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Variation in length, girth and weight of large northern pikes (*Esox lucius*) in Finland

Marco Milardi*, Jyrki Lappalainen & Teppo Juntunen

*Department of Environmental Sciences, Aquatic Sciences, P.O. Box 65, FI-00014 University of Helsinki, Finland (*corresponding author's e-mail: marco.milardi@helsinki.fi)*

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The relationship between total length (L, cm) and weight (W, kg) in the large northern pike (*Esox lucius*) was investigated using a dataset comprising 802 specimens weighing between 1 and 18.8 kg caught during fishing competitions. The applying the data to the equation $W = aL^b$, yielded $a = 6.648 \times 10^{-6}$ and $b = 3.0217$. Weight residuals fluctuate during the fishing season, likely due to conditions of the fish, probably associated with gonad development. Additionally, the equations including maximum girth (G, cm) — $W = aG^b$ and $W = a(L \times G)^b$ — were fitted using a subset of record fish totalling 186 specimens. Comparison of the equations $W = aL^b$ and $W = aG^b$ showed that weight was better described by maximum girth (AIC = 624.9) rather than by length (AIC = 690.0), but the best fit was obtained with the equation $W = a(L \times G)^b$ (AIC = 566.3) with the parameters $a = 2.426 \times 10^{-3}$ and $b = 0.974$.

Introduction

The northern pike (*Esox lucius*) is the most common large fish predator in Finland, occurring both in freshwater and coastal areas of the Baltic Sea (Rask *et al.* 2000). It is also a very important fish species in recreational fishing, totalling the highest landings (FGFRI 2011). The total recreational catches of northern pike in 2010 were 7833 tonnes; of which 18% were caught in the coastal areas of the Baltic Sea and 82% in freshwater (FGFRI 2011). More than 53% of these fish were caught with fishing tackle gear (FGFRI 2011). Currently, no fisheries management measures, such as size limits, are in place anywhere except the Åland islands.

Fishing clubs, organizations and magazines arrange different types of fishing competitions, lasting typically one calendar year. Catches are voluntarily submitted to these competitions following application rules, which generally include instructions on how the fish should be measured and weighed. In some competitions it is also required to submit additional information, like gear description, time and place, photos of the catch or even fish scales or cleithrum bones.

For the northern pike, the fishing season lasts for the whole year; classic angling tackle is used during the open-water period, whereas during winter when waters are ice-covered, fishing tackle is used. In Finland, inland waters are ice-covered from early December to late April in the south, and from late October to mid-June in the northernmost parts (Korhonen 2006). In the coastal areas of the Baltic Sea, the ice-cover period is shorter, varying from 50 days in the

south to 193 days in the north (Jevrejeva *et al.* 2004).

The main aim of this study was to define a relationship between length and weight for the large-sized northern pike, including also large individuals weighing more than 10 kg, which, in general, are not caught during normal field sampling with gill nets (Blahák & Prokeš 1998). Maximum girth was also considered in order to account for body shape. Weight residuals were also compared with the ordinal date, starting from 1 January in each year, because northern pikes are caught both before and after spawning. Northern pikes spawn in shallow waters shortly after the ice melts, when the water temperature reaches 8–14 °C (Casselman & Lewis 1996, Nilsson 2006). This usually takes place in late April or early May in the coastal areas of the Baltic Sea, and in early to late May in lakes and rivers in southern Finland. Weight loss after spawning should be similar to the loss of weight of the gonads. Female gonads weigh at maximum about 16% to 19% of total body weight, while male testes are about 4% of the total weight of the fish (Mann 1976, Bregazzi & Kennedy 1980). Thus, a clear pattern should exist, linking the relative weights on northern pikes and time of the year, with a marked loss of weight during spring months.

