Acta Biol. Univ. Daugavp. 16 (1) 2016
ISSN 1407 - 8953

BEHAVIORAL RESPONSES OF SALMONID FINGERLINGS TO NEW INVASIVE FISH PREDATOR *PERCCOTTUS GLENII*

Arturs Skute, Mihails Pupins, Aija Pupina

Skute A., Pupins M., Pupina A. 2016. Behavioral responses of salmonid fingerlings to new invasive fish predator *Perccottus glenii*. *Acta Biol. Univ. Daugavp., 16 (1): 91 – 98.*

The research on behavioural responses of salmonid fingerlings to the new invasive in Latvia and Europe predator fish Rotan, Amur sleeper, *Perccottus glenii* was conducted as a part of the research on modernization of aquaculture technology. The main aim of the present study was to investigate the antipredator behavior of tiger trout as a model objects of salmonid, exposed to a potential new predator *P.glenii*. The antipredator behaviour of tiger trout fingerlings was investigated in ten small groups (10 specimen each) in a comparison before and after releasing of one big *P.glenii* in their basin. According to its size (250 mm in length from the end of the caudal fin to the tip of the snout; weight 278 g), the model specimen of the *Perccottus glenii* was potential predator for investigated tiger trout fingerlings. In the result of the research we found that tiger trout fingerlings have innate antipredator behaviour used counter new invasive predator *P.glenii*.

Key words: antipredator behaviour, aquaculture, tiger trout, predator, invasive species, *Perccottus glenii*, Chinese sleeper, Perciformes, Gobioidei.

Arturs Skute, Mihails Pupins, Aija Pupina. Daugavpils University, Ecology department, 1A Parades Str, Daugavpils, LV-5401, e-mail: arturs.skute@du.lv, mihails.pupins@gmail.com, bombinalatvia@inbox.lv

INTRODUCTION

At the moment aquaculture is a stable developing and leading section of agriculture in the world and Europe; its main goal is the satisfaction of increasing needs of people. The aquaculture of many species is widely used both to get food stuff and other resources directly, and to recruit natural populations of hydrobionts for different purposes.

One of the important and valuable group of fish species, which is bred and kept in the world aquaculture and released into the nature for food, nature protection, scientific and research, aesthetic and recreational purposes, is Salmonidae. The most frequently they are released in wild at the stage of fingerlings, whitebait, and larvae.

These released Salmonidae can become a prey of predator which reduces economic efficiency of this aquaculture. Thereby the researches devoted to studying of reactions of prey – predator for fingerlings, which are kept in the aquaculture, are actual and widespread (Ferrari et al. 2010, Gall & Mathis 2010).

Such researches have also important scientific value for biology, because they allow to better understand the laws of behaviour formation in the system prey – predator, roles of learnt reactions, social behaviour and first-hand experience in fishes (Berejikian et al. 2003, Blumstein 2006, Brown et al. 2006, 2011).

Of particular interest for research is the antipredator behaviour in fishes, which is directed to the territorially new and evolutionary unknown predators (Sih et al. 2010, Kuehne & Olden 2012).

One of the new species of fish predator in Europe and Latvia, which are potentially dangerous for released fingerlings, whitebait, and fish larvae of many species, including the Salmonidae, is the invasive Amur sleeper, Rotan *Perccottus glenii* Dybowski 1877.

P.glenii naturally distributed in the north-east China, the Far East of Russia, and northern North Korea (Reshetnikov 2009). At the moment the *P.glenii* is widely widespread or registered in many European states: Belarus, Bulgaria, Estonia, Finland, Germany, Hungary, Italy, Latvia, Lithuania, Moldavia, Poland, Romania, Serbia, Slovakia, Ukraine (Kosco et al. 2003, Nalbant et al. 2004, Reshetnikov 2005, Novak et al. 2008, Kosco 2009, Plikss & Aleksejevs 2006, Reshetnikov 2009, 2010, Semenchenko et al. 2009, Ureche et al. 2009). Its current expansion in Europe is going on; *P.glenii* is occupying more and more new territories and water systems (Reshetnikov 2010, 2013, Reshetnikov & Ficetola 2011).

