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# Effects of surgically implanted transmitters on swimming performance, food consumption and growth of wild Atlantic salmon parr

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Experiments were conducted on wild Atlantic salmon *Salmo salar* parr to determine the effect of surgically implanted dummy transmitters on swimming performance, food consumption and growth. Swimming performance of tagged fish (tag 1·7–3·7% of fish mass) was similar to that of control fish 1, 5 and 10 days after surgery. Negative effects on growth, however, were found up to day 36 of a 45 day experiment (tag 0·9–2·6% of fish mass). Consumption rates were similar between tagged and control fish and did not explain differences in growth.



Key words: Atlantic salmon; food consumption; growth; implanted transmitter; swimming performance.

## INTRODUCTION

Surgically implanted radio transmitters have been used to examine the movement and behaviour of Atlantic salmon *Salmo salar* L. adults (Begout-Anras *et al*., 2001), smolts (Aarestrup *et al*., 1999) and parr (Hiscock *et al*., 2002). Population inferences from data collected on tagged fish, however, assume that fish are unaffected by the transmitters.

Studies have indicated that swimming performance, feeding behaviour and growth of surgically tagged parr and smolts are similar to that of untagged controls (McCleave & Stred, 1975; Moore *et al*., 1990). These studies were conducted on hatchery-reared fish and the results for wild conspecifics may differ. Peake *et al*. (1997) studied the swimming performance of hatchery-reared and wild tagged Atlantic salmon smolts and found that only the wild tagged smolts were affected by the transmitter. Therefore, no assumptions could be made on the effects of surgically implanted transmitters on wild Atlantic salmon parr based on previous studies.

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The present study was conducted to examine the effect of surgically implanted dummy transmitters on the swimming performance, food consumption and growth of wild Atlantic salmon parr.

## MATERIALS AND METHODS

### FISH AND SURGICAL PROCEDURE

Atlantic salmon parr were collected from rivers on the Avalon Peninsula (47°5′ N; 53°12′ W), Newfoundland, Canada, with a backpack electrofisher (Smith-Root Model 12). Fish were transported to the laboratory (*c.* 1·5 h) and held in 1 $m^2$ holding tanks for 1 week prior to experimentation. Fish were fed chopped dew-worms *Lumbricus terrestris* daily to satiation during this period.

A surgical procedure similar to that of Adams *et al.* (1998) and Moore *et al.* (1990) was used to implant dummy transmitters (Lotek Wireless Inc., 7 × 12 mm, 0·75 g in air, 0·5 g in water, with a 28 cm whip antenna) into the peritoneal cavity of test fish. Fish were anaesthetized with clove oil (Anderson *et al.*, 1997) and placed ventral side up on a foam pad. The transmitter was inserted through a 10 mm incision on the mid-ventral line anterior to the pelvic girdle. The transmitter antenna was fed through a needle (Jelco; 18 G, 38 mm) inserted through the body wall *c.* 5 mm posterior and dorsal to the incision. The incision was closed with two sutures (USSC; 4-0 coated braided silk and C-13 needle). Surgery took *c.* 2–3 min, and during this time, water was intermittently poured over the fish's gills. Tagged fish were placed in recovery tanks until the effects of the anaesthetic disappeared.

