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Short Communication

Gastric Evacuation in Brook Trout (*Salvelinus fontinalis*) Fry: Effect of Body Size

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KS presented and planned the project and statistically analyzed the results. NB performed the experimental work with the help of NSB. UK wrote the manuscript.

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ABSTRACT

This study was aimed to determine the gastric evacuation (GE) in brook trout (*Salvelinus fontinalis*) fry and to estimate the effect of body mass on their GE rate (GER). A group of small and large sized *S. fontinalis* fry (ranging 0.39−0.66 and 0.76−1.46 g) was fed with commercial pellets under similar conditions to avoid the ingress of any other variable such as temperature and dietary energy density. Their stomach contents were sampled at predetermined postprandial times, and were dried at 60° C to constant weight. The course of GE in both sizes of *S. fontinalis* fry was best described by the square root model. The relationship between GER and body mass was then determined by a power function of fry mass that can be summarized by the equation $\frac{dS_t}{dt} = -0.0033M^{1.316}\sqrt{S_t}$ (g h^{-1}), where S_t is current stomach mass (g), M is fry mass (g), and t is time (h). The course of GE in *S. fontinalis* fry is similar to that previously reported for adult *S. fontinalis*.

The relevance and importance of gastric evacuation (GE) experiments to quantify the daily rations of wild fish (Elliott and Persson, 1978; Bromley, 1994; dos Santos and Jobling, 1995; Seyhan and Grove, 1998; Andersen, 2001) as well as cultivated fish (Windell *et al.*, 1972; Talbot and Higgins, 1983; Riche *et al.*, 2004; Khan *et al.*, 2016; Başçınar *et al.*, 2016) are well recognized. Studying GE rates (GER) in fish will help to quantify their daily ration amount to avoid any overfeeding or underfeeding as both of these are dangerous to fish health and the economic feasibility of aquaculture systems: overfeeding causes the degradation of water quality (e.g. ammonia poisoning, low oxygen levels, low pH levels) and increases faecal production as well as the waste of expensive feed (Fateh *et al.*, 2005), whereas underfeeding of fish can lead to poor growth of fish and sometimes even fish death (Jobling *et al.*, 2012).

The GER is influenced by temperature (Jobling, 1981; Bromley, 1994), fish size (Nobel, 1973; Mills *et al.*, 1984; Andersen, 1998), meal size and energy density of the diet (Grove *et al.*, 1978; Jobling, 1987; Andersen, 2001). Most of GE experiments include adult fish and only a few focus young fish (Nobel, 1973; Silva and Owoyemi 1983; Röusch, 1987; Karjalainen *et al.*, 1991; Bernreuther *et al.*, 2009).

GE experiments have been carried out on adult brook trout (*Salvelinus fontinalis*) under various factors such as at different temperatures (Sweka *et al.*, 2004; Başçınar *et al.*, 2016), body and meal sizes (Khan *et al.*, 2016; Bascinar *et al.*, 2017). According to aforementioned studies the GE of *S. fontinalis* is best described by the square root model except Sweka *et al.* (2004) who chose a linear model over the square root though the square root model best fit their data obtain at 12.1 and 17.0°C.

In this study, the GE in *S. fontinalis* fry with reference to the effect of body size on GER was determined. The fry were fed with commercial pellets and their stomach contents were recovered by the discussed method at predetermined postprandial times.

Materials and methods

Two different sizes fry (ranging 0.39−0.66 and 0.76−1.46 g respectably) were procured from the Surmene Faculty of Marine Sciences, Trabzon (Table I). They were stocked in two separate aquaria of 10 L which were facilitated with recirculating water system where the

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oxygen saturation was ensured by means of continuous air-bubbling. The fish were fed four times daily with 800µ size commercial pellets (crude protein, 55%; crude fat, 12% obtained from Skretting Aquaculture, www.skretting.com.tr) to apparent satiation for a week prior to experiments. The same feed type was used during the GER experiments.

The fish fry were deprived of food for 72 h before starting the GE experiments. They were fed (group-feeding) to apparent satiation; the feeding period lasted for 15 minutes. The uneaten feed was collected by water-pipe. The stomach contents of fry were then sampled at predetermined postprandial times under Stereo microscope. The recovered stomach contents were dried in an Ecocell Drying Oven at 60°C to constant weight. Fish were killed using an overdose of anaesthesia (20 ppm benzocaine).

The simple regression method used by He and Wurtsbaugh (1993), Pääkkönen and Marjomäki (1997), Sweka *et al*. (2004) and Bascinar *et al*. (2016, 2017) was applied to the GE data of *S. fontinalis* fry. The best fit model was determined on the basis of adjusted r^2 and the residual sum of squares (*RSS*) values.

Linear model $\frac{dS_t}{dt} = -\rho t$ integrated:

$$S_t = a - \rho t \ldots\ldots (1)$$

Square root model $\frac{dS_t}{dt} = -\rho\sqrt{t}$ integrated:

$$\sqrt{S_t} = \sqrt{a} - 0.5\rho t \ \ldots\ldots (2)$$

Exponential model $\frac{dS_t}{dt} = -\rho t$ integrated:

$$S_t = ae^{-\rho x} \ \Rightarrow$$

$$\ln(S_t) = \ln(a) - \rho t \ \ldots\ldots (3)$$

where S_t is the recovered stomach content mass (g) at time *t* (h), *a* is the intersection of the regression line with the y-axis that represents the mean ingested meal size S_0, and ρ is the rate parameter (g h^{-1}).

