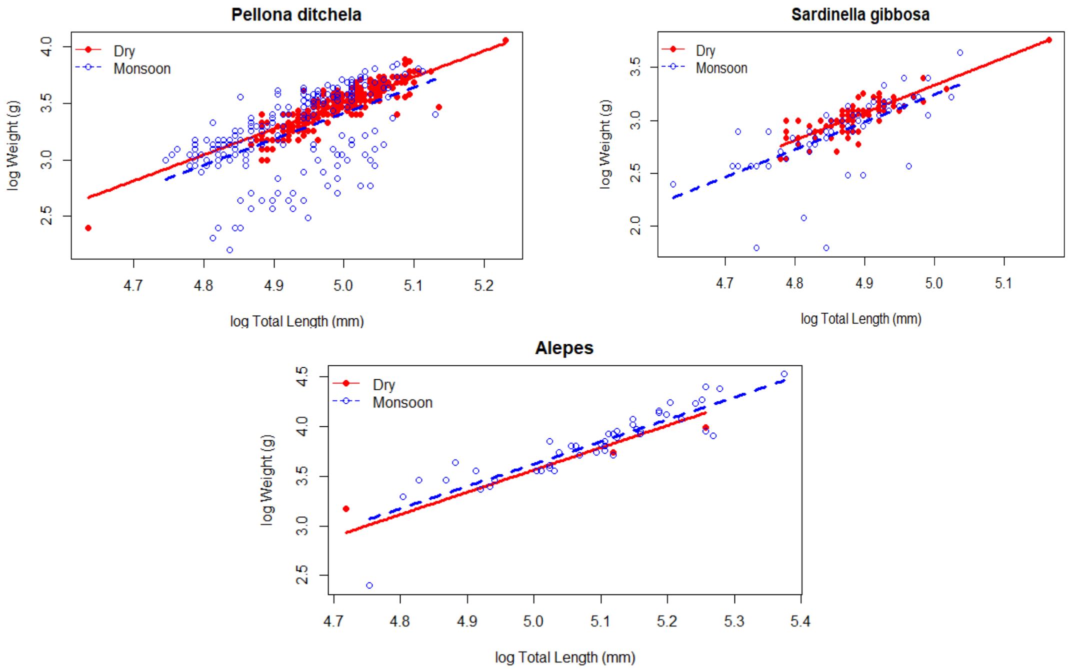

Figure 5. *Fit plot of the length–weight relationship for the three fish during the monsoon and after monsoon (dry) seasons*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

Discussion

This paper provides the first monthly values for the length–weight relationship of three commercially important fish commonly found in Songkhla Lagoon and captured in the coastal areas of the lower Gulf of Thailand. It also contributes with revised values for the maximum length of two of the species studied in the online database FishBase (Froese and Pauly, 2018, *Table 1*): the maximum recorded length for *P. ditchella* **(**Valenciennes, 1847) and *S. gibbosa* (Bleeker, 1849) was previously 160 mm and 170 mm length (Whitehead, 1985), and this study determined new maximums at 187 mm and 175 mm, respectively.

With respect to the LWR, a value of 3 (three) for the slope of the regression (β) corresponds to the ideal growth of fish. However, such situation is seldom found (Allen, 1938) due to changes in the shape of fish during the growth period (Martin, 1949). That coefficient can be affected by factors such as the length and shape of the fish itself and the time of spawning; the fishing gear used (Farran, 1936; Deason and Hile, 1947); or environmental factors such as food supply and season changes in environmental parameters (Brosset et al., 2015). In this study, the average of the monthly values of β for the three fish studied fall below the standard interval of 2.5 to 3.5 as determined by Carlander (1969). The average values from this study are 2.277, 2.357 and 2.099 for *P. ditchella,* Alepes vari and *S. gibbosa*, respectively. This indicates that all three fish have negative allometry, which is interpreted as a sign of poor body condition. This is in line with the views of fishermen contacted for this study, most of whom were of the view that the amount and size of fish has decreased in the coastal area of the southern Gulf of Thailand, which they attribute to the oil drilling activities taking place offshore and the illegal fishing gear, such as: sai nang (sitting cage). 14.29% of the fishermen interviewed in this area said they are using sai nang, they knew that this fishing gear catches all small fishes, but they still have to use because the number of fishes are decreasing sharply (Source: Author). The results from this study are insufficient to establish such a causal relationship though, and a broader investigation would be needed to determine the effects of coastal water quality on the condition of fish in the lower Gulf of Thailand.

