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Comparative assessment of the seasonal breeding patterns of the paddlefish *Polyodon spathula* (Walbaum, 1792) and the impact of growth tendency during winter and summer feeding

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ABSTRACT

Seasonal rhythms affect paddlefish farming practices due to the interactions among internal and external environmental factors in the aquatic ecosystem, including different types of biological, chemical, or physical stressors. In the present study, seasonal variations and the succession of the seasons during the farming periods represent a striking force that reflects the reality of sustainable paddlefish development under Russian aquaculture conditions. Five age groups (28, 29, 30; 26, 27, 28; 24, 25, 26; 19, 20, 21; and 18, 19, 20) were studied based on years of commissioning (1993, 1995, 1997, 2002 and 2003, respectively) and showed different growth rates throughout the seasons during 2017, 2018, and 2019. Consequently, rapid growth rate changes; increasing and decreasing, were observed, as demonstrated in weight gain and specific growth rate parameters. All the growth parameter variables, knowledge base and inference in the growth monitoring analysis model were carried out through computation of weight gain, growth rate, and specific growth rate related to age groups. The results revealed that the descriptive analysis of seasonal variability agreed with the statistical growth performance analysis. Moreover, the findings show that 2017 and 2018 winter and 2017 summer seasons recorded the lowest values of significance (30: 55%, SGR) among the five age groups. In contrast, high values were obtained for 2018 and 2019 winter and 2018 summer seasons (55: 80%, SGR), despite sustainable production. However, it is insufficient to determine the value of the seasonal response in growth rates over four seasons. Therefore, we need to create simulation programmes to predict the impact of seasonal patterns instead of spending more effort and cost on other methods.

INTRODUCTION

The complex fish-farming ecosystems and the developments in which they follow to indicate the instability of the state of aquaculture practices (Stewart *et al.*, 2013). Particularly anthropogenic actions and external moderator variables, which are led to the depletion of freshwater fish populations in the last decade has been recorded around the world (Closs *et al.* , 2015; Gordon *et al*., 2018). Several previous scientific reviews have been studying the history of life and the development of paddlefish farming and hatching around the world (Emlen, 1984; Barannikova *et al*., 1993; Charlesworth, 1994; Scarnecchia *et al*., 2007). They have been written about the evolution of life histories of fishes and other organisms, especially paddlefish (*Polyodon spathula*) as a potential framework for other Acipenseriform fishes (Scarnecchia *et al*., 2011). By studying paddlefish *Polyodon spathula*, Polyodontidae (Walbaum 1792), it is regarded as a giant freshwater species and the oldest river fish species, which are already on the list of endangered fish (Алиева *et al*., 2016; Kramer *et al*., 2019), due to the risk of overfishing and depletion of natural producers stocks (Сокольский & Пономарёв, 2010).

The paddlefish (*Polyodon spathula*) was first introduced in Russian Federation (formerly by the Soviet Union) in 1974, primarily because of its rearing potential in natural organic fertilizer ponds and large southerly reservoirs (Jarić *et al.*, 2019). Paddlefish were also cultivated for roe production along the Russian Volga Delta and meat production to consuming size; particularly, Krasnodar, Volga–Caspian basin, and Saratov (Lobchenko *et al.*, 2002). Russia is not limited to domestic production, but the presence of paddlefish caviar production has moved to the EU's export market so far (Mims and Shelton, 2015). In Russian Federation survey indicated fluctuation in the future paddlefish production trends. Therefore, production was foretelling to stay stable, with an annual growth potential of 5% –10%, and the Maintaining domestic market open to more substantial quantities (Jarić *et al*., 2019). There are many uncertainty opinions about over seasonal depth act in an additive, oppositional, or potentially powerful sense. Because of interactions may depend on biotic or the environment elements conditions. Thereby, observing numerous-stressor effects and determining the factors that drive their interaction are crucial points to the sustainability of aquatic farm production (Lange *et al*., 2018). As a result, seasonal patterns that cause a dramatic change in the fish environment and have significant implications for growth performance (Meulenbroek *et al*., 2018).

The main scope of the current experiment is to assess the growth performance development of the American paddlefish (*Polyodon spathula* Walbaum 1792, Polyodontidae).