In Latvia the *P.glenii* for the first time was found in Daugavpils district (Plikss, Aleksejevs 2006). In 2015, only in 9 years, *P.glenii* is widely widespread on more than half of the territory of Latvia (Bara (ed) 2010, 2013, Ezeri.lv, Pupins & Pupina 2012, Pupina & Pupins 2013, Pupina et al. 2015).

P.glenii is evolutionarily new predator in Europe and in Latvia for many local aquatic organisms, including fishes (Moravec 1994, Froese & Pauly (editors) 2010, Reshetnikov 2005, Pupins &Pupina 2012, Luca & Ghiorghița 2014). It also is a host and can be new vector of expansion of parasites in Latvia (Biserkov & Kostadinova 1997, Kvach et al. 2013, Kirjušina et al. 2014).

One of common habitats of *P.glenii* in Latvia are in Latvian aquaculture popular fish ponds and lakes (Pupina et al. 2015), which have to be stocked with fish, where the salmonid and other fingerlings are commonly released in Latvia. *P.glenii* is met in catchment basins of many Latvian rivers and lakes, in which Salmonidae naturally lives or were released (Bara (ed) 2010, 2013, Ezeri.lv; Pupina & Pupins 2013).

All these factors make the research on behavioural responses of salmonid fingerlings to new invasive predator *Perccottus glenii* in Latvia actual.

MATERIAL AND METHODS

We conducted this research in 2015 as a part of the research on modernization of aquaculture technology.

We chose tiger trout – a sterile, intergeneric hybrid of the brown trout (*Salmo trutta*) and the brook trout (*Salvelinus fontinalis*), as a model object of salmonid. As the hybrid tiger trout is becoming more popular for releasing into Latvian waterbodies due to its rapid growth, relatively high adaptability to the environmental conditions and inability to reproduce independently.

For the experiment we used tiger trout fingerlings, kept from eggs in aquaculture in indoor plastic basin. These tiger trout fingerlings were raised using dry feed and did not have experience of contacting predators or live feed. They accustomed to people who took care of them and did not experience any compelled fear of people.

We randomly caught with a landing net from initial group of 2542 tiger trout 100 individuals from 35 to 44 mm long and having mass as much as 0.5g, and divided them into 10 experimental groups, 10 individuals per each group.

Square plastic experimental basin had a size of 1,12 x 1,12 x 0,71 m, it was similar to main basin where tiger trout fingerlings were being kept. Conditions of water, light, material and colour of experimental pool were the same as in the main pool for tiger trout fingerlings keeping. We used for video recording video camera *Logitech* connected to notebook and controlled by software *Free2X Webcam Recorder*, located at a height of 1.8m above experimental pool. Camera filmed the basin from above (Fig. 1).

We compared the behaviour of tiger trout fingerlings in each group before and after demonstration of predator. In the experiment, each group of 10 tiger trout fingerlings one by one was placed into the experimental basin. During the experiment we imitated the situation when tiger trout fingerlings were released into the wild, and almost at once met evolutionary new predator, therefore we chose adaptation period of 1 minute for all groups.

