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The Sagittal Otolith Morphology Observations of Sturgeon Species in Iranian Waters of the Caspian Sea

Observaciones sobre la Morfologia de Otolitos Sagitales de Varias Especies de Esturion en las Aguas Iranies del Mar Caspio

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SUMMARY. The morphology of the sagittal otolith of Great sturgeon (*Huso huso*), Persian sturgeon (*Acipenser persicus*) and starry sturgeon (*Acipenser stellatus*) species from the Iranian waters of the Caspian Sea were studied. Three otolith measurements and three shape indices were recorded from 90 sturgeon specimens. Fish biometry traits were measured and relationship between sagittal otolith length (OL)-total length (TL), and sagittal otolith weight (WO)-body weight of fish (BW) were estimated. Sagittal otolith has a triangle shape with irregular edges in great sturgeon, elongate triangle with smooth surfaces in Persian sturgeon, and relatively circular with smooth surface in starry sturgeon. The ratio of the WO/BW in starry sturgeon was significantly higher ($P < 0.05$) than great sturgeon and Persian sturgeon. There is a direct proportional relationship between BW and WO in Persian sturgeon ($r^2=0.7$), great sturgeon ($r^2=0.9$) and starry sturgeon ($r^2=0.9$). Regression line slope for these relationships in starry sturgeon were less than Persian sturgeon and great sturgeon. Furtheremore, there is significant linear regression between OL-TL. Results showed that it is possible to identify Caspian sturgeon species based on body morphometry and sagittal otolith characteristics.

KEY WORDS: Otolith shape; Huso huso; *Acipenser persicus; A. stellatus*.

INTRODUCTION

Comparison of body structure characteristics and morphometry in living organisms is used as one of key factors of biological studies (Reyment, 2010). Morphological studies of sturgeon fishes started from early eighteen century using taxonomical studies (Ruban *et al*., 2008) and morphological variation of different populations (Walsh *et al*., 2001). However, there is scarce literature on the use of comparative morphological studies of otolith for discrimination of most sturgeon species, especially Caspian sturgeon fish, despite the fact that otholoiths are useful tools in identifying teleost fishes (Torres *et al*., 2000; Chalupnicki & Dittman, 2016). The otoliths are versatile structures that have applications in ecology, fish biology, and fisheries science (Zischke *et al*., 2016). Differences in otolith morphology among species can occur for genetic differences, variability in habitat and behavior, changes in environmental conditions and differences in food habits (Cardinale *et al*., 2004). Otolithis including three types entitled lappillus, asteriscus and sagitta. Sagittal otoliths is the largest otoliths in most species (Torres *et al*.). Sagittal otoliths have been used to investigate age and growth, movement and habitat, population structure, and trophic ecology (Rooker *et al*., 2008). Sagittal otoliths correlated with genetics and environmental factors, and have special shape, so its characteristics used for identyfing of species and populations (Campana, 2005) and evolutional relationships (Lombarte *et al*., 2003). The aim of this work was to provide measurements of otoliths of Great sturgeon (*Huso huso*), Persian sturgeon (*Acipenser persicus*) and starry sturgeon (*Acipenser stellatus*) species by means of morphological characteristics of sagittal otoliths and also study of relationships between this calcified structure and their ecological characteristics.

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MATERIAL AND METHOD

A total of 30 great sturgeon, 30 Persian sturgeon and 30 starry sturgeon were sampled from the south Caspian Sea using commercial beach seines. Total length and total weight recorded for all fish samples were measured to the nearest 1 cm and 0.01 g. Right sagittal otoliths removed and washed by distilled water and then dried in a dark room (Reñones *et al*., 2007). Sagittal otoliths weighted to the nearest 0.0001 g and then photographed using stereo microscope (20-30×) equipped with a digital camera. The shape indices were calculated according to Tuset *et al*. (2008) to describe shape of otoliths.

Relationships between sagittal otolith weight and body weight, and also between sagittal otolith length and body length estimated using linear regression. Sagittal otolith weight/body weight and sagittal otolith length/total length ratios and also condition factor among studied species compared using one-way analysis of variance. Means were compared using the Tukey test when there were significant differences. Prior to the statistical analysis, all data were examined for normality and homogeneity of variance and nonparametric analysis was used, and classical data transformations was used (Zar, 1996).

