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Growth and whole body composition of lake trout (*Salvelinus namaycush*), brook trout (*Salvelinus fontinalis*) and their hybrid, F_1 splake (*Salvelinus namaycush* × *Salvelinus fontinalis*), from first–feeding to 16 weeks post first-feeding

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Abstract

Lake trout (*Salvelinus namaycush*), brook trout (*Salvelinus fontinalis*) and their hybrid, F_1 splake (*S. namaycush* × *S. fontinalis*) account for approximately 80% of total fish stocked for lake rehabilitation in Ontario. Yet, little information exists in the literature on the patterns of growth and whole body composition for these species under hatchery conditions. Such information may be useful for the development of feed requirement and waste output models for these fish species. Growth and whole body composition of lake trout, brook trout and F_1 splake (initial body weight ca. 0.2 g) were monitored from first-feeding to 16 weeks post first-feeding. Fish were reared separately, in fry troughs, at ambient water temperature (8 °C) and fed salmonid starter feeds (ca. 53% crude protein, 17% lipid) in excess. Live body weight was determined every 28 days and whole body samples taken every 28 days for analysis of proximate composition. Final body weights were 2.5 ± 0.01, 3.3 ± 0.02, and 4.1 ± 0.03 g for lake trout, brook trout and F_1 splake, respectively. Final whole body moisture, crude protein, lipid, ash and phosphorus contents were 80 ± 0.7, 14 ± 0.3, 4 ± 0.7, 2 ± 0.06 and 0.2 ± 0.01 percent for lake trout, brook trout and F_1 splake, respectively. Changes in whole body contents (absolute basis, g g fish^{-1}) with increasing body weight were best described by a series of linear ($R^2 \geq 0.98$) equations. This data can now be used to modify existing feed requirement and waste outputs models; improving their applicability to stocks of lake trout, brook trout and F_1 splake.

Keywords: Lake trout; Brook trout; Splake; Growth pattern; Whole body composition

1. Introduction

Lake trout (*Salvelinus namaycush*), brook trout (*Salvelinus fontinalis*) and their hybrid, F_1 splake (*S. namaycush* ♀ × *S. fontinalis* ♂) account for about 80%

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Table 1
Proximate composition of diets (as fed basis)

Composition	Nutra Mash	Purina HiPro	MNR98-HS
Dry matter (%)	95.3	93.1	92.5
Crude protein (%)	52.5	54.1	53.0
Lipid (%)	17.1	17.0	16.1
Ash (%)	9.1	10.9	9.1
Nitrogen-free extract (%)[a]	21.3	18.1	21.8
Phosphorus (%)	1.5	1.7	2.0
Gross energy (MJ kg^{-1})	22.2	21.2	21.2

[a] Nitrogen-free extract (%) = 100 − (Crude Protein (%) − Lipid (%) − Ash (%)).

of total fish stocked in lake rehabilitation efforts of many governmental fish hatcheries in Ontario (Kerr, 2000a,b; Kerr and Lasenby, 2001). Little information exists in the literature, however, on growth patterns and whole body composition for these species under hatchery conditions, especially from first-feeding to the body weights at which they are typically stocked (3–60 g) (Sadler et al., 1986). Information on growth patterns and whole body composition could be useful for the development of bioenergetics, feed requirement, and waste output models for these fish species (Cho and Bureau, 1998). The growth and whole body composition of lake trout, brook trout and F_1 splake were monitored during the initial 16 weeks of growth following first-feeding. This 'early rearing' growth trial was exploratory in nature and provides new information on the patterns of growth and nutrient deposition in lake trout, brook trout and F_1 splake.

2. Materials and methods

2.1. Eggs and incubation

Six thousand eyed-eggs per species, lake trout (Killala Lake strain), brook trout (Hills Lake strain) and F_1 splake (Killala Lake × Hills Lake), were received from an Ontario Ministry of Natural Resources fish culture station (Englehart, Ontario,