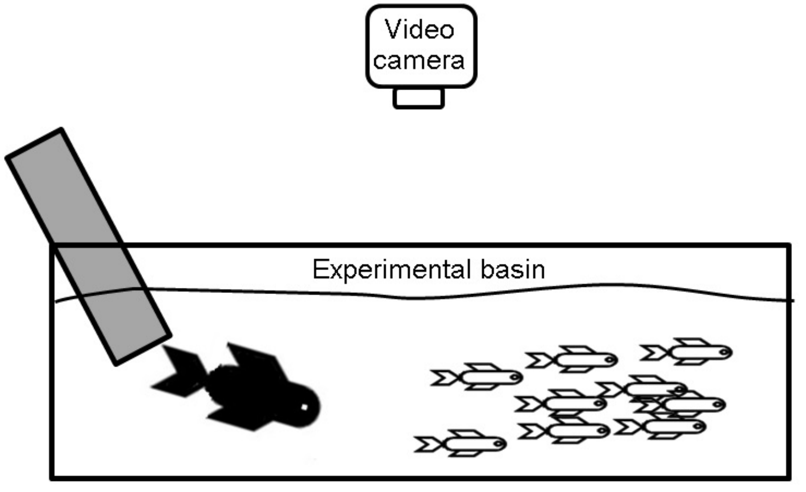

Fig. 1. Scheme of the experimental basin and video recordering. Black fish – predator, white fishes – fingerlings, gray – pipe for releasing of predator.

Fig. 2. Large adult *Perccottus glenii* male used in the experiment.

After this standard period for all groups, we video recorded 10 seconds of tiger trout fingerlings behaviour. This behaviour was accepted as control behaviour.

After that, we released large adult *Perccottus glenii* male sized 250 mm in length from the end of the caudal fin to the tip of the snout, it weighed 278 g caught in Latvian lake Trikartu, into the same experimental basin. Due to its size this *P.glenii* could be a potential predator for experimental tiger trout fingerlings (Fig. 2).

We released *P.glenii* through non transparent plastic pipe; the end of pipe for releasing was placed into water, at a depth of 20 cm in order to reduce the possibility of splashing (Fig. 1).

We used the same individual of the *P.glenii* in all experiments to eliminate possible individual influence (individual differences in gender, smell, behaviour, mass, colour, size etc.) of different *P.glenii*.

Directly after that, we video recorded again 10 seconds of tiger trout fingerlings behaviour (Fig. 3), because we were interested in the initial reaction of fingerlings to the appearance of predator.

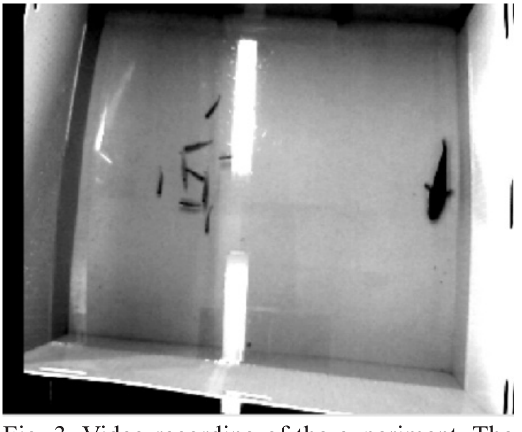

Fig. 3. Video recording of the experiment. The biggest fish is the predator *Perccottus glenii*, smaller - tiger trout fingerlings.

After the experiment with the given group of tiger trout fingerlings was completed; we removed them and *P.glenii* from the basin.

Before the beginning of experiment with the next group, we waited for water in the basin to be replaced at least 5 times with water filtered through the basin filtration system, in order to reduce possible impact of chemical substances which remained in the basin from the previous experiment.

Recorded control and experimental video files were processed using standard features of *LoliTrack* software. For behaviour analysis of multiple individual fish based on contrast, e.g. no markers with *LoliTrack* software was used. We analysed 10 tiger trout fingerlings for each control and experimental group. After the threshold bars were set, *LoliTrack* sorted all actual pixels and fitted them regarding the object's last frame positions. Velocity, acceleration, active and inactive time and distance moved by each tiger trout fingerling were recorded and analysed.

The obtained results were processed using methods of descriptive statistics and t-Test for two-sample assuming unequal variances and using *Excel* for *Windows* and *StatGrafics* software.

RESULTS

As a result of the conducted experiment we obtained the data on velocity, acceleration, active and inactive time and distance moved for control and experimental groups. Average values of these parameters and confidence intervals are cited in the table (Tab. 1).