MATERIALS AND METHODS

Study area and data collection

Astrakhan is the most important and strongest farming location for paddlefish breeding in Russia's southern federal region. Which, is now the most effective area for the collection, distribution, and study of fish products (Williot *et al*., 2002). Federal state scientific institution "CaspNIRKh" is considered as the official research institute and competent to research the Delta-Volga River region and the Caspian Sea territorial fish farms (Муханова *et al*., 2018; Ruban *et al*., 2019;). Located at GPS Coordinates [(46° 4' 23.9664" N; 47° 43' 45.1056" E) lat.: 46.073324 & long.: 47.729196] west of Astrakhan region. Sampling data for the study were collected through the fishponds and follow-up ponds of the Institute. All parameters were obtained over the last two-summer production seasons (2017-2018). As well as, dataset of the previous wintering season`s (2017-2018 & 2018-2019). Samples were collected monthly and calculated an average of biomass (Initial and Final weights, Kg). Age groups divided into five groups; each one holds numerous individuals that were classified and located underlie to prepare data-entry. Therefore, age groups vary according to season variations in terms of their representation via distributional patterns (Table 1). The preparation of records for the weight parameters were performed in both season / age criteria.

Table 1: Overview of seasonal sampling patterns.

Year of commissioning for age groups (At the age of 4 years)	Age group No.	Summer 2017		Summer 2018		Winter (2017-2018)		Winter (2018-2019)	
		Age	Weight gain* (Kg) Mean	Age	Weight gain (Kg) Mean	Age	Weight gain (Kg) Mean	Age	Weight gain (Kg) Mean
1993	1	28	-0.70	29	4.63	29	-0.17	30	-0.80
1995	2	26	3.23	27	1.73	27	-2.40	28	-0.40
1997	3	24	1.06	25	1.68	25	-1.78	26	-0.52
2002	4	19	0.64	20	1.05	20	-1.65	21	-0.70
2003	5	18	0.24	19	1.38	19	-1.30	20	-0.42

* Weight gain, It is calculated by the difference between the initial and the final weight.

Parameters identification and measurements

Seasonal variability

The current paper is precedent as a novelty, which deals with the study of the seasonal patterns (winter-summer rhythm) impact underlying aquaculture conditions in Russia for paddlefish and the extent to which this was affected by different age groups factor after the second generation of paddlefish life history in Eastern Europe in general.

Classification of herds into five age - groups depends on the years of commissioning (at the age of 4 years), which were divided according to four seasons sorted by dynamic feeding. Periodically, two low-active feeding seasons in winter of 2018 and 2019 were named (2017-2018) & (2018-2019). In contrast, active nutrition is represented in two next summer seasons (2017 and 2018). While the present active summer season 2019 not observed yet. In all seasons, age and weight gain (Kg) were calculated and recorded relay on age group numbers, as shown in Table (1).

The data obtained were differing among seasons, a consequence of summer-winter rhythm, magnitude of sample density, and the directional starting with the drifting period, which varied among age groups and weight parameters. Therefore, a turning point was considered building confidence rates of growth performance parameters. Individuals (Age groups) related seasonal patterns with peak densities during the summer season, which carried out from spring (April) period to autumn (September) determined were observed in the previous seasons with commercial feeding supported as a targeted to market size. On the other hand, the dramatic rhythm during the winter season with the lack of nutrition support for the increase in growth and the total dependence on the food in the waters of the ponds, where the season starts from the fall (October) to spring (March). All of them were studied and expressed as a function of growth parameters.

Growth parameters

Aquaculture production rates are rising sharply, depending on the performance of growth rates (Barreto-Curiel *et al*., 2018). Thus, the growth performance is the most reliable indicator of the success of the aquaculture system in light of the weight scales with different seasons (Meulenbroek *et al*., 2018; Torrans and Ott, 2018). The growth performance was expressed through body weight (BW/kg) in both initial and final body weight, referring to equations (1&2). Attempted a general easy-to-use growth model to evaluate growth rapidly as a function for description, increasing and decreasing of weight gain (WG), on a par. Growth performance evaluated with the following indexes:

Weight gain (Kg) = final weight of fish (W_2) – initial weight of fish (W_1) **(1)**

Specific growth rate (SGR) was calculated as:

SGR (% per year) = $[(\text{Loge } W_2 - \text{Loge } W_1) / (T_2 - T_1)] *100$ **(2)**

Where: W_2 = weight of fish at time T_2 (End of season), W_1 = weight of fish at time T_1 (The beginning of the season).

The most common use among all measures of growth performance is the specific growth rate (SGR); its results are given in percentage increase per day or season like current status, which is why it is a more flexible method than the whole growth measurements (Lugert *et al*., 2016). In terms of weight, the SGR might even produce an excellent fitting outcome. By extending the parameters of the two other variables, it is interacting with fluctuations between the last two seasons. Thus, we are selected at least the previous and surveillance present production season.