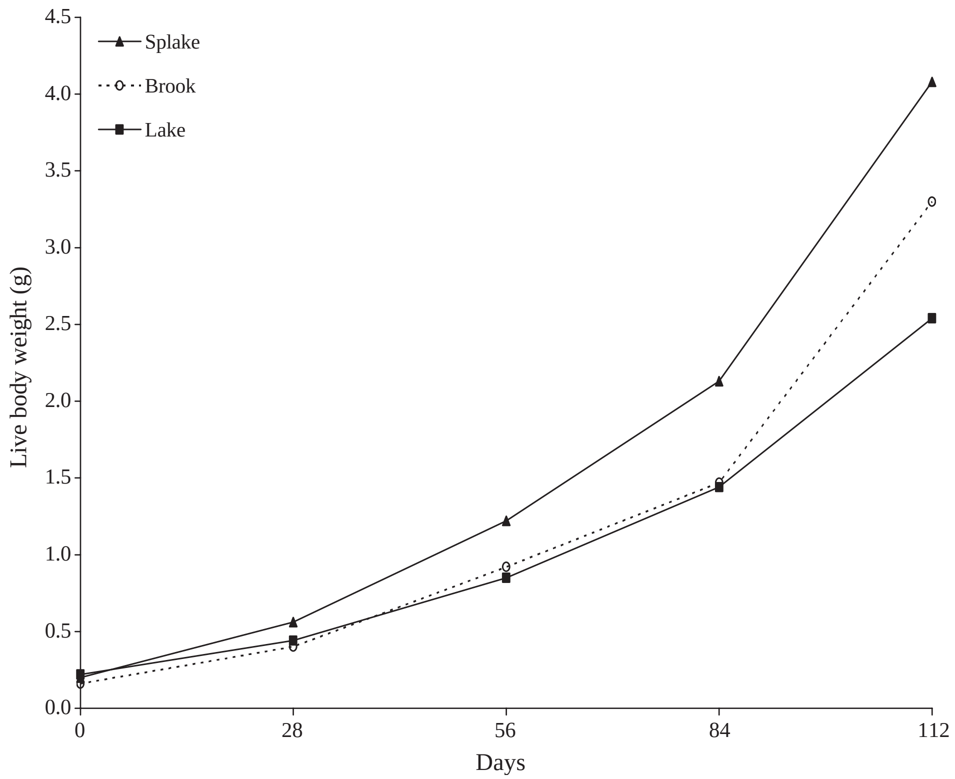

Fig. 1. Growth curves of lake trout, brook trout and F_1 splake from first-feeding to 16 weeks post first-feeding.

Table 2
Initial (IBW) and final (FBW) body weights, weight gain and thermal-unit growth coefficient (TGC) growth rates of lake trout, brook trout and F_1 splake from first-feeding to 16 weeks post first-feeding; mean ± S.D.

	IBW (g)	FBW (g)	Weight gain (g)	TGC
Lake trout	0.22 ± 0.00	2.54 ± 0.01	2.32 ± 0.01	0.086
Brook trout	0.16 ± 0.00	3.30 ± 0.02	3.14 ± 0.01	0.107
F_1 splake	0.20 ± 0.01	4.08 ± 0.03	3.88 ± 0.02	0.115

Canada) on 21 November, 2000. Eggs of each species were transferred to individual trays of a Heath Vertical Incubation System (Marisource, Tacoma, WA, USA). Eggs were incubated at ambient water temperature (8.7 ± 0.3 °C) and supplied with filtered (50 μm cartridge filter, Fish Farm Supply, Elmira, Ontario, Canada), sterilised (LifeGard QL25 UV Sterilizer, Rainbow Plastics, El Monte, CA, USA) well water. The relative percentage of hatched eggs was estimated and dead eggs were removed on a daily basis.

2.2. Fish, rearing conditions and diets

Once approximately 50% of the eggs of each species had hatched, eggs and sac-fry were moved to 130 L trough and basket up-welling incubators for completion of hatching. At the completion of hatching, baskets were removed from troughs and sac-fry were reared in 130 L, individually aerated (DO = 9.3 ± 0.6 mg L^{-1}, mean ± S.D.), fry troughs. Troughs were continuously supplied with flow-through well water (15 L min^{-1}) at ambient temperature (7.9 ± 0.8 °C, mean ± S.D.). Mean total ammonia, nitrate and nitrite levels were 0.2 ± 01, 08 ± 0.6 and <0.1 mg L^{-1} (mean ± S.D.), respectively. When the fish showed increased activity commercial starter feeds (Table 1) were supplied daily to monitor feeding response. Brook trout fry, being the smallest, were supplied with a mash (<0.5 mm particle size) starter feed (53% CP, 22 MJ kg^{-1} gross energy (GE); Nutra Mash, Moore-Clark, St. Andrews, New Brunswick). Lake trout and splake, being larger than brook trout, were supplied with 0.5 mm starter feed (54% CP, 21 MJ kg^{-1} GE; Purina HiPro, Purina Mills LLC, St. Louis, Missouri). Once a few fish were feeding, they were hand fed several times a day until all fish started feeding, at which time feed was supplied between 0800 and 2000 h, in excess, using automated 12-h belt feeders (Fish Farm Supply Co., Elmira, Ontario). As fish size increased, feed size was increased from mash to 0.5 mm for the brook trout, and then to a 0.7 mm MNR98-HS starter feed (53% CP, 21 MJ kg^{-1} GE; manufactured by EWOS Canada LTD., Surrey, BC, Canada) for all fish for the remainder of the early rearing period.

