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Short communication

Lipid content in rainbow trout (*Oncorhynchus mykiss*) fry and parr reared in spawning tributaries of Lake Taupo, New Zealand

MICHEL DEDUAL
Department of Conservation
Private Bag, Turanga Place
Turangi, New Zealand
email: mdedual@doc.govt.nz

Abstract The total lipid content of fry (25–30 mm) and parr (55–110 mm) of rainbow trout (*Oncorhynchus mykiss* Richardson 1836) was measured in spring 1996 and 1997 and in autumn 1997 in six trout-rearing tributaries of Lake Taupo, New Zealand. The fat content of fry was variable between streams and some streams had a higher inter-annual variation than others. The fat content of parr was also variable among streams but no difference could be found between seasons. The streams that produced fry with high fat content did not always produce parr with high fat content.

Keywords fat content; fry; parr; rainbow trout; Taupo streams

INTRODUCTION

Lipids serve many roles in vertebrates, particularly as an energy source and as the main components of cellular membranes. Stored lipids are thought to be the main source of energy for fish during the winter starvation period (Black & Love 1997) and also during gonad development before reproduction (Shulman 1974; Rowe et al. 1991). Overwintering mortality is higher for young salmonids with low fat reserves (Gardiner & Geddes 1980; Toneys & Coble 1980; Elliott 1993) especially during the early part of winter (Smith & Griffith 1994). In fish stocked for mitigation purposes, the amount of energy reserves could be a crucial factor for survival in the natural environment. Burrows (1969) observed that the survival of stocked chinook salmon (*Oncorhynchus tshawytscha*) fingerlings to adulthood was correlated with energy reserves at time of release. Peterson (1973) also correlated higher adult returns with high lipid content in Atlantic salmon (*Salmo salar*) smolts at time of release.

A large number of nursery streams support the Taupo, New Zealand rainbow trout (*Oncorhynchus mykiss* Richardson 1836) fishery. These streams are different in their physical habitat, and probably in the quality and quantity of food they produce.

Juvenile trout in Taupo spend from a few months to more than a year in the nursery streams (Stephens 1989; Pitkethley 1990; Rosenau 1991) before moving downstream into the lake. The ultimate fate of these fish is currently unknown, but fat juveniles will have a better chance of survival in the lake than lean and moribund fish. Thus, we anticipate that streams contribute to the recruitment of adult trout in Lake Taupo not only by the number of juveniles they produce, but also by their quality (i.e., fat content).

The aims of the present study were to: (1) assess the total fat content of rainbow trout fry and parr in different streams; and (2) compare the amount of fat in juvenile trout before and after winter.

MATERIALS AND METHODS

Study site

Fry and parr were sampled in seven and six spawning streams respectively on the eastern shore of Lake Taupo (Fig. 1). Only the Hinemaiaia River has an artificial flow regime with three hydro-dams. All streams and rivers are fed principally by run-off, except the mainly spring-fed Waitahanui Stream. Environmental characteristics for each stream are summarised in Table 1.