Analysis t-Test for two-sample assuming unequal variances showed reliable difference between control and experiment ($p < 0,001$) for all parameters.

Thus, the behaviour of salmonid fingerlings in control and experiment was significantly different. The biggest difference between control

Tab. 1. Repeatability (R) values with 95% confidence intervals for various measures of salmonid fingerlings behavioral variables (n=100; p < 0,001)

Variable	**Control**		**Experiment**	
	R	**Confidence intervals**	**R**	**Confidence intervals**
Avg. velocity [cm/sec]	70,93	60,85 - 81,01	22,50	19,56 - 25,44
Avg. Acceleration [cm/sec^2]	2420,21	2061,62 - 2778,80	767,25	673,74 - 860,76
Active time [sec]	3,01	2,69 - 3,33	0,95	0,88 - 1,02
Active time [%]	30,06	26,81 - 33,31	9,50	8,76 - 10,24
InActive time [s]	6,09	5,77 - 6,41	8,14	8,07 - 8,21
InActive time [%]	60,85	57,60 - 64,10	81,41	80,67 - 82,15
Distance moved [cm]	116,87	106,96 - 126,78	36,89	33,03 - 40,75

and experiment (more than by 3 times) was noted for all parameters, except for InActive time, which had a difference of 1, 3 times. Nevertheless, the coefficient of variation of InActive time in experimental group decreased for more than 5 times in comparison with the control group. It can serve as a proof that during facing the predator in the experiment, group anti-predatory behaviour prevails over individual models of behaviour appeared in control.

Thus, responses of salmonid fingerlings to new invasive predator *Perccottus glenii* were reliably demonstrated in the research.

DISCUSSION

This research demonstrates distinct anti-predator behaviour of salmonid to new invasive predator *Perccottus glenii*. Could any other unaccounted in the research factors, for example, experimenter himself, his appearance, fluctuations in substratum produced by him, smell, changes of light etc., cause this kind of behaviour? We suppose, that fingerlings used in this experiment, raised in aquaculture and accustomed to the regular appearance of human, did not perceive experimenter as a threat which also proves the behaviour of control group. Measures taken during the experiment (predator release through the pipe without splashes, constant artificial light, same composition and temperature of water, replacing water in experimental pool in the intervals between the experiments etc.) allowed to avoid the impact of unaccounted factors on the behaviour of fingerlings or, at least, made it same for control and experimental groups.

In the research we did not have a goal to find out which characteristics exactly of used *Perccottus glenii* caused fingerlings to react to it as to a predator. Nevertheless, these experimental ‘predator-naive’ fingerlings reliably demonstrated predator-specific behaviour towards such evolutionary new and personally before unknown object for them. Thus, presented *Perccottus glenii* obviously had some universal characteristics of predator for tiger trout, which caused protective response among experimental.

During the conducted experiment it was discovered that while the absence of predator, tiger trout distinctly shows individual models of behaviour. Appearance of predator causes more unified behavioural reaction for all group, expressed in cessation of movement and standing motionless. Possibly, the unified group model of behaviour is more beneficial while the appearance of predator and allows in this situation to minimize the loss of energy both among individuals and in a group itself.

CONCLUSIONS

Tiger trout fingerlings show predator-specific behaviour to new non-native invasive fish *Perccottus glenii*.

This predator-specific behaviour to new predator *Perccottus glenii* can be seen among fingerlings with the first appearance of the predator, and without provisional learning.

Individual models of behaviour among tiger trout fingerlings are replaced with unified group anti-predator behaviour models with the appearance of predator *Perccottus glenii*.

ACKNOWLEDGEMENTS

This research was supported by the ESF Project "Creation of a new scientific group for modernization of aquaculture technology" # 2013/ 0067/ 1DP/ 1.1.1.2.0/ 13/ APIA/ VIAA/ 060. We thank A.Karklins for cooperation in research of *Perccottus glenii* in Latvia and for the *Perccottus glenii* used in the experiment.