Statistical analysis of measurements

Statistical analysis was conducted to obtain results of measurements for age groups; weight gain and specific growth rate to express as a function in the growth performance output undergo seasonal patterns labeling of statistical model components. In this context, a statistical model constructed to analyze the variance, correlation, and regression between the variables to determine which season achieves the highest variance significant and influential in the dependent variable during the breeding season. The statistical manner followed by the data was implemented to keep track of:

Data were subjected to one-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test for the means at a significance level $P<0.05$ (confidence interval %: 95) and tolerance: 0.0001. Moreover, LS means were performed to estimate the degrees of significant differences between the age groups. Subsequently, it can determine which fitness values should elect to compose into most variable components with obtaining detailed statistical analysis knowledge, i.e., variable distribution fitting, correlation coefficient, standardized coefficients, and regression coefficient. There were multiple individuals per age group per season. Overall rearing months, they were differing from season to season depending on multi-factors (e.g., marketing time, survival rates, stressors, etc.). As a whole, five age groups were stable along all seasons. Statistical analyses were carried out by using XLSTAT ® statistical analysis software last academic version 2019.2.1 (XLSTAT, 2019). Process follow-up begins with the preparation of data and testing assumptions. Then, they were subjected to arithmetic influence diagnostics as a residual value to obtain standardized residuals; constructing bi-plot distributions. P-value of the F statistic computed in the ANOVA with a significance level of 5% to compare with the information brought by the explanatory variables for LS mean for desirable ranges determination. The data are shown as means.

RESULTS AND DISCUSSION

Seasonal variability and Growth parameters

Seasonal patterns variability results are conforming to feeding habitat; commercial feedstuff applied only in the summer-periods that started and ended between 6 months (from April to September). In contrast, in the wintering-period, the fish rely entirely on natural feeding in the pond (from October to March). Therefore, it is likely that the differences in weights due to natural and commercial food's fluctuation, taking into account other stress factors. Summer seasons are expected to increase growth rates and contrast in winter, according to the equations (1&2) as a function in performed growth performance. Thereby, the results obtained were compared per age groups-related-age (seasonal patterns, as a parallel pattern coordinates) shown in Figure (1).