RESULTS

Total length for Great sturgeon, Persian sturgeon and Starry sturgeon species ranged 50-101, 55-134, and 28-123 cm, respectively. Three different shapes of sagittal otolith were found in the studied species (Fig. 1). Sagittal otolith was triangular with irregular edges for Great sturgeon, an elongated triangle with smooth surface for Persian sturgeon, and relatively circular with smooth surfaces for Starry sturgeon (Fig. 1). In all species, when the body weight increased, then sagittal otolith weight increased. Regression slope in Persian sturgeon and Great sturgeon were significanly higher ($P<0.05$) than Starry sturgeon (Table I).

Fig. 1. - Sagittal otoliths (lateral view) of (a) *A. persicus* (total length, LT = 52.5 cm) (b) *H. huso* (total length, LT = 85 cm) and (c) *A. stellatus* (total length, LT =101 cm). Scale bars = 1mm

Table I. Regression equations between body weight-otolith weight and total length-otolith length. BW, body weight (g); WO, otolith weight (g); OL, otolith length (mm); TL, total length (cm); r^2, coefficient of determination.

Species / Relationship	*Huso huso*	r^2	*Acipenser stellatus*	r^2	*Acipenser persicus*	r^2
BW-WO	WO=0.009BW-0.054	0.90	WO=0.001BW-0.001	0.98	WO=0.012BW-0.077	0.79
TL-OL	OL=0.031TL+2.023	0.94	OL=0.012TL+1.739	0.94	OL=0.029TL+1.368	0.86

Table II. Comparison of sagittal otolith weight/body weight ratio (WO/BW), sagittal otolith length/total length ratio (OL/TL) and condition factor (CF) in Great sturgeon, Persian sturgeon and Starry sturgeon*.

Species Parameter	*Huso huso*	*Acipenser stellatus*	*Acipenser persicus*	P
WO/BW	$0.058 \times 10^{-4} \pm 0.025 \times 10^{-5,b}$	$0.140 \times 10^{-4} \pm 0.410 \times 10^{-5,a}$	$0.061 \times 10^{-4} \pm 0.092 \times 10^{-5,b}$	0.025
OL/TL	$0.06 \pm 0.029 \times 10^{-2,a}$	$0.052 \pm 0.830 \times 10^{-2,a}$	$0.050 \pm 0.160 \times 10^{-2,a}$	0.056
CF	$0.447 \times 10^{-2} \pm 0.2 \times 10^{-2,a}$	$0.159 \times 10^{-2} \pm 0.360 \times 10^{-2,c}$	$0.323 \times 10\text{-}2 \pm 0.160 \times 10^{-3,b}$	0.000

*Means within each row with no common superscript differ significantly at $P<0.05$. Values in rows with different superscripts are significantly different.

The sagittal WO/BW ratio in Starry sturgeon was significantly higher (P <0.05, Table II) than Persian sturgeon and Great sturgeon. Meanwhile, the condition factor varied significantly among the three studied species (P <0.05) and in great sturgeon was significantly higher (P <0.05) than Persian sturgeon and Starry sturgeon

It was found that when body length increased, sagittal otolith length increased in all three studied species. Regression slope in Persian sturgeon and Great sturgeon were higher than Starry sturgeon (Table I). As result, 80.0 %, 90 % and 80 % of total variation of sagittal otolith length in Persian sturgeon, Starry sturgeon and Great sturgeon, respectively are related to variation of body length.

DISCUSSION

The sagittal otoliths are widely used in comparative studies because their form, consistency, chemical composition, weight and growth have a degree of interspecific variation and difference in the shape of otoliths between closely related species of the same habitat has been widely found (Zorica *et al*., 2010). Differences were found in the geometric forms of otoliths in all three species of sturgeon. The differences in the patterns of otolith growth among the species may also be associated with differences in their body growth and condition factor (Bani *et al*., 2013), so greater weight of Starry sturgeon sagittal otolith is related to low growth rate. The three species have different habitats (Bakhshalizadeh *et al*., 2013a, 2013b). Lombarte *et al*. demonstrated that the great otolith mass is related to shallow and warm waters. Persian sturgeon is a typically benthic inhabitant of coastal waters in seas and it remain close to the bottom (Vlasenko *et al*., 1989), while the Starry sturgeon utilizes the middle and upper water layers (Shubina *et al*., 1989), and Great sturgeon inhabits the pelagic zone of marine waters in comparison to other sturgeon species (Pirogovskiĭ *et al*., 1989).