Material and methods

Several data sets from different sources were used in this study: a record of 247 trophy-sized fish reported to the Finnish Angling Association (SVK, http://www.vapaa-ajankalastaja.fi/), a record of catches from the Polytechnic Fishing Association (POKA, http://www.poka.fi/), and some personal records from members of the Finnish Pike Association (SHS, http://www.suomenhaukiseura.com/), the latter two totalling 555 specimens. The first data set included only fish above 10 kg, whereas the second and third data sets included 216 fish above 100 cm in total length (from the snout to the tip of the tail), commonly considered to be a trophy fish threshold in European northern pike fishing competitions. A subset of 186 individuals from the SVK data set, for which measures of maximum girth were also available, was chosen to estimate weight in relation to length and girth. These data sets contained fish caught in several-year long and recurring angler competitions. In the SVK data set, each fish captured was confirmed by a witnesses, landed fish were weighed/measured using certified scales and documented with pictures. The fish in the POKA and SHS data sets were only measured by anglers and subsequently released. There was no information on gender in any of the data sets analysed.

The relationship between total length (L, cm) and weight (W, kg):

$$W = aL^b, \quad (1)$$

was first tested using a data set including all available data (SVK and POKA data sets, 802 samples in total) and fitted using a NLMIXED procedure without random variables and specifying a normal distribution for weight (SAS 2009). Weight residuals and AIC values were then extracted for further analysis. To evaluate the possible effects of gonad weights, we compared weight residuals with the ordinal date, based on the assumption that gonad weight loss would occur after spawning and that spawning would occur in a limited time window.

The Loess smoothing procedure (Cleveland & Devlin 1988) was used to evaluate the relationships between length–weight residuals and date. It is based on a local regression technique in which i least-square regressions are fitted for neighbourhoods centred on a predictor value x_i, where data are weighted as an increasing function of their proximity to x_i. A smoothing parameter determines the neighbourhood size used and here it was chosen objectively using an automatic selection criterion based on the unbiased selection criterion AICc (Hurvich & Tsai 1989, SAS 2009).

A weight estimation method was subsequently tested on a subset of 186 trophy-sized (> 10 kg) fish for which accurate measurements of length, maximum girth and weight were available (LGW subset). The relationships between maximum girth (G, cm) and weight:

$$W = aG^b, \quad (2)$$

and between weight and a combination of length and maximum girth:

$$W = a(L \times G)^b \quad (3)$$

were tested. Equation 3 had previously been tested for a closely related species, the muskie (*Esox masquinongy*), and was fitted to a dataset of trophy-sized fish (Casselman & Crossman 1986).

Equations 2 and 3 were then fitted similarly to Eq. 1 (SAS 2009). AIC values were used as an estimation criterion to compare the gain in adding a further variable to the equation.

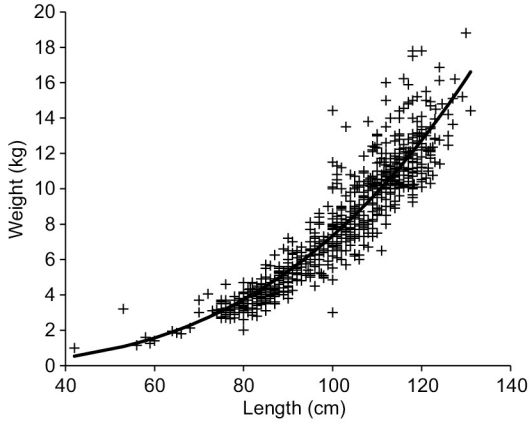

Fig. 1. Relationship between length and weight in large-sized northern pike (n = 802).

Results

The size range of analysed northern pikes was substantial; weights ranged from 1 to 18.8 kg and total lengths from 42 to 131 cm (Table 1). The relationship between weight and length (Eq. 1) was analysed and the values of 6.648×10^{-6} for a and 3.0217 for b were obtained (Fig. 1). Some specimens in our sample could be considered very odd: for example there were individuals about 100 cm in total length whose weight varied from 3 to more than 14 kg (Fig. 1). No measurements, however, were removed as these weights, albeit unusual, are entirely possible for starving to overfed fish, respectively.