2.3. Sampling

The onset of feeding (first-feeding) marked the start of the 16-week early rearing trial. Live weight of the fish was determined every 28 days from the mean of eight grab samples each comprised of at least 30 fish. Temperature was recorded daily and the degree-day used to describe timing of hatching and feeding, was calculated as follows:

$$\sum \text{number of days} \times \text{mean daily temperature.}$$

Growth rate of the fish was calculated using the thermal-unit growth coefficient (TGC) method, modified from Iwama and Tautz (1981) by Cho (1990), in which:

$$\mathrm{TGC} = \left[\left(\mathrm{FBW}^{1/3} - \mathrm{IBW}^{1/3}\right) / \sum (\mathrm{T} \times \mathrm{D})\right] \times 100$$

where FBW = final body weight; IBW = initial body weight; T = water temperature, °C; D = number of days. Whole body samples, representing at least 100 g of biomass (wet weight basis), were taken at the

Table 3
Body composition of lake trout, brook trout and F_1 splake from first-feeding to 112 days post first-feeding

	Day	Body weight (g)	% H_2O	% CP	% Lipid	% Ash	% P
Lake trout	0	0.22	84.97	11.49	2.43	1.38	0.27
	28	0.44	84.90	11.44	2.18	1.51	0.27
	56	0.85	82.20	13.08	3.00	1.84	0.34
	84	1.44	81.19	13.97	3.33	1.94	0.37
	112	2.54	80.33	14.27	3.62	2.09	0.41
Book trout	0	0.16	86.55	9.84	2.36	1.26	0.21
	28	0.40	85.71	10.34	2.62	1.42	0.24
	56	0.92	83.04	11.92	3.04	1.70	0.33
	84	1.47	81.95	13.02	3.10	1.94	0.36
	112	3.30	80.05	13.80	4.19	2.09	0.40
F_1 splake	0	0.20	84.66	11.15	2.96	1.21	0.28
	28	0.56	84.03	11.40	3.03	1.44	0.33
	56	1.22	81.77	12.35	4.09	1.67	0.37
	84	2.13	80.55	13.74	4.13	1.74	0.40
	112	4.08	78.82	14.46	5.09	1.97	0.43

initiation of the trial and every 28 days thereafter for each species. Whole body samples were autoclaved for 30 min at 110 °C, ground to slurry, freeze-dried, reground, sieved and stored at −20 °C until analysis.

2.4. Proximate analysis

Diet and whole body samples were analyzed in duplicate for dry matter (DM) and ash according to AOAC (1995), for crude protein (CP) (% Nitrogen × 6.25) using a Kjeltech auto analyzer (Model # 1030, Tecator, Höganäs, Sweden), for lipid using method of Bligh and Dyer (1959), for gross energy (GE) using an automatic bomb calorimeter (Parr 1271, Parr Instruments, Moline, Illinois) and for phosphorus (P) using the method of Heinonen and Lahti (1981).

2.5. Statistical analysis

Linear regression analysis of whole body contents was performed using the SAS general linear model (GLM) procedure (SAS 1999, SAS Institute INC.)

$$Y_i = \alpha + \beta^* X_i + \epsilon_i$$

where α = intercept, Y_i = ith observation of dependent variable, β = regression coefficient of the dependent variable, X_i = ith observation of the independent variable, ϵ_i = random error.

3. Results

3.1. Hatching and first-feeding

Lake trout were the first species to reach 50% hatch and be transferred to the trough and basket incubators. Compared to lake trout hatch (degree-day 0), the brook trout and F_1 splake achieved 50% hatch on degree-days 35 and 61, respectively. First-feeding refers to the day on which at least 50% of the fish in a species showed feeding activity. Lake trout first-