According to Campana, total variation due to length growth in Persian sturgeon and Starry sturgeon is based on their phylogenetical relationships compared with Great sturgeon. Sagittal OL/LT ratio have same trend in all three studied sturgeons (Table I). Since sagittal otolith growth is related to body growth (Vallisneri *et al*., 2008), relative variations in length and weight of otoliths among species, can therefore be affected by their growth rate (Bani *et al*.) which is associated with environmerntal factors such as temperature and depth of their habitats. Different habitats and feedig patterns affect fish biological and ecological behaviours (Lombarte *et al*.).

It was found that the otolith mass variations are related to body weight. This shows that the otolith mass is a more sensitive measure of the variations in the sturgeon growth rate, as has been found in other species (Fletcher, 1991). Residues of variation are correlated with habitats, hearing system function (Lombarte *et al*.) and cranial shape (Bani *et al*.) in each species.

In conclusion, it was found that based on our findings, description of sagittal otolith morphological characteristics can be used for identification and discrimination of different sturgeon species and understanding of their phylogenetical and ecological relationships.

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BAKHSHALIZADEH, S.; BANI, A.;ABDOLMALAKI, S. & PONCE-PALAFOX, J. T. Observaciones sobre la morfología de otolitos sagitales de varias especies de esturión en las aguas iranies del mar Caspio. *Int. J. Morphol., 36(2)*:523-526, 2018.

RESUMEN: Se estudió la morfología del otolito sagital del gran esturión (*Huso huso*), el esturión persa (*Acipenser persicus*) y el esturión estrellado (*Acipenser stellatus*) de las aguas iraníes del Mar Caspio. Se registraron tres mediciones de otolitos y tres índices de forma, de 90 especímenes de esturión. Se midieron los rasgos de la biometría de los peces y se estimó la relación entre la longitud del otolito sagital (LO) - longitud total (LT) y el peso del otolito (PO) – peso del cuerpo de los peces (PC). El otolito sagital tiene forma de triángulo con márgenes irregulares en el gran esturión (*Huso huso*), triángulo alargado con superficies lisas en esturión persa y relativamente circular con superficie lisa en esturión estrellado. La relación del PO / PC en el esturión estrellado fue significativamente mayor (P <0.05) que el gran esturión y el esturión persa. Existe una relación directamente proporcional entre PC y PO en el esturión persa (r2 = 0.7), el gran esturión (r2 = 0.9) y el esturión estrellado (r2 = 0.9). La pendiente de la línea de regresión para estas relaciones en el esturión estrellado fue menor que el esturión persa y el gran esturión. Por otra parte, existe una regre-

sión lineal significativa entre LO-LT. Los resultados mostraron que es posible identificar especies de esturión del Caspio basadas en la morfometría corporal y las características del otolito sagital.

PALABRAS CLAVE: Formas otolito; *Huso huso*; *Acipenser persicus*; *A. stellatus*.

REFERENCES

Bakhshalizadeh, S.; Bani, A. & Abdolmalaki, S. Comparative morphology of the pectoral fin spine of the Persian sturgeon *Acipenser persicus,* the Russian sturgeon *Acipenser gueldenstaedtii*, and the Starry sturgeon *Acipenser stellatus* in Iranian waters of the Caspian Sea. *Acta Zool., 94(4)*:471-7, 2013a.

Bakhshalizadeh, S.; Bani, A. & Abdolmalaki, S. Morphometric features in the pectoral fin spine of the great sturgeon (*Huso huso*) and the ship sturgeon (*Acipenser nudiventris*, Lovetsky, 1828). *J. Appl. Ichthyol., 29(4)*:730-2, 2013b.

Bani, A.; Poursaeid, S. & Tuset, V. M. Comparative morphology of the sagittal otolith in three species of south Caspian gobies. *J. Fish Biol., 82(4)*:1321-32, 2013.

Campana, S. E. Otolith science entering the 21st century. *Mar. Freshw. Res., 56(5)*:485-95, 2005.