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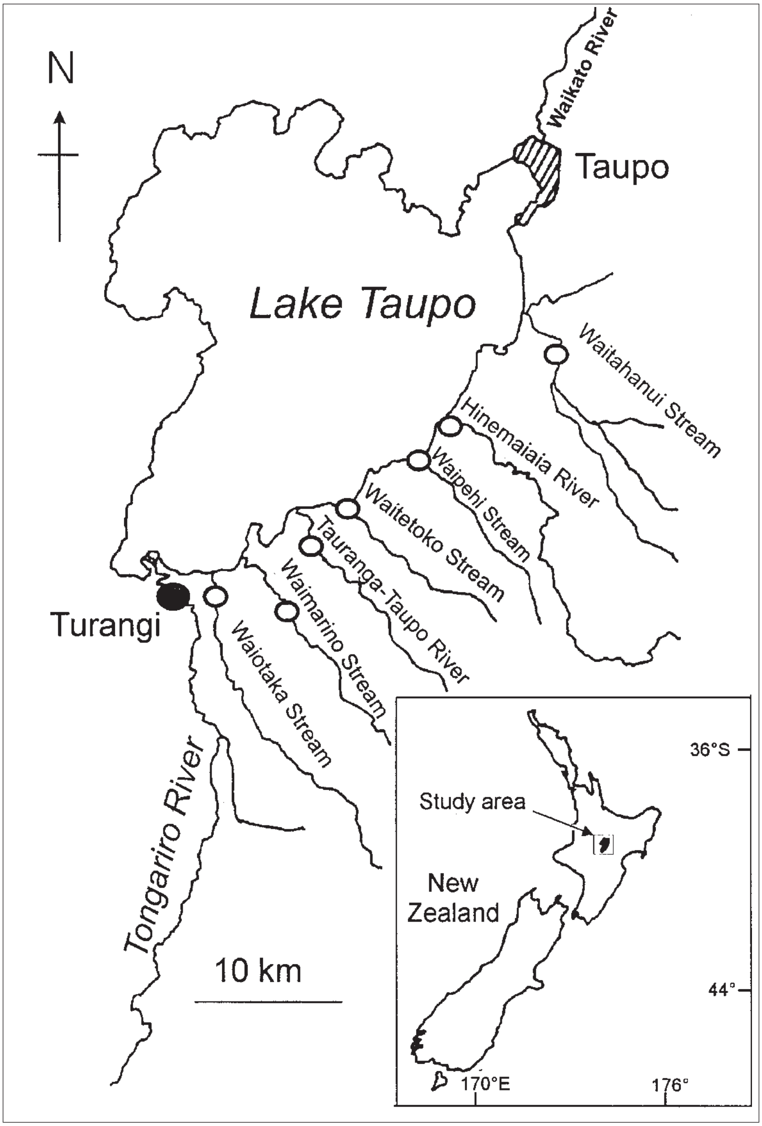

Fig. 1 Lake Taupo, North Island, New Zealand, showing the nursery streams where rainbow trout (*Oncorhynchus mykiss*) fry and parr were sampled (circles) in 1996 and 1997.

Table 1 Values of physico-chemical parameters of the streams where rainbow trout (*Oncorhynchus mykiss*) fry and parr were sampled for fat content measurements, eastern catchment of Lake Taupo, New Zealand, 1996–97. Values for conductivity, alkalinity, and calcium (Ca) concentration are expressed as average ±SD.

Stream	Catchment area (km^2)	Average flow (m^3 s^{-1})	Length (km)	Conductivity @ 25°C (mS m^{-1})	Alkalinity (g m^{-3})	Ca (g m^{-3})	*n*
Waitahanui	190	6.8	16.0	6.7 ± 0.3	26.6 ± 1.6	3.0 ± 0.1	24
Hinemaiaia	165	5.9	6.0	5.6 ± 0.6	23.5 ± 4.4	3.1 ± 0.5	24
Waipehi	26	0.4	0.8	6.4 ± 0.1	16.0 (*n* = 1)	3.5 (*n* = 1)	10
Waitetoko	18	0.2	7.0	6.9 ± 1.0	17.0 (*n* = 2)	4.3 ± 0.3	11
Tauranga-Taupo	216	8.7	20.0	4.9 ± 0.6	20.5 ± 3.0	3.5 ± 0.4	24
Waimarino	79	3.1	13.0	4.6 ± 0.2	10.0 ± 2.0	4.5 ± 0.2	4
Waiotaka	70	2.4	21.0	5.0 ± 0.3	12.0 ± 1.2	4.1 ± 0.6	9

Fish sampling

Only fish between 25 and 30 mm total length (TL) were considered as fry. They were sampled on one occasion at each site during spring 1996 (6 November) and spring 1997 (31 October–7 November). Another sample was taken in the Waitahanui Stream in autumn 1997 (7 May).

Parr (50–110 mm TL) were sampled in spring at the same sites and on the same dates as fry. A sample was also taken at the same sites in autumn 1997 (7 May) to compare the fat content of the fish before and after winter. For this comparison only parr of similar sizes were used.

All fish were captured by electric fishing (Kainga EFM300). They were killed in benzocaine, rinsed, wrapped in plastic bags to avoid desiccation, and preserved on ice before being frozen at –16°C for laboratory analysis 2 weeks later.

Fat analysis

In the laboratory each fish was measured to the nearest mm (TL) and weighed to the nearest mg (W); fish condition (K) was calculated as:

$K = 100\ W/TL^3$

For analysis of fry fat content, 25 individuals were pooled to obtain c. 3 g of material. For the fat analysis of the parr, duplicates of each individual were analysed to provide a check on the methodology.