The parameters of equations 1, 2, and 3 were determined by PROC GLM procedure from SAS (SAS Institute Inc, 2015). After determining the model that best fit the GE data of *S. fontinalis* fry, the effect of body size on GER was then determined by a simple power function.

Results

The course of GE in each size *S. fontinalis* fry was best described by the square root model. The square root model consistently provided a higher value of adjusted r^2 and the lowest value of *RSS* (Table II). The differences between square root and linear models were small compared to that of the exponential model.

Fry body mass (g) was used to quantify the effect of body size on GER. The rate parameters obtained by the square root model were plotted (y-axis) against the mass of fry (x-axis) and a curve line was provided using the simple power function. Hence, the relationship between body size and GER can be summarized as:

$$\frac{dS_t}{dt} = -0.0033M^{1.316}\sqrt{S_t}\,(gh^{-1}) \ldots\ldots (4)$$

where S_t is current stomach mass (g), *M* is fry mass (g), and *t* is time (h).

Table I.- Basic experimental data (mean ± S.E.) from gastric evacuation experiments on brook trout *Salvelinus fontinalis* fry fed on commercial pellets.

Exp. no.	Temperature (°C)	Mass (g)	Total length (cm)	Meal size (g)*	Obs. (n)
1	17.3	0.49 ± 0.01	4.44 ± 0.03	0.003 ± 0.000	21
2	17.3	1.08 ± 0.03	5.39 ± 0.03	0.020 ± 0.000	24

*stomach contents recovered at time 0

Table II.- Estimates (mean ± S.E.) of the intercept and rate parameter ρ in the square root model, linear model and exponential model from gastric evacuation data of brook trout *Salvelinus fontinalis* fry fed meals of commercial pellets.

	Square root model				Linear model				Exponential model			
Exp. no.	*a*	*ρ* (×10^{-2})	RSS	Adj. r^2	*a*	*ρ* (×10^{-2})	RSS	Adj. r^2	*a*	*ρ* (×10^{-2})	RSS	Adj. r^2
1	0.53 ± 0.01	-1.32 ± 0.04	0.00	0.923	0.03 ± 0.00	-46.00 ± 0.30	1.27	0.924	-57.55 ± 1.46	-42.39 ± 0.01	3.02	0.812
2	1.38 ± 0.04	-3.30 ± 0.14	0.00	0.766	0.18 ± 0.00	-0.31 ± 0.00	0.00	0.755	-38.67 ± 1.02	-36.75 ± 0.01	4.43	0.730

This equation, obtained from combined GE data of both fry sizes was used to provide the GE curves in Figure 1.

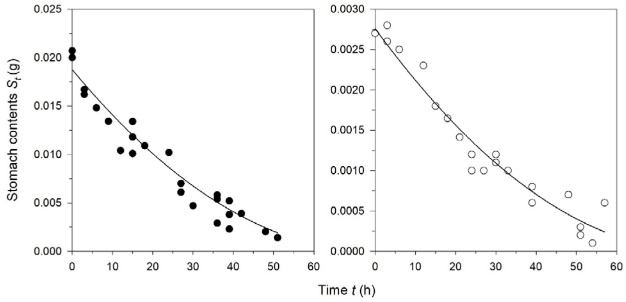

Fig. 1. Gastric evacuation of brook trout *Salvelinus fontinalis* fry: large size (●), small size (○). The curves were provided by use of equation (4).

Discussion

The square root model adequately described the course of GE in both sized *S. fontinalis* fry which is in accordance with the results obtained from adult *S. fontinalis* in previous studies (Khan *et al*., 2016; Başçınar *et al*., 2016, 2017). Khan *et al*. (2016) fed adult *S. fontinalis* with a range of meal sizes (100%, 50% and 25% of satiation meal size) and found the square root model to adequately describe the GE of *S. fontinalis* independent of meal size. The square root model also described the GE of vendace (*Coregonus albula*) L. fry fed with live zooplankters: copepod nauplii and copepodids (Karjalainen *et al*., 1991). Whereas, the course of GE in sprat (*Sprattus sprattus*) fry was reported to be best described by so called surface-area dependent model (Bernreuther *et al*., 2009).

In this study, the effect of body size on GER of *S. fontinalis* was quantified using fry mass instead of length. While for adult *S. fontinalis* Khan *et al*. (2016), and Başçınar *et al*. (2017) used the fish total length (though they also estimated the mass exponent) to quantify the effect of body size on the GER of adult *S. fontinalis* in accordance with Andersen (2001). However, in the present study using *S. fontinalis* fry length to quantify the effect of body size on GER gave an unrealistic length exponent value (4.79). In contrast to fry length, using fry mass gives a realistic value for the mass exponent (1.31) and the summarized equation (4) adequately provided a good curve to the data (Fig. 1). Bernreuther *et al*. (2009) obtained a mass exponent value of 0.503 for sprat fry.

Conclusion

The result of this study, together with the result of Khan *et al*. (2016), suggested that the GE of *S. fontinalis* fed commercial pellets can be adequately described by the square root model. The square root model can therefore from a limited number of growth experiments be used to estimate the stomach fullness at return of appetite as well as the fullness that provides optimum food conversion efficiency and maximum growth rate. This information can then be extrapolated to other situations (temperature and energy density of feed), and this way reduce the number of time consuming and expensive growth experiments.

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Statement of conflict of interest

Authors have declares that there is no conflict.

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