The study also found that two of the fish captured after the monsoon season (dry season), namely *P. ditchella* and *S. gibbosa* were on average fatter than when captured during the monsoon season. This is in line with the result from the author, only 13.6% amount of fish was caught during monsoon season, 39.98% was before monsoon season and 46.42% was after monsoon season (Source: Author). This may be due to the biology of these two species, as both migrate to the mangroves in the estuarine and freshwater environments of the lagoon (Hue et al., 2018), which affects their growth negatively compared to life in the marine environment of the coastal waters. Eventhough, Alepes was found thinner in the dry season, but due to its small sample size (N = 3), it is not appropriate for a correct statistical evaluation, to conclude about Alepes, it requires further study.

The main limitation of this study is the relatively short study period of seven months, which is insufficient for studying the biology of the fish included in the assessment. Despite this limitation, it has unveiled statistically significant differences in selected growth parameters between two seasons in the lower Gulf of Thailand. The fish studied are all of high commercial importance, yet are subject to increasing anthropogenic pressure from fishing, including the use of illegal gear such as sitting cage (Source: Author), offshore drilling for oil and habitat destruction (Satumanatpan and Pollnac,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127

2017). In view of these pressures and the need to improve the management of commercial fish stocks, the findings of this study are potentially very useful for current and future stock estimation and evaluation studies. Moreover, these findings could be useful for comparing the body condition of fish over time and between different regions. Further studies of similar nature and involving some elements of the biology of commercially important species are necessary to support the formulation of policies for the sustainable utilization and appropriate management of fisheries resources in the southern Gulf of Thailand and in the whole the country.

Conclusion

Seven months for studying the biology of fish may not be a long time but this is enough time to see the difference of growth parameters between two typical seasons in the lower gulf of Thailand for some fish species. In the investigated area, these species have high commercial value, however, high pressure on population caused by fishing, illegal fishing gear (trawl), oil drilling from human activities are destroying fish habitat. Findings of present research are very important for stock estimation and evaluation studies in the future. Moreover, they will give an opportunity to compare fish conditional living over the time and between regions.

Further studies of similar nature and involving some biological aspects of commercially important species are necessary to support the formulation of policies for sustainable utilization and appropriate management of fisheries resources in the country.

Acknowledgements. This paper has been partly prepared with the support of the Higher Education Research Promotion and the Thailand's Education Hub for the Southern Region of ASEAN Countries Project Office of the Higher Education Commission. Financial support was granted by the Graduate School, Prince of Songkla University, Thailand. The authors would like to thank the Fishermen Association in Sathing Pra district for giving us the chance to go fishing with, thanks to the MACORIN research team for helping authors to do the lab works. Thanks NICA for agreeing authors to use the data.

Conflict of interest. The authors confirm that this article content has no conflict of interest.

REFERENCES

[1] Ahmed, Q., Benzer, S., Elahi, N., Ali, Q. M. (2015): Concentrations of heavy metals in Sardinella gibbosa (Bleeker, 1849) from the coast of Balochistan, Pakistan. – Bulletin of Environmental Contamination and Toxicology 95(2): 221-225. DOI: 10.1007/s00128-015-1572-y.

[2] Ajani, E. G., Beatrice, B. O., Olufemi, O. (2013): Comparative condition factor of two Penaeid shrimps, Peneaus notialis (Pink shrimp) and Peneaus monodon (Tiger shrimp) in a coastal state, Lagos, South West Nigeria. – Nature and Science 11(4). http://www.sciencepub.net/nature/ns1104/001_16157ns1104_1_3.pdf.

[3] Allen, K. R. (1938): Some observations on the biology of the trout (Salmo trutta) in Windermere. – Journal of Animal Ecology 7(2): 333-349. DOI: 10.2307/1168.

[4] Blackwell, B. G., Brown, M. L., Willis, D. W. (2000): Relative weight (Wr) status and current use in fisheries assessment and management. – Reviews in Fisheries Science 8(1): 1-44. DOI: 10.1080/10641260091129161.