REFERENCES

Bara J. (ed). 2010. Dabas parka "Daugavas loki" dabas aizsardzības plāns. [Nature conservastion plan for "Daugavas loki" nature park.]. Daugavpils novada dome: Pp. 209 (In Latvian).

Bara J. (ed). 2013. Dabas parka „Daugavas ieleja" dabas aizsardzības plāns. [Nature conservastion plan for "Daugavas ieleja" nature park.]. Riga: Pp. 104 (In Latvian).

Berejikian B.A., Tezak E.P. & LaRae A.L. 2003. Innate and enhanced predator recognition in hatchery-reared Chinook salmon. *Environmental Biology of Fishes*, 67, 241–251.

Biserkov V., Kostadinova A., 1997. Development of the plerocercoid I of *Ophiotaenia europea* in reptiles. *Int. J. Parasitol*., 21: 1513–1516.

Blumstein, D.T., 2006. The multipredator hypothesis and the evolutionary persistence of antipredator behavior. *Ethology* 112.3, 209–217.

Brown G.E., Rive A.C., Ferrari M.C.O., Chivers D.P. 2006. The dynamic nature of antipredator behavior: prey fish integrate threat-sensitive antipredator responses within background levels of predation risk. *Behav Ecol Sociobiol* 61:9–16.

Brown, G.E., Ferrari, M.C.O., Malka, P.H., Russo, S., Tressider, M. & Chivers, D.P. 2011. Generalization of predators and nonpredators by juvenile rainbow trout: learning what is and is not a threat. *Animal Behaviour* 81: 1249–1256.

Ezeri.lv. http://www.ezeri.lv/. Downloaded: 20.04.2015. (In Latvian).

Ferrari, M.C.O., Brown, G.E., Jackson, C.D., Malka, P.H., Chivers, D.P. 2010. Differential retention of predator recognition by juvenile rainbow trout. *Behaviour* 147, 1791–1802.

Froese R., Pauly D. Editors. 2010. *FishBase – Percottuss glenii*. http://www.fishbase.us/summary/Perccottus-glenii.html#. Downloaded: 23.04.2015.

Gall B.G. & Mathis A. 2010. Innate predator recognition and the problem of introduced trout. *Ethology*, 116, 47–58.

Kirjušina M., Lazdāne M., Zolovs M. 2014. Parasitofauna of *Perccottus glenii* Dybowski, 1877 (Osteichthyes, Odontobutidae) in water bodies of the Southern part of Latgale (Latvia). *Acta Biologica Unversitaes Daugavpiliensis*, 14 (2): 137–143.

Kosco J. 2009. Non-native fishes in the Middle Europe, a review. "*Aquatic biodiversity* *international conference*", Sibiu/Romania/ European Union: 3–4.

Kosco J., Lusk S., Halacka K., Luskova V. 2003. The expansion and occurrence of the Amur sleeper (*Perccottus glenii*) in eastern Slovakia. *Folia Zool.*, 52 (3): 329–336.

Kuehne L.M. & Olden J.D. 2012. Prey naivety in the behavioural responses of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) to an invasive predator. *Freshwater Biology* 57, 1126–1137

Kvach Y., Drobiniak O., Kutsokon Y., Hoch I. 2013. The parasites of the invasive Chinese sleeper *Perccottus glenii* (Fam. Odontobutidae), with the first report of *Nippotaenia mogurndae* in Ukraine. *Knowledge and Management of Aquatic Ecosystems*, 409: 05p1–05p11.

Luca M., Ghiorghița G. 2014. The invasive species *Perccottus glenii* – a threat for the fresh water ecosystems. *Analele* Științifice *ale Universității „Alexandru Ioan Cuza" din Iași, s. Biologie animală*, Tom LX: 129–138.