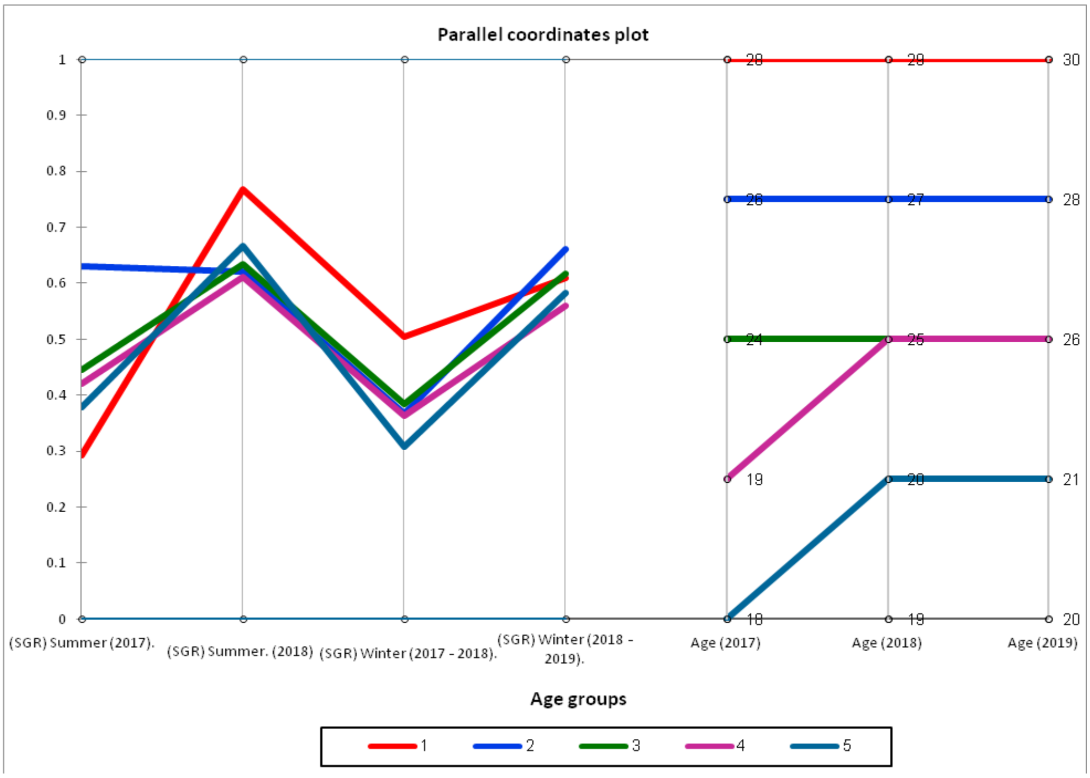

Fig. 1: Parallel coordinate plot to describe growth performance underlie seasonal variability (Specific growth rate (SGR) & age groups-related-age) for season period.

The results showed that seasonal patterns (Age groups-related-Age) moved to undergo scale of composed of SGR as we observed elevated of Age group No. 1 along seasonal variability except summer-period 2017 involved ages (28, 29 & 30 old) for seasons of (2017, 2018 and 2019) respectively. In contrast to the state-of-harmonic trend in seasonal variability through age groups, Group No. 5 is unique in seasonal fluctuations between groups. Where mediated SGR values in summer 2017 and winter (2018-2019). Moreover, it makes up less growth rate (SGR) among the rest of the other groups in winter (2017-2018).

In conjunction with other groups monitoring, The age groups 3 and 4 for individuals distributional together in the same ages (25 and 26 old) participate in the 2018 and 2019 production seasons, while SGR results among them have differed along four seasonal patterns which observed elevated for age group 3 more than group 4. Irrespective of age and feeding activity criterions, it is clear that summer 2018 and winter (2018 and 2019) are the best seasons in terms of expressing the growth rates during the different seasonal patterns. Which, shows how the general trend to get out of the low growth rate in seasons is accompanied by a rapid rise in the following seasons (as compensation for weight loss during Spawning periods and high water temperatures). It means some age groups of paddlefish fluctuated and effected according to seasonal variability, and this is shown by specific growth rates.

Statistical analysis

Independence assumption and Normality test

The present analysis (Table 2), independence assumption, and normality test were used to detect outliers in the response variables. Variables and interact between themselves were performed. Subsequently, determined which fitness variable should elect to compose into a monitoring system in the future production seasons.

Table 2: Normality test (SGR –Seasons) significance.

Variable\Test	Shapiro-Wilk	
Specific growth rate (SGR). Summer (2017).	0.002	*
Specific growth rate (SGR). Summer (2018).	0.000	**
Specific growth rate (SGR). Winter (2017-2018).	< 0.0001	***
Specific growth rate (SGR). Winter (2018 - 2019).	0.001	*

*P < 0.05: Significant. ** P < 0.000; More significant. *** P< 0.0001; highly significant.

Variable distribution fitting and correlation coefficient:

At the end of the paddlefish seasons respectively, all parameters were collected as a record and statistically investigated by using normal distribution test with a significance level (5%). Statistics estimated on the input data and computed using the estimated parameters of the normal distribution for (SGR summer-period 2017, SGR summer-period 2018, SGR winter-period 2017-2018, and SGR winter-period 2018-2019) p-value (Shapiro-Wilk test) appeared in table 2. The results showed the only high significant normal distribution for (SGR winter-period 2017-2018); as calculated p-value is minor with low significance level alpha=0.05, one ought to refuse the null hypothesis and admit the substitution hypothesis. On the other, variables from which the sample was extracted do not follow a normal distribution with the Shapiro-Wilk test; p-value is more significant than the significance level alpha=0.05. One cannot reject the null hypothesis, which indicates that the sample follows a normal distribution. For that following up fitness distribution, which indicates the sample follows a normal distribution of the evidence test to confirm our decision, the variable moved dramatically underlying normal distribution movement. Normal Q-Q plots and fitting distribution histograms for four variables were performed, as shown in Figure (2).

Correlation coefficients and Regression coefficient

ANOVA tested with a confidence interval (95%), and tolerance (0.0001) overuse least squares means was conducted to evaluate the effects on growth performance and seasonal patterns (Table 3). Weighs and age groups dataset were introduced as a variable to identify an interaction between themselves over the rearing seasons. P-Value correlation matrix (Pearson), for describing relationship interaction among variables (SGR-Seasons & Age-Season) showed significant in the variable SGR winter (2017-2018) cross age-season refers to the high decreasing rates of growth performance during this season. On the other hand, SGR summer (2017) showed the highest growth rate recorded between the seasons, indicated in bold in.