Part of the weight variation was connected to dates when the fish were caught. Residual weights were on average slightly higher than would be expected based on the lengths during the spring, they were then lower during the summer months, and they rose again during the autumn (Fig. 2). More fish were caught during spring and autumn, which probably resulted from higher fishing effort. Unfortunately, fishing effort was not included in the analysis.

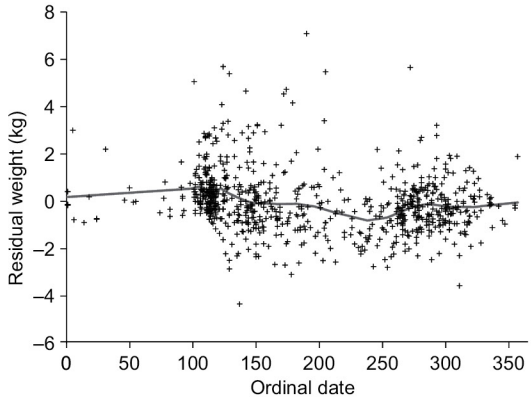

Fig. 2. Weight residuals from the relationship between length and weight (Eq. 1) against ordinal date number when northern pikes were caught. The line is based on the Loess smoothing procedure.

In the SVK data set, maximum girths of 186 fish — all over 10 kg — were measured. Fitting of Eqs. 1 and 2 to the SVK dataset showed that girth provided a better fit than length when analysed separately (Table 2). This is also evident

Table 1. Lengths and weights of northern pikes in different datasets.

Dataset	Mean weight (kg) (min–max)	Mean length (cm) (min–max)	n
SVK	11.8 (10–18.8)	115.1 (100–131)	247
POKA + SHS	6.2 (1–14)	93.7 (42–123)	555
LGW subset of SVK	11.8 (10–18.8)	115.5 (100–131)	186
All data	7.9 (1–18.8)	100.3 (42–131)	802

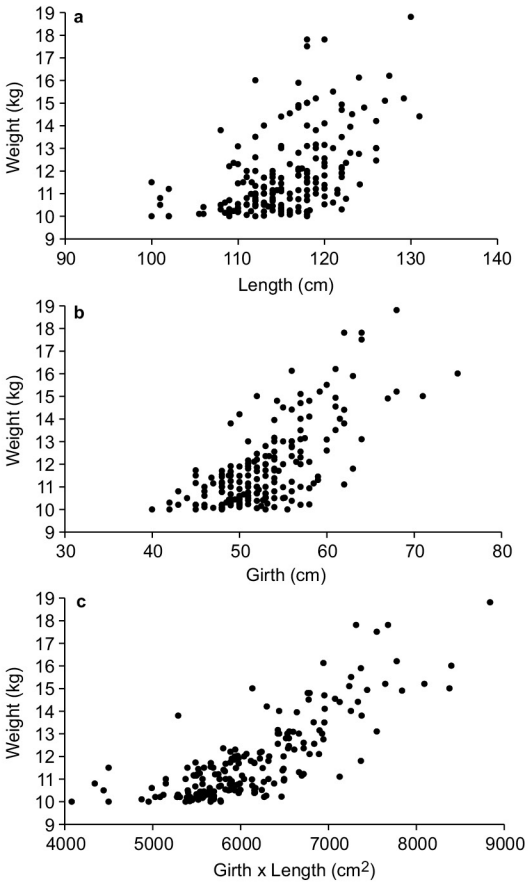

Fig. 3. (**a**) Length, (**b**) maximum girth and (**c**) maximum girth × length in relation to weight in large northern pikes (n = 186).

when girth is plotted against weight (Fig. 3). However, the best fit was obtained with Eq. 3 using both length and girth of pikes, yielding values of 2.426×10^{-3} for a and 0.974 for b (Table 2). In both models, however, the parameter a was not significant ($p > 0.5$), likely because the analyses lacked small sized fish.