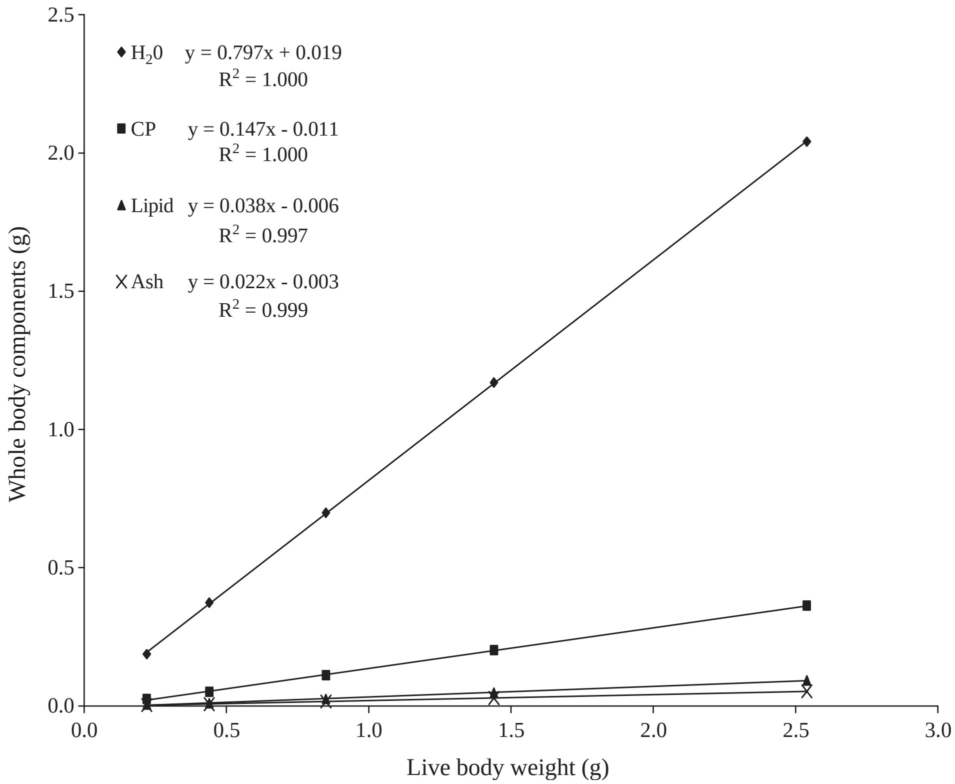

Fig. 2. Absolute whole body contents of lake trout from first-feeding to 16 weeks post first-feeding.

feeding was observed on degree-day 216, brook trout on degree-day 248 and F_1 splake on degree-day 280. By degree-day 360, all fish were feeding and yolk sacks were no longer visible. This day was chosen as day 0 of the 112-day early rearing growth period and sampling was initiated as described previously.

3.2. Growth

Initial body weights were 0.22 ± 0.00, 0.16 ± 0.00 and 0.20 ± 0.01 g for lake trout, brook trout and F_1 splake, respectively. The growth rate of F_1 splake was higher than lake trout and brook trout from the onset of first-feeding (Fig. 1). The final body weights, gain and TGC of the three species for the 112-day period are presented in Table 2. The growth rate of lake trout and brook trout was similar during the first 84 days of growth; TGC of 0.095 and 0.084, respectively. It is evident from Fig. 1 that the growth rate of brook trout from days 84 to 112 increased relative to that of lake trout. The TGC for brook trout during this period was 0.138 vs. 0.093 for lake trout. What is not clear from Fig. 1 is that brook trout growth rate exceeded that of F_1 splake (TGC = 0.122) during this period. Over the 112-day trial however, splake had the highest growth rate and weight gain, brook trout intermediate and lake trout the lowest (Table 2).

3.3. Whole body composition

Whole body moisture, CP, lipid, ash and P contents in lake trout, brook trout and F_1 splake are presented in Table 3. Moisture represented the highest percentage of the whole body at 80% but decreased as the body weight of lake trout, brook trout and F_1 splake increased. All remaining contents increased as the live weight of the three groups increased. Crude protein represented 10–15%, lipid 2–5%, ash 1–2% and P less than 0.5% of the fish.

Moisture, CP, lipid, ash and P contents were examined on an absolute basis ($g \cdot g\ fish^{-1}$). Analysis

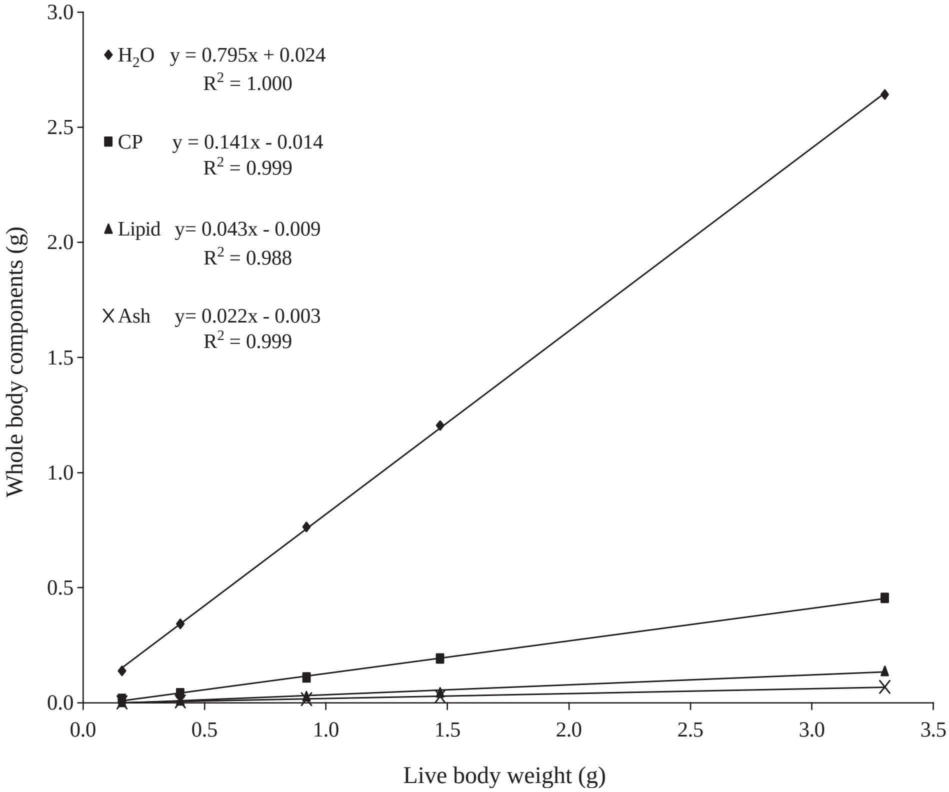

Fig. 3. Absolute whole body contents of brook trout from first-feeding to 16 weeks post first-feeding.