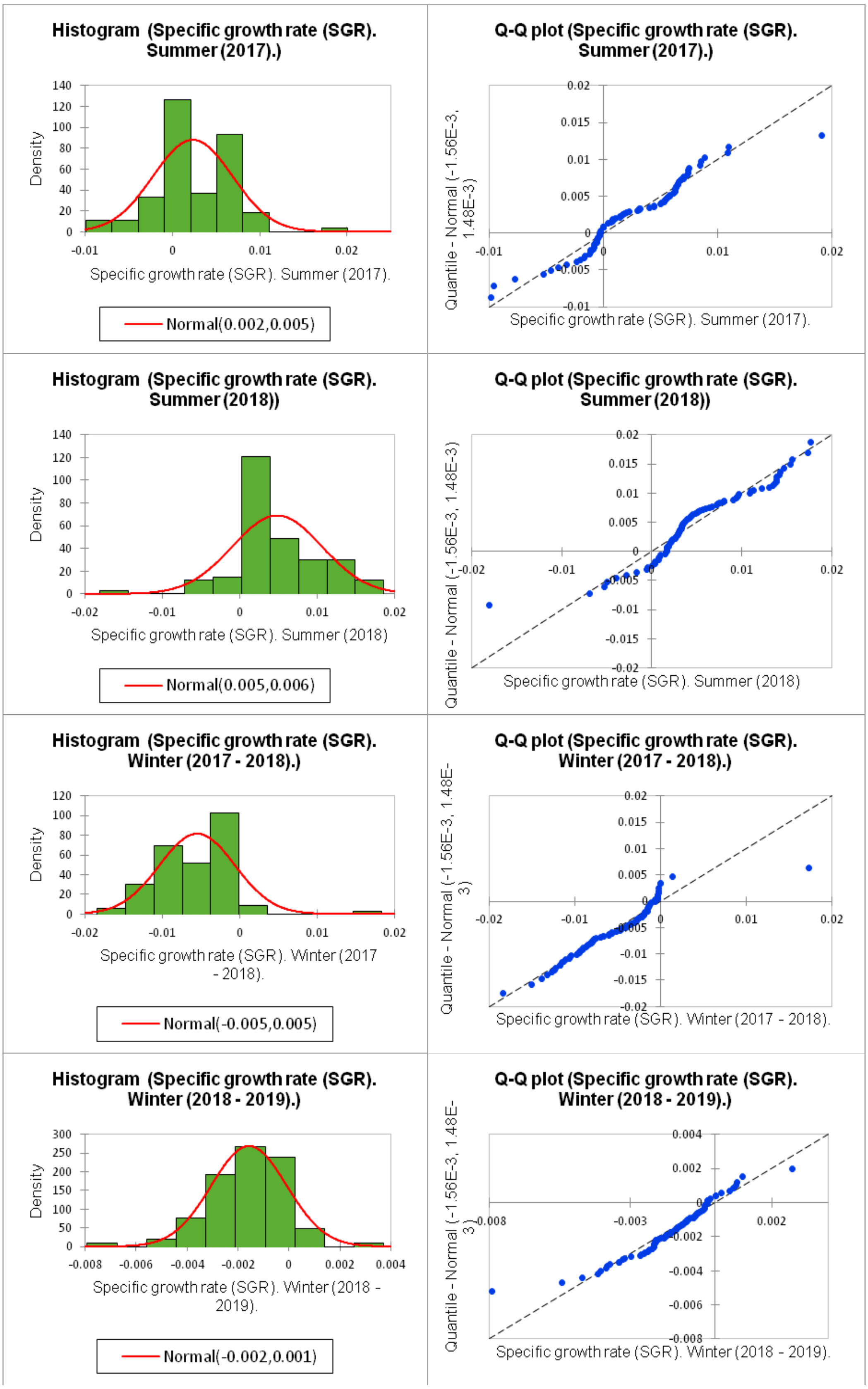

Fig. 2: Normal Q-Q plots and fitting distribution histogram for *SGR-Seasons*.

Table 3: P-values (Correlation matrix-Pearson) among SGR-Seasons and Age.