[5] Boonjorn, N., Noranarttragoon, P., Sanitmajjaro, W., Pankaew, K. (2012): Stock assessment of Goldstripe sardinella, Sardinella gibbosa (Bleeker, 1849) resources in the

Gulf of Thailand. – Department of Fisheries, Thailand (in Thai). https://www.fisheries.go.th/marine/research/files/en/abs%201_56%20eng.pdf.
[6] Bolger, T., Connolly, P. L. (1989): The selection of suitable indices for the measurement and analysis of fish condition. – Journal of Fish Biology 34: 171-182. DOI: 10.1111/j.1095-8649.1989.tb03300.x.
[7] Brosset, P., Menard, F., Fromentin, J, M., Bonhommeau, S., Ulses, C., Bourdeix, J, H., Bigot, J, L., Van, B, E., Roos, D., Saraux, C. (2015): Influence of environmental variability and age on the body condition of small pelagic fish in the Gulf of Lions. – Marine Ecology Progress Series 529: 219-231. DOI: 10.3354/meps11275.
[8] Carlander, K. D. (1969): Handbook of Freshwater Fishery Biology. – The Iowa State University Press, Ames, Iowa.
[9] Chesoh, S., Choonpradub, C. (2009): Method for analyzing fish assemblage distribution with application to fishery landings of tropical shallow lake as Songkhla Lake, Thailand. – Modern Applied Science 3(5): 179-192. DOI: 10.5539/mas.v3n5p179.
[10] Chesoh. S., Choonpradub, C. (2011): A model for clustering fish community structure with application to Songkhla Lake bi-monthly catches 2003-2006. – Turkish Journal of Fisheries and Aquatic Sciences 11(2): 177-184. DOI: 10.4194/trjfas.2011.0201.
[11] Chesoh, S., Lim, A. (2008): Forecasting fish catches in the Songkhla Lake basin. – ScienceAsia 34(3): 335-340. DOI: 10.2306/scienceasia1513-1874.2008.34.335.
[12] Correia, E., Granadeiro, J. P., Regalla, A., Catry, P. (2017): Weight relationship of fish species from the Bijagós Archipelago, Guinea-Bissau. – Journal of Applied Ichthology 2017: 1-3. DOI: 10.1111/jai.13522.
[13] Davenport, J., Ekaratne, S. U. K., Walgama, S. A., Lee, D., Hills, J. M. (1999): Successful stock enhancement of a lagoon prawn fishery at Rekawa, Sri Lanka using cultured post-larvae of penaeid shrimp. – Aquaculture 180(1-2): 65-78. DOI: 10.1016/S0044-8486(99)00141-6.
[14] Deason, H. J., Hile, R. (1947): Age and growth of the kiyi, Leucichthys kiyi Koelz, in Lake Michigan. – Transactions of the American Fisheries Society 74(1): 88-142. DOI: 10.1577/1548-8659(1944)74[88:AAGOTK]2.0.CO;2.
[15] Farran, G. P. (1936): On the mesh of herring drift- nets in relation to the condition factor of the fish. – ICES Journal of Marine Science 11(1): 43-52. DOI: 10.1093/icesjms/11.1.43.
[16] Fricke, R., Kulbicki, M., Wantiez, L. (2011): Checklist of the fishes of New Caledonia, and their distribution in the Southwest Pacific Ocean (Pisces). – Stuttgarter Beiträge zur Naturkunde A, Neue Serie 4: 341-463.
[17] Froese, R. (2006): Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. – Journal of Applied Ichthyology 22(4): 241-253. DOI: 10.1111/j.1439-0426.2006.00805.x.
[18] Froese, R., Pauly, D. (2018): FishBase. World Wide Web Electronic Publication. – www.fishbase.org (accessed on 02/2018).
[19] Hamasaki, K., Kitada, S. (2013): Catch fluctuation of Kuruma prawn, Penaeus japonicus in Japan relative to ocean climate variability and a stock enhancement program. – Reviews in Fisheries Science 21(3-4): 454-468. DOI: 10.1080/10641262.2013.800781.
[20] Hue, H. T. T., Pradit, S., Lim, A., Goncalo, C., Nitiratsuwan, T. (2018): Shrimp and fish catch landing trends in Songkhla lagoon, Thailand during 2003-2016. – Applied Ecology and Environmental Research 16(3): 3061-3078. DOI: 10.15666/aeer.
[21] ONEP (Office of Nature and Environmental Policy and Planning) (2005): Master plan for Songkhla Lake Basin Development Project (Final Report). – Ministry of Natural Resources and Environment, Bangkok, Thailand.
[22] Martin, W. R. (1949): The Mechanics of Environmental Control of Body Form in Fishes. – The University of Toronto Press, Publication of the Ontario Fisheries Research Laboratory, No. 70, South Part, ON.