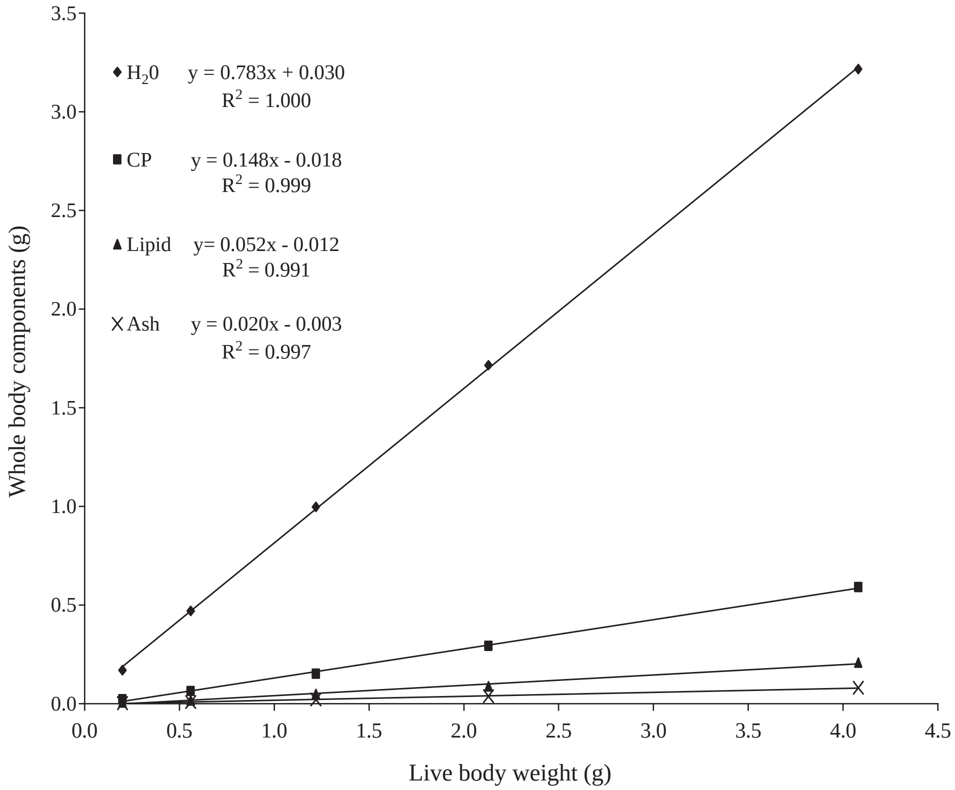

Fig. 4. Absolute whole body contents of F_1 splake from first-feeding to 16 weeks post first-feeding.

revealed a linear (R^2>0.98) increase in water, CP, lipid and ash contents with an increase in body weight, for lake trout (Fig. 2), brook trout (Fig. 3) and F_1 splake (Fig. 4). A linear (R^2>0.99) relationship was also found for P content of all species; for clarity P content is presented in a separate figure (Fig. 5). The patterns of moisture, CP, lipid, ash and P deposition in lake trout, brook trout and F_1 splake were ca. 0.80, 0.15, 0.04 0.02 and 0.004 g g fish^{-1}, respectively. Gross energy content was found to increase as body weight increased and was best described using separate non linear equations for each species (Fig. 6). Gross energy content was highest in F_1 splake, lower in lake trout and lowest in brook trout.

4. Discussion

Lake trout were the first species to hatch and start feeding. Lake trout gained the least amount of body weight, however, because of a relatively slow growth rate (Table 2). During the first 84 days, lake trout and brook trout grew at relatively similar rates, however, an increase in the growth rate of brook trout during the final 28 days meant that, overall, brook trout growth rate and weight gain was higher than that of lake trout. F_1 splake had the highest growth rate and body weight despite being last to hatch and start feeding. These results are contrary to the results of Sadler et al. (1986) who found that, over a 31-day period at an initial stocking density of 0.6 fish/L, lake trout (IBW=3.3 g) grew faster than brook trout (IBW=2.1 g) at 10 °C and that F_1 splake (IBW=2.9 g) grew at a rate between that of lake trout and brook trout.