Variables	SGR. Summer (2017).	SGR. Summer (2018).	SGR. Winter (2017 - 2018).	SGR. Winter (2018 - 2019).	Age-season (2017)	Age-season (2018)	Age-season (2019)
SGR. Summer (2017).	**0**	0.73	0.11	0.09	0.16	0.10	0.08
SGR. Summer (2018)	0.73	**0**	0.76	0.21	0.87	0.99	0.99
SGR. Winter (2017 - 2018).	0.11	0.76	**0**	0.28	**0.015***	**0.046***	**0.044***
SGR. Winter (2018 - 2019).	0.09	0.21	0.28	**0**	0.15	0.15	0.12
Age-season (2017)	0.16	0.87	**0.015***	0.15	**0**	**< 0.0001*****	**< 0.0001*****
Age-season (2018)	0.10	0.99	**0.046***	0.15	**< 0.0001*****	**0**	**< 0.0001*****
Age-season (2019)	0.08	0.99	**0.044***	0.12	**< 0.0001*****	**< 0.0001*****	**0**

*P < 0.05: Significant. ** P < 0.000: More significant. *** P< 0.0001; highly significant.

As a result of the high correlation between variables, it is evident that there is no significant difference between the seasons, as shown by the analysis of variance due to the usual dramatic effect of the decline in winter growth rates and higher growth rates in the summer (Table 4). As a result of several factors, including the promotion of commercial nutrition and desired temperatures, etc., the analysis of variance showed only the extent of observed tiny differences between seasons.

Table 4: Summary of statistical analysis SGR- Season and Age-Season

	SGR-Season			
	(SGR). Summer (2017).	(SGR). Summer (2018)	(SGR). Winter (2017 - 2018).	(SGR). Winter (2018 - 2019).
R^2	4%	0.3%	8%	3%
F	1.124	0.090	2.326	0.857
Pr > F	0.344	0.966	0.080	0.467
Mean ± SD	0.002 ± 0.005	0.005 ± 0.006	-0.005 ± 0.005	-0.002 ± 0.001
Age (2017)	0.156*	0.268	2.763	0.054
	0.694**	0.606	0.100	0.817
Age (2018)	0.051	0.063	0.387	0.213
	0.822	0.802	0.536	0.646
Age (2019)	0.552	0.000	0.052	0.435
	0.460	0.984	0.820	0.511

*Analysis of variance (F-Value). ** Analysis of variance (Pr > F-Value).

Standardized coefficients

Estimates are resulting from a regression analysis of variables that have been standardized so that the variability of factors. Therefore, standardized coefficients results refer to how many standard deviation dependent parameters will differ per standard deviation excess in the foreteller factor. For simple linear regression following orthogonal predictors, the standardized regression coefficient corresponds to the correlation between all seasonal variables. As a result given, the R^2 8% of the variability of the dependent variable Y SGR Winter-season (2017-2018). It is explained by the explanatory variable, given the p-value of the F statistic computed in the ANOVA table 4. Standardized coefficients are shown by the distribution of age groups throughout the seasons and the extent of their association with the production season, which is reflected in the weights and the consequent to determine the performance of growth rates succession the winter season with summer demonstrated in Figure (3). The age groups are moved between scales of standard deviation units within a given range for each season to express themselves in terms of the dependent variables (SGR-seasons). The results showed a small scale for first season SGR-2017-summer (positive) & SGR- 2017-2018- winter (Negative), 0.01 and -0.01, respectively. On the other side, the second last season recorded large scale of movements SGR-2018-summer (Positive) & SGR- 2017-2018- winter (Negative), 0.015 and -0.002, respectively. We conclude from the above that the 2017 season includes age groups more stable with a rate of change in the performance of growth. In contrast, the season of 2018 active age groups to express a non-steady rate of growth performance, although that performance is useless. In this context, with low diversity between four-season patterns (summer-winter) as an interpretation to answer critical problems behind production tendency forward stability according to (Jarić *et al*., 2019), because of low significance of paddlefish growth performance along seasonal periodically under aquaculture production in south Russian territories especially Delta-Volga river.