Chalupnicki, M.A. & Dittman, D.E. North American sturgeon otolith morphology. *Copeia, 104(1)*:260-6, 2016.

Fletcher, W. J. A Test of the relationship between otolith weight and age for the Pilchard *Sardinops neopilchardus*. *Can. J. Fish. Aquat. Sci., 48(1)*:35-8, 1991.

Lombarte, A.; Torres, G. J. & Morales-Nin, B. Specific Merluccius otolith growth patterns related to phylogenetics and environmental factors. *J. Mar. Biol. Assoc. U. K., 83(2)*:277-81, 2003.

Pirogovskiĭ, M. I.; Sokolov, L. I. & Vasilev, V. P. *General Introduction to Fishes Acipenseriformes*. In: Holcík, J. (Ed.). The Freshwater Fishes of Europe. Wiesbaden, Verlag, 1989.

Reñones, O.; Piñeiro, C.; Mas, X. & Goñi, R. Age and growth of the dusky grouper *Epinephelus marginatus* (Lowe 1834) in an exploited population of the western Mediterranean Sea. *J. Fish Biol., 71(2)*:346-62, 2007.

Reyment, R. A. *Morphometrics: an Historical Essay, Morphometrics for Nonmorphometricians*. In: Elewa, A. M. T. (Ed.). Morphometrics for Nonmorphometricians, Lecture Notes in Earth 9 Sciences 124. Berlin, Springer-Verlag, 2010.

Rooker, J. R.; Secor, D. H.; DeMetrio, G.; Kaufman, A. J.; Belmonte Ríos, A. & Ticina, V. Evidence of trans-Atlantic movement and natal homing of bluefin tuna from stable isotopes in otoliths. *Mar. Ecol. Prog. Ser., 368*:231-9, 2008.

Ruban, G. I.; Kholodova, M. V.; Kalmykov, V. A. & Sorokin, P. A. Morphological and molecular genetic study of the Persian sturgeon *Acipenser persicus* Borodin (Acipenseridae) taxonomic status. *J. Ichthyol., 48(10)*:891-903, 2008.

Shubina, T. N.; Popova, A. A. & Vasilev, V. P. *General Introduction to Fishes Acipenseriformes*. In: Holcík, J. (Ed.). The Freshwater Fishes of Europe. Wiesbaden, ALUA Verlag, 1989. pp.395-443.

Torres, G. J.; Lombarte, A. & Morales-Nin, B. Variability of the sulcus acusticus in the sagittal otolith of the genus Merluccius (Merluciidae). *Fish. Res., 46(1)*:5-13, 2000.

Tuset, V. M.; Lombarte, A. & Assis, C. A. Otolith atlas for the western Mediterranean, north and central eastern Atlantic. *Sci. Mar., 72(Suppl. 1)*:7-198, 2008.

Vallisneri, M.; Trotta, V.; Cavicchi, S. & Piccinetti, C. Sex-specific somatic–otolith growth relationship in two Gadidae. *J. Fish Biol. 72(3)*:724-30, 2008.

Vlasenko, A. D.; Pavlov, A. V. & Vasilev, V. P. *General Introduction to Fishes Acipenseriformes*. In: Holcík, J. (Ed.). The Freshwater Fishes of Europe. Wiesbaden, ALUA Verlag, 1989. pp.345-66.

Walsh, M. G.; Bain, M. B.; Squiers, T.; Waldman, J. R. & Wirgin, I. Morphological and genetic variation among shortnose Sturgeon *Acipenser brevirostrum* from adjacent and distant rivers. *Estuaries, 24(1)*:41-8, 2001.

Zar, J. *Biostatistical Analysis*. 3rd ed. New Jersey, Prentice Hall, 1996.

Zischke, M. T.; Litherland, L.; Tilyard, B.; Stratford N.; Jones, E. & Wang, Y. G. Otolith morphology of four mackerel species (*Scomberomorus spp.*) in Australia: Species differentiation and prediction for fisheries monitoring and assessment. *Fish. Res., 176*:39-47, 2016.

Zorica, B.; Sinovcic, G. & Cikeskec, V. Preliminary data on the study of otolith morphology of five pelagic fish species from the Adriatic Sea (Croatia). *Acta Adriat., 51(1)*:89-96, 2010.

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