[23] Martínez, M. L., Intralawana, A., Vázquezb, G., Pérez-Maqueoa, O., Suttond, P., Landgrave, R. (2007): The coasts of our world: Ecological, economic and social importance. – Ecological Economics 63(2-3): 254-272. DOI: 10.1016/j.ecolecon.2006.10.022.
[24] Le Cren, E. D. (1951): The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). – Journal of Animal Ecology 20: 201-219.
[25] Mc Gurk, M. D. (1985): Effects of net capture on the post preservation morphometry, dry weight, and condition factor of Pacific herring larvae. – Transactions of the American Fisheries Society 114(3): 348-355. DOI: 10.1577/1548-8659(1985)114<348: EONCOT>2.0.CO;2.
[26] Niamaimandi, N., Zarshenas, G. A. (2015): Economic valuation of stock enhancement of banana prawn (Fenneropenaeus merguiensis) in the Strait of Hormuz. – Fishery Bulletin 113(1): 40-46. DOI: 10.7755/FB.113.1.4.
[27] Ogle, D., College, N. (2013): fishR Vignette - Length-Weight Relationships. – http://derekogle.com/fishR/examples/oldFishRVignettes/LengthWeight.pdf.
[28] Ogle, D. H. (2018): FSA: Fisheries Stock Analysis. – R package version 0.8.20.
[29] Pauly, D. (1983): Some simple methods for the assessment of tropical fish stocks. – FAO Fisheries Technical Paper No. 234. https://s3-us-west-2.amazonaws.com/legacy.seaaroundus/doc/Researcher+Publications/dpauly/PDF/1983/Books+and+Chapters/SomeSimpleMethodsAssessmentTropicalFishStocks.pdf.
[30] Pauly, D., Cabanban, A., Torres, F. S. B. Jr. (1996): Fishery biology of 40 trawl-caught teleosts of western Indonesia. – ICLARM Studies and Reviews 23: 135-216. http://www.reefbase.org/resource_center/publication/pub_6864.aspx.
[31] Pradit, S., Pattarathomrong, M. S., Panutrakul, S. (2013): Arsenic cadmium and lead concentrations in sediment and biota from Songkhla Lake: a review. – Procedia Social and Behavioral Sciences 91: 573-580. http://linkinghub.elsevier.com/retrieve/pii/S1877042813025871.
[32] R Core Team. (2018): R: A Language and Environment for Statistical Computing. – R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.
[33] Ricker, W. E. (1973): Linear regressions in fisheries research. – Journal of Fisheries Research Board of Canada 30(3): 409-434. DOI: 10.1139/f73-072.
[34] Riede, K. (2004): Global register of migratory species - from global to regional scales. Final Report of the R&D-Projekt 808 05 081. – Federal Agency for Nature Conservation. https://www.researchgate.net/publication/235225727_Global_register_of_migratory_species_from_global_to_regional_scales_final_report_of_the_RD-Projekt_808_05_081.
[35] Russell, B. C., Houston, W. (1989): Offshore fishes of the Arafura Sea. – Beagle: Records of the Museums and Art Galleries of the Northern Territory 6(1): 69-84. https://search.informit.com.au/documentSummary;dn=941910625031493;res=IELHSS.
[36] Satumanatpan, S., Pollnac, R. (2017): Factors influencing the well-being of small-scale fishers in the Gulf of Thailand. – Ocean and Coastal Management 142: 37-48. DOI: 10.1016/j.ocecoaman.2017.03.023.
[37] Stern, N., Rinkevich, B., Goren, M. (2015): First record of the Goldstripe sardinella - Sardinella gibbosa (Bleeker, 1849) in the Mediterranean Sea and confirmation for its presence in the Red Sea. – BioInvasions Records 4(1): 47-51. DOI: 10.3391/bir.2015.4.1.08.
[38] Thomas, R. C, Jr., Willette, D. A., Carpenter, K. E., Santos, M. D. (2014): Hidden Diversity in Sardines: genetic and morphological evidence for cryptic species in the goldstripe sardinella, *Sardinella gibbosa* (Bleeker, 1849). – PLoS ONE 9(1): e84719. DOI: 10.1371/journal.pone.0084719.
[39] Wang, Q., Zhuang, Z., Deng, J., Ye, Y. (2006): Stock enhancement and translocation of the shrimp Penaeus chinensis in China. – Fisheries Research 80(2006): 67-79. DOI: 10.1016/j.fishres.2006.03.015.

[40] Whitehead, P. J. P. (1985): FAO Species Catalogue. Vol. 7. Clupeoid fishes of the world (suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. – FAO Fish Synopsis 125(7/1): 1-303. http://www.fao.org/3/a-ac482e.pdf.

[41] Xu, J., Xia, M., Ning, X., Mathews, C. P. (1997): Stocking, enhancement, and mariculture of Penaeus orientalis and other species in Shanghai and Zhejiang Provinces, China. – Marine Fisheries Review 59(4): 8-14. http://aquaticcommons.org/9811/1/mfr5942.pdf.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_61136127