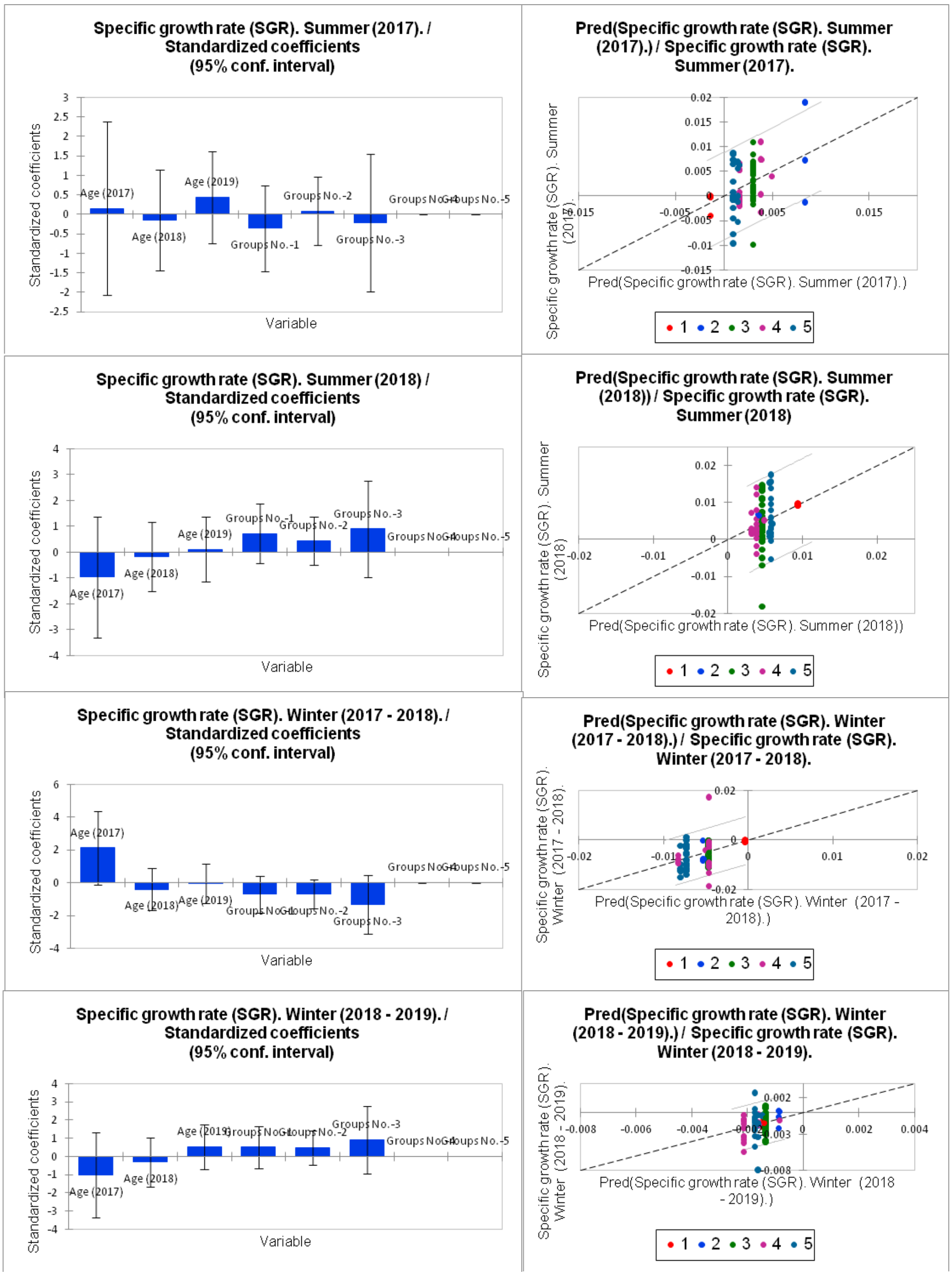

Fig. 3: Standardized coefficients (SGR- Season and Age-Season) for paddlefish rearing.

CONCLUSION

The present study sheds light on the fluctuation of growth performance during seasonal patterns in the field of paddlefish aquaculture. A comprehensive and updated compilation of statistical analysis to describe the seasonal impact on growth parameters per age group. Ongoing paddlefish specific growth rate in the status with the help of previous seasonal knowledge, we have shown that by trial, a rigorous attempt has been made to estimate seasonal rhythm originate from changing environmental conditions and their control. All the conventional statistical analyzes have been indicated the actual situation we are experiencing. Therefore, we can be utilized to predict and control cultivation rhythm on growth performance with age groups. Winter season (2017-2018) and summer season 2017 were represented to be the lowest growth rates and affected by seasonal receptions during the ages of 2017 and 2018.