Although no published studies were found that expressed the growth of lake trout, brook trout and F_1 splake using TGC, calculation of TGC growth coefficients were performed for the lake trout data of Dwyer et al. (1981) and Edsall and Cleland (2000) and for the brook trout data of Hokanson et al. (1973) and Dwyer et al. (1983) (Table 4). The

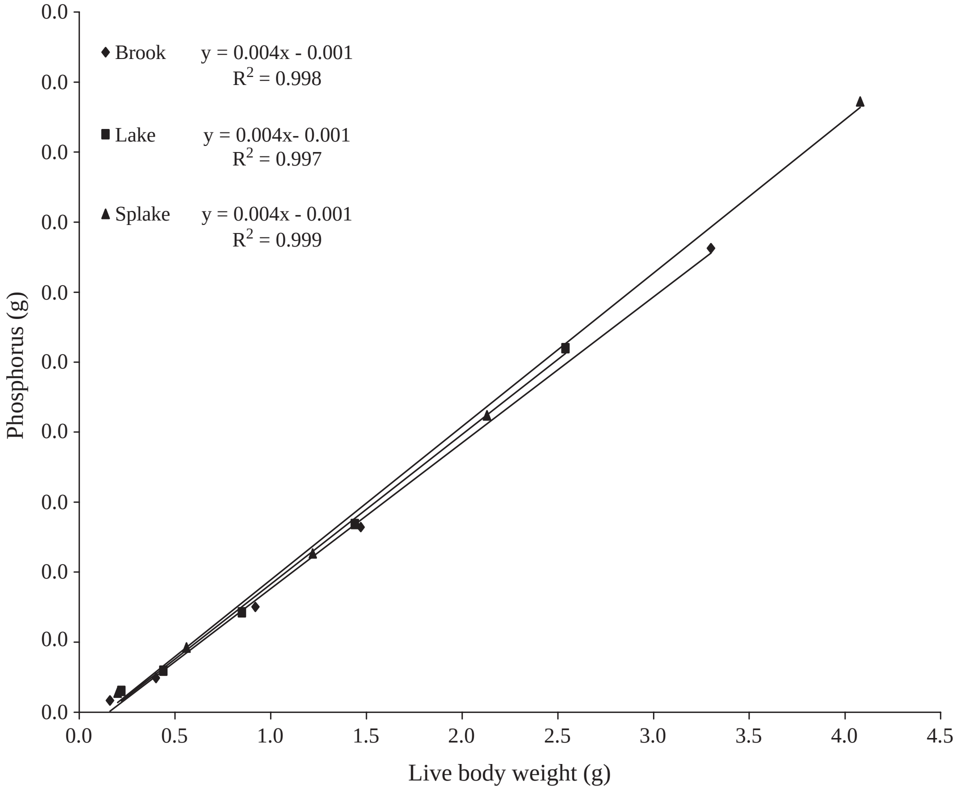

Fig. 5. Absolute phosphorus contents of lake trout, brook trout and F_1 splake from first-feeding to 16 weeks post first-feeding.

calculated TGC coefficients indicated that the growth rates of lake trout and brook trout from the present study fell within the range of growth rates found in previous studies with lake trout and brook trout. Also, it appears that the growth rates of lake trout and brook trout from the most recent studies (Edsall and Cleland, 2000 TGC = 0.089 and Dwyer et al., 1983 0.101, respectively) were closer to the growth rates of lake trout and brook trout in the present study (TGC = 0.086 and 0.107, respectively).

On a percentage wet weight basis, certain general trends were observed for the changes in whole body contents. Moisture content was found to decrease, while CP, lipid, ash and P contents increased as weight of lake trout, brook trout and F_1 splake increased. The trends in moisture and lipid content of the lake trout in the present study were in agreement with the findings of O'Connor et al. (1981) who found that moisture content decreased while lipid content increased as body weight increased for lake trout (IBW 26–37 g). Ash content, which was found to increase with body weight in the present study, was found by O'Connor et al. (1981) to both increase (1970 trial) and decrease (1972 trial) as body weight increased. O'Connor et al. (1981) offered no plausible explanation for the discrepancy. Neither CP nor P contents were analyzed in the study by O'Connor et al. (1981). Although the relative percentages of moisture, lipid and ash in the study by O'Connor et al. (1981) were made without reference to fish size, O'Connor et al. (1981) stated that the changes in whole body contents of lake trout were a function of body weight, which appears to be the case in the present study.

Changes in whole body contents of brook trout were similar to those observed by Phillips et al. (1960) who found that the moisture content of brook trout decreased, while crude protein, lipid and ash content increased as body weight increased from 2 to 9 g. Also, at approximately 3 g live-weight the relative amounts of moisture, CP and ash were similar to those found in the present study (78, 14 and 2%, respectively). Lipid content was slightly