Fish bodies were ground into a homogenous mixture. The paste was weighed, hydrolysed in 4*N* hydrochloric acid, then filtered in a preweighed glass vial and extracted in petroleum spirit (boiling point 40–50°C) for total fat (ISO 1973). After evaporation of all solvent the glass vial was weighed again. Fat content was calculated as the difference between the weight of the vial before and after evaporation and expressed as percentage of body weight (wet weight). The fat measurements were carried out by the Meat Industry Research Institute of New Zealand (MIRINZ) in Hamilton.

Fat percentage data were normalised by arcsine transformations (Zar 1984). Differences in juvenile trout fat content between streams and seasons were tested by a 2-way analysis of variance using general linear model (GLM) procedure. Coefficient of variation (CV) was calculated as the quotient of standard deviation (SD) divided by the arithmetic mean expressed in percent. Relationships between fat content, fish length, and condition were explored by correlation analysis. Significance level was set at $P < 0.05$. All statistical analysis was carried out using SPSS software.

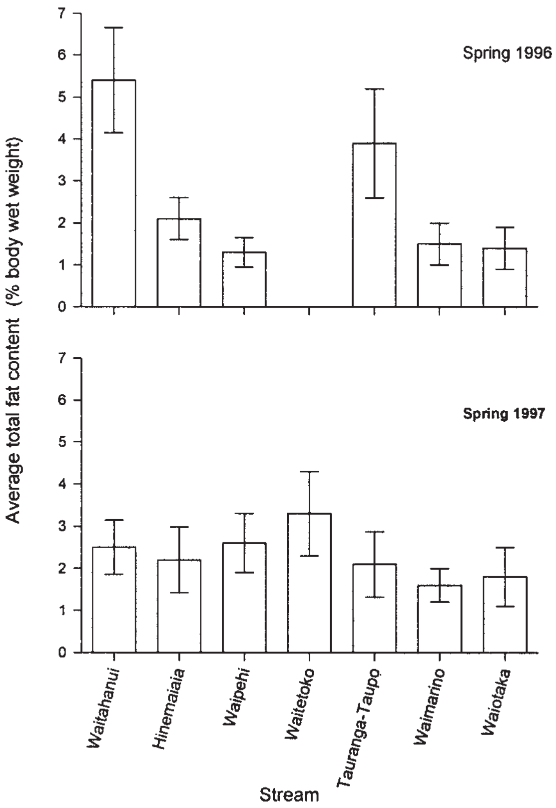

Fig. 2 Average fat content measured in 25 rainbow trout (*Oncorhynchus mykiss*) fry collected in Lake Taupo, New Zealand, tributaries in 1996 and 1997.

RESULTS

Fry fat content

The average fat content of fry sampled in spring 1996 was 2.3% and ranged from 1.3% in the Waipehi Stream to 5.4% in Waitahanui Stream (Fig. 2). During spring 1997 the average fat content was 2.2%, ranging from 1.6% in the Waimarino Stream to 3.3% in the Waitetoko Stream. No significant difference in average fat content was detected between spring 1996 and 1997 ($P = 0.92$). However, variability between streams was greater in 1997 (CV = 65%) than in 1996 (CV = 25%).

Fry caught in autumn 1997 in the Waitahanui Stream had a very low fat content (0.4%).

Parr fat content

During spring 1996 the fat content of parr averaged (±SD) 2.85 ± 0.89% but varied among streams (Fig. 3). Juvenile trout from Waimarino Stream had a