Discussion

The basic model of the length–weight relationship had difficulties in correctly describing the weights of large northern pikes, especially those that were more than 14 kg, being heavier than expected based on their lengths. The most obvious reason for this could be overestimation of weight by fishermen (Blahák & Prokeš 1998) caused by intentional weight exaggeration or unintentional measurement errors (e.g. due to imprecise scales or length measurements). Our SVK data set comprising the largest northern pikes, however, consisted of the fish that were weighed on certified scales and whose total lengths were measured precisely as requested by the competition rules. The POKA and SHS data sets on the other hand were potentially more prone to measurements errors, given different scales used and potential cheating that is involved in voluntary reporting of angling catches. In general, weight rather than length measurements should be more prone to errors due to scale inaccuracies.

This relationship when applied to the whole dataset did not appear to be able to describe the whole size range of analysed pikes. Very likely, this was a direct result of variability in body shapes of large northern pikes but two other factors could also play a role. Differences in stomach content (particle size/density) and gonad weight could explain weight variability in otherwise similar fish. Such factors are not easily treated in statistical analysis and cannot always be completely accounted for without gutting the fish. While gutted weight would yield lower variation in weights and allow for the exclusion of these factors, such data were not available in this study because most recreational catches (including those culled) are measured before gutting.

Table 2. Parameters a and b in the length–weight relationship (Eq. 1) for the whole dataset, and comparisons of AIC values and parameters a and b for Eqs. 1, 2 and 3 in a subset of data in which maximum girth was measured. Smaller AIC values indicate a better fit (n/a = not applicable).

Dataset	Relationship	a	b	AIC value	ΔAIC	n
SVK + POKA + SHS	LW (Eq. 1)	6.648×10^{-6}	3.0217	2678.7	n/a	802
LGW subset	LW (Eq. 1)	0.004859	1.6417	690.0	0	186
LGW subset	GW (Eq. 2)	0.204450	1.0224	624.9	–65.1	186
LGW subset	LGW (Eq. 3)	0.002426	0.9739	566.3	–123.7	186

To accommodate for gonad weight we plotted weight residuals against the ordinal date number. This analysis showed a decrease in weight of ca. 10% (mean body weight ~10 kg) during spring, which is consistent with previous estimates of relative gonad weight (Frost & Kipling 1967) and spawning times. This also indicates that, in future analyses, sex should be taken into account as it could be an important factor accounting for the variation.

Similarly, a comparison of residuals *versus* weight showed that length alone may not be a reliable predictor of body weight, especially for large northern pikes. A better description could be achieved using maximum girth, which contains information on body conditions and/or stomach contents. Also, using more than one variable related to body shape improved the overall results as it yields lower AIC values and smaller residuals.

The length–weight–girth relationship presented by Casselman and Crossman (1986) for the muskie seems to be usable also for the northern pike. It was not possible to determine whether differences between parameters calculated in Casselman and Crossman (1986; $a = 4.18 \times 10^{-5}$ and $b = 1.441$) and those calculated by us are a direct result of differences in body proportions between the two species. Given the similarity of the constants, a data-set related effect cannot be excluded.

FishBase (www.fishbase.org) lists parameters of length–weight relationships for 80 populations of the northern pike. The parameters estimated by us using Eq. 1 were not substantially different from those in FishBase based on larger pikes (41 populations, total length range: 3.2–110 cm): $a = 0.007$ (in grams) and $b = 3.0216$ in our study, and $a = 0.001$–0.021 and $b = 2.723$–3.411 (min–max) in FishBase. Therefore, on average, large specimens do not necessarily diverge from the length–weight relationship estimated based on smaller individuals. However, according to our data, weight seems to vary more in large pikes (> 100 cm TL) than in smaller ones.

Since measuring a precise weight (or gutted weight) of a fish in the field conditions may be difficult and prone to errors, weight assessment using total length and maximum girth measurements seems a viable approach.

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