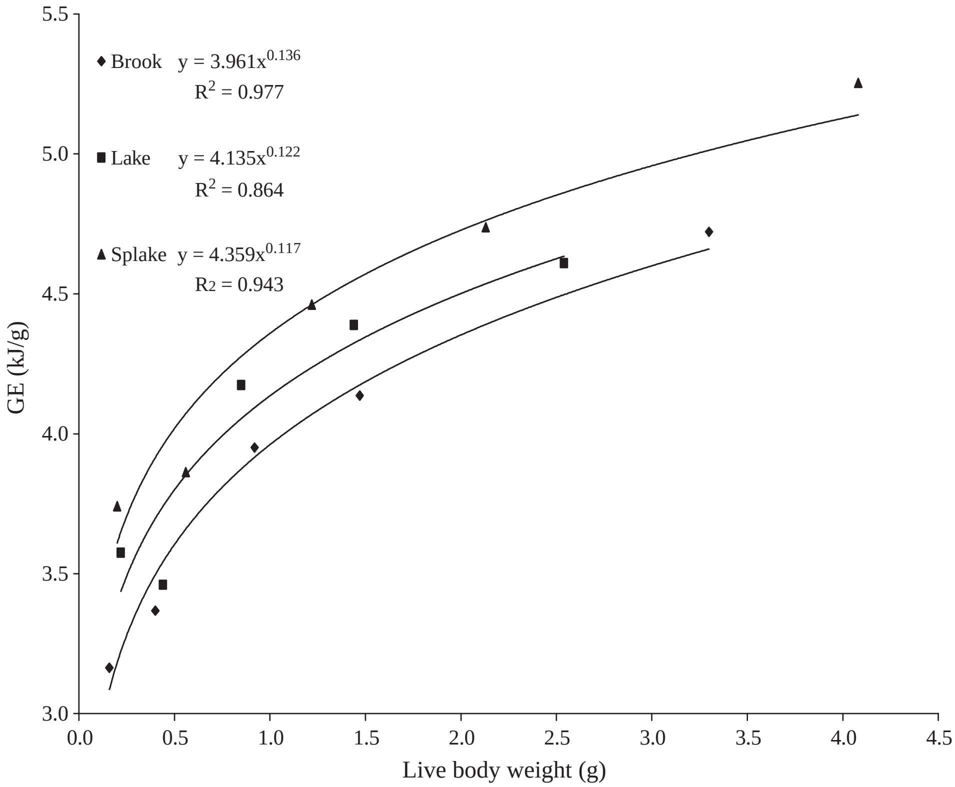

Fig. 6. Gross energy contents of lake trout, brook trout and F_1 splake from first-feeding to 16 weeks post first-feeding.

higher (5.5%) than in the present study (ca. 4%); a small, perhaps negligible difference that may be attributed to differences in lipid content of the diet between the two studies (Shearer, 1994). Phosphorus contents were not analyzed in the study by Phillips et al. (1960). Similar to lake trout, it appears that the changes in moisture, CP, ash P contents of brook trout are a function of body weight, while lipid content appears to be a function of body weight but may be simultaneously affected by lipid content of the diet.

Whether or not the results for F_1 splake in the present study are comparable to results from other studies remains a question since no study was found that examined the whole body composition of F_1 splake over time. Since the results of lake trout and brook trout from the present study were, however, in agreement with results from published sources, the results of the F_1 splake should also be considered reliable.

The expression of whole body contents on an absolute basis was suggested by Shearer (1994) as a method of better examining the effect of exogenous factors on whole body composition. Results of the present study indicated that the changes in absolute whole body contents were similar between species and increased in a linear fashion as a function of body size. Absolute whole body contents were calculated for the brook trout reared at 8 °C in a study by Phillips et al. (1960). These results were in general agreement with the results of the present study; indicating that increases in moisture, CP, lipid and ash contents were also linear ($R^2 > 0.97$) and functions of body weight. No published data with lake trout and F_1 splake was available for comparison.

Whole body energy content was found to vary between lake trout, brook trout and F_1 splake such that separate non-linear equations were needed to describe the pattern of whole body energy content of each species. The GE content of an organism depends

Table 4
Calculated TGC growth rates of lake trout and brook trout for the 16 week early rearing period, for lake trout published[a] data

Lake trout	TGC	Brook trout	TGC
This study	0.086	This study	0.107
Dwyer et al., 1981	0.111 ± 0.016[b]	Hokanson et al., 1973	0.065 ± 0.010[c]
Edsall and Cleland, 2000	0.089 ± 0.022[d]	Dwyer et al., 1983	0.101 ± 0.012[e]

[a] Dwyer et al. (1981) and Edsall and Cleland (2000) and for Brook Trout Data from Hokanson et al. (1973) and Dwyer et al. (1983).
[b] TGC (mean ± S.E.M.) calculated from six treatments: IBW = 0.85 g; FBW = 4.42–33.21 g; water temperatures of 4–19 °C; 140 days.
[c] TGC (mean ± S.E.M.) calculated from five treatments: IBW = 82.3 g; FBW = 156–223 g; water temperatures of 10–21 °C; 148 days.
[d] TGC (mean ± S.E.M.) calculated from four treatments: IBW = 0.44–0.63 g; FBW = 1.35–2.72 g; water temperatures of 5–18 °C; 47 days.
[e] TGC (mean ± S.E.M.) calculated from six treatments: IBW = 0.6 g; FBW = 1.5–33.5 g; water temperatures of 4–19 °C; 140 days.

on its carbohydrate, CP and lipid contents (Bureau et al., 2002). Carbohydrate, CP and lipid contain 17.2, 23.6 and 39.5 kJ g^{-1} GE, respectively. Since the carbohydrate content of fish is relatively small (Shearer, 1994) its contribution to the GE content of the whole body is negligible. The GE content of fish is, therefore, dependent on CP and lipid contents. In the present study, CP content was found to be similar for lake trout, brook trout and F_1 splake. It appears, therefore, that the GE contents of the lake trout, brook trout and splake were affected by the lipid content. Hence, F_1 splake which had the highest lipid content had the highest GE content; lake trout had and intermediate amount of lipid resulting in an intermediate GE content, while brook trout had the lowest lipid content which resulted in the lowest GE content.