Moravec F. 1994. Parasitic nematodes of freshwater fishes of Europe. Academia, Praha: Pp. 473.

Nalbant T., Battes K., Pricope F., Ureche D. 2004. First record of the Amur sleeper *Perccottus glenii* (Pisces, Perciformes: Odontobutidae) in Romania. *Travaux du Museum National d'Histoire Naturelle "Grigore Antipa"*, Vol. XLVII: 279–284.

Novak M., Szcerbik P., Tatoj K., Popek W. 2008. Non-native freshwater fishes in Poland: an overview. *AACL Bioflux*, 1(2): 173–191.

Plikss M., Aleksejevs E. 2006. *Percottus glehni* Dyb. <http://www.latvijasdaba.lv/4/view_0_descr.asp?id=98> Downloaded: 05.06.2015 (in Latvian).

Pupina A., Pupins M. 2013. Invasive fish *Perccottus glenii* (Perciformes: Gobioidei: Odontobutidae) distribution in catchment basins of Salmonid lakes in Latvia. Latvijas universitātes 71. Zinātniskā konference. Rīga, 2013. gada 18. februāris. *Latvijas* ūdeņu *vides pētījumi un aizsardzība. Referātu tēžu krājums,* 54–56.

Pupina A., Pupins M., Skute A., Pupina Ag., Karklins A. 2015. The distribution of the invasive fish amur sleeper, rotan *Perccottus glenii* Dybowski, 1877 (Osteichthyes, Odontobutidae), in Latvia. *Acta Biologica Universitatis Daugavpiliensis*, 15 (2): 329 – 341.

Pupins M., Pupina A. 2012. Invasive fish *Perccottus glenii* in biotopes of *Bombina bombina* in Latvia on the north edge of the fire-bellied toad's distribution. *Acta Biologica Universitatis Daugavpiliensis,* Suppl. 3: 82–90.

Reshetnikov A. 2005. Introduced fish, rotan *Percottus glenii* – an unavoidable threat for European amphibians. -*Froglog*, Nr.67: 3–4.

Reshetnikov A.N. 2009. Sovremennyi areal ryby rotana (Perccottus glenii Dybovski, 1877) v Evrazii. *Rossiyskiy zhurnal biologicheskih invaziy*, Nr.1: 17–27 (In Russian).

Reshetnikov A.N. 2010. The current range of Amur sleeper *Perccottus glenii* Dybowski, 1877 (Odontobutidae, Pisces) in Eurasia. *Russian Journal of Biological Invasions*, 1(2): 119-126.

Reshetnikov A.N. 2013. Spatio-temporal dynamics of the expansion of rotan *Perccottus glenii* from West-Ukrainian centre of distribution and consequences for European freshwater ecosystems. *Aquatic Invasions*, 8 (2): 193–206.

Reshetnikov A.N., Ficetola G.F. 2011. Potential range of the invasive fish rotan (*Perccottus* *glenii*) in the Holarctic. *Biological Invasions* 13 (12): 2967–2980.

Semenchenko V.P., Rizevsky V.K., Mastitsky S.E., Vezhnovets V.V., Pluta M.V., Razlutsky V.I., Laenko T. 2009. Checklist of aquatic alien species established in large river basins of Belarus. *Aquatic Invasions*, 4 (2): 337–347.

Sih A., Bolnick D.I., Luttbeg B., Orrock J.L., Peacor S.D., Pintor L.M. 2010. Predator–prey naïveté, antipredator behavior, and the ecology of predator invasions. *Oikos*, 119, 610–621.

Ureche D., Battes K., Ureche C. 2009. Research regarding the distribution of the invasive species *Perccottus glenii* Dybowski 1877 (Pisces: Osteichtes) within the upper midbasin of the river Siret, Romania. *Aquatic biodiversity international conference*. Sibiu/Romania/European Union: Pp. 34.

Received: 10.07.2016.
Accepted: 12.05.2016.