In contrast, seasonal influences were a potent force in the winter seasons (2018-2019) and summer 2018 during the age groups 2018 and 2019. After the statistical analysis to determine the dependence on the impact of seasonal patterns and their effects on the growth rates. The differences were minor and useless, but prove the fact that the winter seasons for paddlefish is a period of weight loss, which is quickly compensated in the following summer seasons; confirming that, the paddlefish increase and lose weight in the range (1: 2 kg) during five winter months in adult stages. The monitoring process was the most enormous and tremendous step among all rearing management to determine the most critical part which impacts eco-system production during the season, as well as to mention paddlefish marketing value. In this context, to conclude in the future, we need to spend all efforts on monitoring and controlling technique the rest of the variables affecting all aspects of paddlefish breeding. Notably, in the Caspian region and promote researchers to use those approaches.

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ARABIC SUMMARY

التقييم المقارن لأنماط تربية أسماك المجداف (*Polyodon spathula* Walbaum 1792, Polyodontidae) الموسمية وتأثر ميل النمو خلال تعاقب التغذية الصيفية والشتوية

فاسيليفا لديا ميخائيلوفنا [١] ، محمود النقيب [١،٢]

١- قسم التقنية الحيوية، علم الحيوان و الاستزراع المائي، كلية البيولوجيا، جامعة أستراخان الحكومية، ٤١٤٠٠٠ سوفيا بيروفيسكايا، أستراخان، روسيا الاتحادية.

٢- قسم الإنتاج الحيواني، كلية الزراعة، جامعة الازهر، القاهرة، مصر.

تؤثر الإيقاعات الموسمية على ممارسات زراعة اسماك المجداف بسبب التداخل بين العوامل البيئية الداخلية والخارجية في النظم المائية، ايا كانت أنواع الضغوطات البيولوجية، الكيميائية، أو الفيزيائية. الدراسة الحالية تسلط الضوء علي عامل تأثير الاختلافات الموسمية وتعاقب الفصول خلال موسم الزراعة حيث يعد قوة لافتة تعكس حقيقة التنمية المستدامة لأسماك المجداف تحت ظروف الاستزراع المائي الروسي.

تم دراسة خمس مجموعات عمرية (٢٨ ، ٢٩ ، ٣٠ ؛ ٢٦ ، ٢٧ ، ٢٨ ؛ ٢٤ ، ٢٥ ، ٢٦ ؛ ١٩ ، ٢٠ ، ٢١ و ١٨ ، ١٩ ، ٢٠). تتباين تدريجياً على التوالي خلال مواسم التربية وتشمل فترات الصيف - الشتاء (٢٠١٧ و ٢٠١٨ و ٢٠١٩) لسنوات التكليف للفئات العمرية (١٩٩٣ و ١٩٩٥ و ١٩٩٧ و ٢٠٠٢ و ٢٠٠٣)، بالتتابع يرافقه النمو السريع، أيا كان في الاتجاه الإيجابي أو السلبي كما هو موضح في زيادة الوزن ومعايير معدل النمو المحددة.

جميع المتغيرات تم تحديدها وإنشاء نماذج احصائية لتقييمها والتنبؤ بمعايير النمو اعتماداً علي قاعدة المعرفة للمواسم السابقة والاستدلال في نموذج تحليل مراقبة النمو خلال مواسم الدراسة وتم تنفيذها من خلال حساب زيادة الوزن، والنموالمتحصل في نهاية كل موسم، ومعدل النمو النسبي والتي جميعها مرتبطة بالفئات العمرية الخمسة. يتوافق التحليل الوصفي لأنماط التقلبات الموسمية مع تحليل أداء النمو الإحصائي. وتوضح النتائج أن فصلي شتاء (٢٠١٧-٢٠١٨) وصيف ٢٠١٧ سجل أدنى قيم في معدل النمو النسبي (٣٠: ٥٥ ٪ ، SGR) في خمس فئات عمرية. في المقابل، تم تمثيل القيم العالية في فصلي شتاء (٢٠١٨-٢٠١٩) وصيف ٢٠١٨ مواسم (٥٥: ٨٠ ٪ ، SGR). استنادا إلى النتائج التي تم الحصول عليها، على الرغم من الإنتاج المستدام، ومع ذلك لا يكفي تحديد قيمة الاستجابة الموسمية في معدلات النمو على مدار أربعة مواسم لخمس فئات عمرية. لذلك، نحتاج إلى إنشاء برامج محاكاة للتنبؤ بتأثير الأنماط الموسمية بدلاً من إنفاق المزيد من الوقت والجهد. وتوصي الدراسة بإستخدام النمذجة الرياضية للمواسم القادمة مع مقارنة المواسم السابقة، فهذا العمل سوف يساعد في إنشاء تلك النماذج.