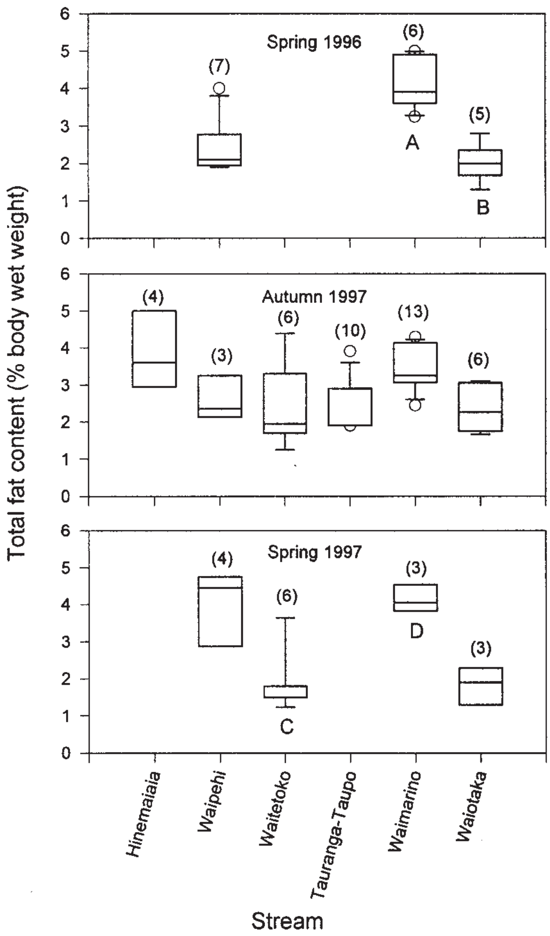

Fig. 3 Box-and-whisker plots of individual fat content measured in juvenile rainbow trout (*Oncorhynchus mykiss*) in Lake Taupo, New Zealand, tributaries in 1996 and 1997. Box gives the range of the middle 50% of the values, the horizontal line within the box represents the median. Whiskers indicate the range (10 and 90%), and the outliers are plotted as individual points. Boxes sharing different letter are significantly different (Mann-Whitney $P < 0.05$). Numbers in parentheses indicate the number of fat measurements.

higher ($P = 0.02$) fat content (4.1%) than the juvenile trout from the Waiotaka Stream (2.02%). Average fat content among the streams had a high CV (36%).

During autumn 1997 the average fat content of the parr was 2.91 ± 0.59%. No difference between streams was found in the fat content of the parr. Fat content in juveniles from all streams combined had a lower CV in autumn 1997 (22%) than in spring 1996.

In spring 1997 the average fat content peaked at 2.94 ± 1.06%. Juvenile trout in the Waimarino Stream had higher ($P = 0.05$) fat content (4.16%) than in the Waitetoko Stream (1.8%). CV of the average fat content among streams was 42%.

No significant difference in the average fat content could be detected in any stream between the three seasons sampled ($P = 0.06$).

Fat content was not correlated with length ($P = 0.86$), weight ($P = 0.97$), or condition ($P = 0.17$) of the parr.

DISCUSSION

Fry fat content

The fry fat contents measured in this study are similar to those measured by Corti (1950), who found 37-day-old hatchery rainbow trout had a fat content of 2%. Fry of that age reared at water temperature of 11 ± 0.5°C are c. 30 mm long (E. Cudby, Department of Conservation pers. comm.). Parker & Vanstone (1966) measured a total fat content varying from 2 to 6% of the body weight in pink salmon fry under 40 mm (TL).

The difference in fry fat content between streams indicates that the streams provide different conditions for the rearing of fry. During our study some streams like the Hinemaiaia River, the Waimarino, and the Waiotaka streams were consistent in the quality of the fry they produced, whereas the others showed a greater variability from one year to the next. For example, fry from the Waitahanui Stream and Tauranga-Taupo River had a higher fat content in spring 1996 than in spring 1997, compared with fry from the Waipehi Stream that had a higher fat content in 1997.

Most Taupo streams produce fry all year round (Department of Conservation unpubl. data), however, the low fat content of fry collected in the Waitahanui Stream in autumn 1997 can be expected to reduce their probability of survival over winter. Fry having such a low fat content can be described as "moribund" (*sensu* Elliott 1993) and are likely to be displaced downstream towards the lake. The fate of these fry in the lake is unknown and it remains to be demonstrated if these fish are important or not for the overall recruitment of adult trout in Lake Taupo.

Parr fat content

The variation in fat content of parr between the different streams and seasons indicates that the difference in rearing quality of the different streams also exists when the fish are larger than fry. The large variation in average fish fat content between streams measured in spring indicates that at this time of the year the streams differ in their rearing conditions. The Waimarino Stream illustrates how in spring a stream can provide "poor" conditions for fattening fry but "first-rate" conditions for fattening parr. However, in autumn it appears that most of the streams provide comparable and suitable rearing conditions.

Contrary to Cunjak (1988) we did not find any significant change between autumn and spring fat content. Winters in New Zealand latitudes are characterised by fluctuating water temperature and discharge, which necessitates continued activity by stream trout (Reimers 1963) and specialised behavioural patterns with continued feeding (Cunjak & Power 1986, 1987). The lack of difference in fat content between autumn and spring indicates that rearing conditions in Taupo streams do not deteriorate markedly throughout the year and that fish overwintering do not lose much condition during winter.

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