### SWIMMING PERFORMANCE

Eighty fish were randomly selected and placed in one of four treatment groups. Three groups underwent surgical implantation of dummy transmitters and were placed individually in 76 l flow-through aquaria until testing. The fourth group had no procedure and was used as the control group (mean ± S.E., mass 29·2 ± 1·3 g, 142·6 ± 0·2 mm fork length, $L_F$). Fish were fed chopped worms daily to satiation. Fish were not fed 24 h prior to testing. The swimming performance of the first tagged group was tested 1 day after surgery (mass 31·9 ± 1·5 g, 144·0 ± 2·2 mm $L_F$, tag 2·4 ± 0·1% of fish mass), the second tagged group was tested 5 days after surgery (mass 31·2 ± 1·6 g, 143·8 ± 2·3 mm $L_F$, tag 2·5 ± 0·1% of fish mass) and the third tagged group was tested 10 days after surgery (31·1 ± 1·4 g, 143·6 ± 1·9 mm $L_F$, tag 2·5 ± 0·1% of fish mass). Each fish was only tested once. Control and tagged fish were similar in both mass ($P = 0·96$) and $L_F$ ($P = 0·62$). Critical swimming speed (maximum velocity of fish maintained for a defined period of time; Brett, 1964) was determined using a modified Blazka swim chamber (Smith & Newcomb, 1970). A test fish was acclimated to the swim chamber for 1 h at a speed of 15 cm $s^{-1}$, *c.* 1 body length per second (BL $s^{-1}$). The speed was then increased at increments of 20 cm $s^{-1}$ every 10 min until the fish fatigued. Fatigue was determined as the condition when a fish rested against the back screen of the chamber and was unable to return to a free-swimming position (Brett, 1964). The experiment was conducted between 9 and 31 July 2000 and water temperature in the aquaria and swimming chamber ranged from 15·9 to 16·8° C (mean ± S.E., 16·3 ± 0·1° C) throughout the study.

Critical swimming speeds were converted to BL $s^{-1}$ and analysed using one-way ANOVA to explore differences within the four treatment groups.

### FOOD CONSUMPTION AND GROWTH

A 45 day experiment was conducted between 27 August and 11 October 1999 and repeated between 27 July and 10 September 2000. Fish randomly selected for the tagged group were weighed and measured prior to surgery and control fish were anaesthetized,

TABLE I. Mean ± S.E. (range in parentheses) initial sizes of tagged and control wild Atlantic salmon parr used in the food consumption and growth experiments

| | 1999 | 2000 |
|---|---|---|
| Tagged | $n=11$ | $n=9$ |
| (Tag mass) (fish mass)$^{-1}$ (%) | 0·9–2·6 | 1·4–2·5 |
| Mass (g) | 45·5 ± 5·1 | 37·8 ± 2·6 |
| $L_F$ (mm) | 152 ± 5 (134–191) | 150 ± 3 (143–162) |
| Control | $n=10$ | $n=9$ |
| Mass (g) | 41·2 ± 5·2 | 39·2 ± 1·9 |
| $L_F$ (mm) | 149 ± 6 (129–185) | 151 ± 2 (144–164) |

weighed and measured (Table I). The water temperature in the aquaria ranged from 13·8 to 17·3° C in 1999 and from 16·2 to 18·4° C in 2000.

Tagged and control fish were placed individually in 76 l flow-through aquaria. Starting 24 h after surgery, day 1 of the experiment, fish were fed a weighed quantity of chopped worms exceeding satiation levels every second day. Remaining worms were removed from the tank and weighed 24 h after feeding. Worm mass was reduced by 24% to compensate for water absorbed overnight in the tank. This 24% adjustment was determined in preliminary trials. Fish were anaesthetized, weighed and measured after every fourth feeding (*i.e.* days 9, 18, 27, 36 and 45 of the experiment).

Consumption rate was calculated as grams consumed per gram fish mass and growth as per cent body mass change through each 9 day feeding period. To analyse growth, a General Linear Model (GLM) was developed with year, treatment and feeding period, as well as their interaction terms, as categorical variables and consumption rate as the covariate.

## RESULTS

No fish died during the experiments. During the food consumption and growth experiments, transmitters were expelled from two fish on days 27 and 29 in 1999 and three fish on days 20, 27 and 29 in 2000. Two of these transmitters were observed emerging through the antenna hole, which later appeared slightly swollen. Transmitters in two fish in 1999 (days 8 and 9) and one in 2000 (day 11) moved toward the posterior end of the body cavity, flipping the antenna toward the fish's head. All tagged fish were necropsied at the end of the 45 day experiment. All incisions were completely healed and transmitters were encapsulated in a fibrous capsule on the body wall. No external or internal infections were apparent.

### SWIMMING PERFORMANCE

Swimming performance was similar between control fish ($8{\cdot}8 \pm 0{\cdot}4$ BL s$^{-1}$) and tagged fish tested 1 day after surgery ($7{\cdot}8 \pm 0{\cdot}4$ BL s$^{-1}$), 5 days after surgery ($8{\cdot}2 \pm 0{\cdot}5$ BL s$^{-1}$) and 10 days after surgery ($P = 0{\cdot}49$).