5. Conclusions

When expressed on an absolute basis, the whole body contents of lake trout, brook trout and F_1 splake can be explained by simple linear equations that, except for lipid are independent of species. Such highly linear relationships between whole body contents and body weight bode well for the development of bioenergetics, feed requirement and waste output models, since key to the functionality of such models is their simplicity and applicability to many fish species. Gross energy content was, however, best described by species specific non-linear equations. This has consequences in the development of bioenergetics, feed requirement and waste output models; increasing the complexity of such models or resulting in the development of a model for each species. The information gathered in this trial can now be used to modify existing feed requirement and waste outputs models; improving their applicability to stocks of lake trout, brook trout and F_1 splake.

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References

AOAC, 1995. Official Methods of Analysis of AOAC International, 16th edition. Agricultural Chemicals, Contaminants, Drugs, vol. I. AOAC International, Arlington, VA.
Bligh, E.G., Dyer, W.J., 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol. 37, 911–917.
Bureau, D.P., Kaushik, S.J., Cho, C.Y., 2002. Bioenergetics. In: Halver, J.E., Hardy, R.W. (Eds.), Fish Nutrition. Academic Press, San Diego, CA, pp. 1–53.
Cho, C.Y., 1990. Fish nutrition, feeds and feeding: with special emphasis on salmonid aquaculture. Feed Rev. Int. 6, 333–357.
Cho, C.Y., Bureau, D.P., 1998. Development of bioenergetic models and the Fish-PrFEQ software to estimate production, feeding ration and waste output in aquaculture. Aquat. Living Resour. 11, 199–210.
Dwyer, W.P., Smith, C.E., Piper, R.G., 1981. Lake trout *Salvelinus namaycush* growth efficiency as affected by temperature. Dev. Fish Cult., Bozeman Inf. Leafl. 22, 1–18.
Dwyer, W.P., Smith, C.E., Piper, R.G., 1983. Brook trout growth efficiency as affected by temperature. Prog. Fish-Cult. 45, 161–163.
Edsall, T.A., Cleland, J., 2000. Optimum temperature for growth and preferred temperatures of age-0 lake trout. North Am. J. Fish. Manage. 20, 804–809.

Heinonen, J.K., Lahti, R.J., 1981. A new and convenient colorimetric determination of inorganic orthophosphate and its application to the assay of inorganic pyrophosphatase. Anal. Biochem. 113, 313–317.

Hokanson, K.E.F., McCormick, H.J., Jones, B.R., Tucker, J.H., 1973. Thermal requirements for maturation, spawning, and embryo survival of the brook trout, *Salvelinus fontinalis*. J. Fish. Res. Board Can. 30, 975–984.

Iwama, G.K., Tautz, A.F., 1981. A simple growth model for salmonids in hatcheries. Can. J. Fish. Aquat. Sci. 38, 649–656.

Kerr, S.J., 2000a. Brook trout stocking: an annotated bibliography and literature review with an emphasis on Ontario waters. Fish and Wildlife Branch, Ontario Ministry of Natural Resources. Peterborough, Ontario. http://www.mnr.gov.on.ca/MNR/pubs/brook_bio.pdf.

Kerr, S.J., 2000b. F_1 splake: an annotated bibliography and literature. Fish and Wildlife Branch, Ontario Ministry of Natural Resources. Peterborough, Ontario. http://www.mnr.gov.on.ca/MNR/pubs/splake_bio.pdf.

Kerr, S.J., Lasenby, T.A., 2001. Lake trout stocking in inland lakes: an annotated bibliography and literature review. Fish and Wildlife Branch, Ontario Ministry of Natural Resources, Peterborough, Ontario. http://www.mnr.gov.on.ca/MNR/pubs/LakeTrout_bibliog.pdf.

O'Connor, D.V., Rottiers, D.V., Berlin, W.H., 1981. Food consumption, growth rate, conversion efficiency, and proximate composition of yearling lake trout. Administrative Report No. 81-5, U.S. Fish and Wildlife Service. 21 pp.

Phillips Jr., A.M., Livingston, D.L., Dumas, R.F., 1960. Effect of starvation and feeding on the chemical composition of brook trout. Prog. Fish-Cult. 22, 147–154.

Sadler, S.E., Friars, G.W., Ihssen, P.E., 1986. The influence of temperature and genotype on the growth rate of hatchery-reared salmonids. Can. J. Anim. Sci. 66, 599–606.

Shearer, K.D., 1994. Factors affecting the proximate composition of cultured fishes with emphasis on salmonids. Aquaculture 119, 63–88.