### FOOD CONSUMPTION AND GROWTH

Due to a strong year and feeding period interaction term in the original model (repeated measures ANCOVA, $F_{9,157} = 10{\cdot}95$, $P < 0{\cdot}0001$), the 1999 and

2000 data were analysed separately. In 1999, control fish had significantly greater growth than tagged fish on day 9. Growth was then similar up to day 36 and tagged fish outgrew control fish on day 45 [Fig. 1(a)]. In 2000, control fish had significantly greater growth than tagged fish up to day 18 and on day 36 [Fig. 1(b)].

## DISCUSSION

Surgically implanted dummy transmitters did not affect the swimming performance of wild Atlantic salmon parr over a 10 day period. Negative effects on growth, however, were found in both the 1999 and 2000 experiments. The longer duration of growth effects in 2000 may be related to the smaller size of

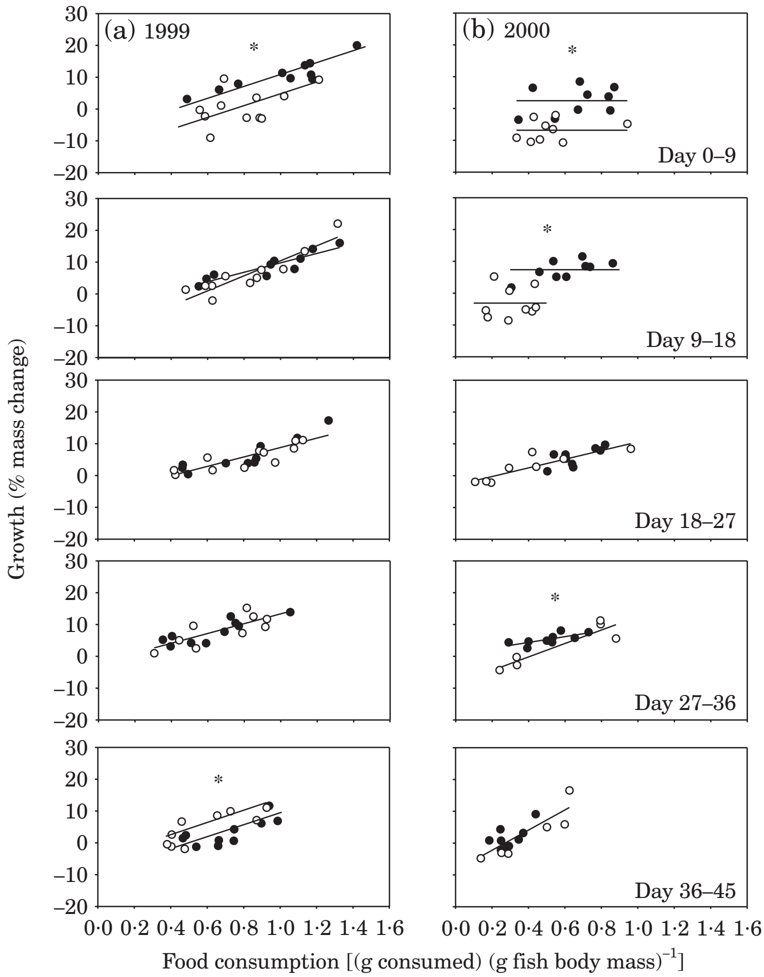


FIG. 1. The relationship between individual food consumption rate and individual growth of surgically tagged wild Atlantic salmon parr (○) and non-tagged controls (●) over 9 day feeding periods. Tagged and control fish were compared using GLM. *, a significant difference between tagged and control fish at $P > 0{\cdot}05$.

fish used that year as tagging effects have been shown to be inversely related to fish size (McCleave & Stred, 1975; Greenstreet & Morgan, 1989).

Food consumption rates were similar between tagged and control fish. Therefore, energy intake could not explain differences in growth between groups. Tagged fish may have expended more energy than control fish as a result of the physiological stress response to surgery (Jepsen *et al.*, 2001), protein synthesis for wound healing and transmitter encapsulation (Brafield & Llewellyn, 1982; Marty & Summerfelt, 1986) and higher activity levels (Adams *et al.*, 1998). In 1999, tagged fish grew faster than control fish in the last 9 days of the experiment, possibly indicating compensatory growth (Maclean & Metcalfe, 2001; Morgan & Metcalfe, 2001).

The results from the present study suggest that researchers can be confident making population inferences on the swimming performance of surgically tagged wild Atlantic salmon parr $>$120 mm using one of the smallest transmitters currently available. Although sample sizes in the growth experiment were low, the results suggest that caution is needed when interpreting growth data collected on surgically tagged wild Atlantic salmon parr.

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## References

Aarestrup, K., Jepsen, N., Rasmussen, G. & Ökland, F. (1999). Movement of two strains of radio tagged Atlantic salmon, *Salmo salar* L., smolts trough a reservoir. *Fisheries Management and Ecology* **6,** 97–107.

Adams, N. S., Rondorf, D. W., Evans, S. D., Kelly, J. E. & Perry, R. W. (1998). Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile chinook salmon (*Oncorhynchus tshawytscha*). *Canadian Journal of Fisheries and Aquatic Sciences* **55,** 781–787.

Anderson, W. G., McKinley, R. S. & Colavecchia, M. (1997). The use of clove oil as and anaesthetic for rainbow trout and its effects on swimming performance. *North American Journal of Fisheries Management* **17,** 301–307.

Begout-Anras, M. L., Lagardere, J. P., Gosset, C., Rives, J. & Prouzet, P. (2001). Migratory behaviour and hydrodynamics: radio tagging of the Atlantic salmon in the Adour. *Proceedings of the 7th International Symposium on Oceanography of the Bay of Biscay, No. 31*, (Elbee, Jd′ & Prouzet, P.), pp. 340–345. Plouzane: IFREMER.

Brafield, A. E. & Llewellyn, M. J. (1982). *Animal Energetics*. London: Blackie.

Brett, J. R. (1964). The respiratory metabolism and swimming performance of young sockeye salmon. *Journal of the Fisheries Research Board of Canada* **21,** 1183–1226.

Greenstreet, S. P. R. & Morgan, R. I. G. (1989). The effect of ultrasonic tags on the growth rates of Atlantic salmon, *Salmo salar* L., parr of varying size just prior to smolting. *Journal of Fish Biology* **35,** 301–309.

Hiscock, M. J., Scruton, D. A., Brown, J. A. & Clarke, K. D. (2002). Winter movement of radio-tagged juvenile Atlantic salmon in Northeast Brook, Newfoundland. *Transactions of the American Fisheries Society* **131,** 577–581.

Jepsen, N., Davis, L. E., Schreck, C. B. & Siddens, B. (2001). The physiological response of chinook salmon smolts to two methods of radio-tagging. *Transactions of the American Fisheries Society* **130,** 495–500.

Maclean, A. & Metcalfe, N. B. (2001). Social status, access to food, and compensatory growth in juvenile Atlantic salmon. *Journal of Fish Biology* **58,** 1331–1346. doi: 10.1006/jfbi.2000.1545.

Marty, G. D. & Summerfelt, R. C. (1986). Pathways and mechanisms for expulsion of surgically implanted dummy transmitters from channel catfish. *Transactions of the American Fisheries Society* **115,** 577–589.

McCleave, J. D. & Stred, K. A. (1975). Effect of dummy telemetry transmitters on stamina of Atlantic salmon (*Salmo salar*) smolts. *Journal of the Fisheries Board of Canada* **32,** 559–563.

Moore, A. & Russell, I. C. & Potter, E. C. E. (1990). The effects of intraperitoneally implanted dummy acoustic transmitters on the behaviour and physiology of juvenile Atlantic salmon, *Salmo salar* L. *Journal of Fish Biology* **37,** 713–721.

Morgan, I. J. & Metcalfe, N. B. (2001). Deferred costs of compensatory growth after autumnal food shortage in juvenile salmon. *Proceedings of the Royal Society of London, Series B* **268,** 295–301.

Peake, S., McKinley, R. S., Scruton, D. A. & Moccia, R. (1997). Influence of transmitter attachment procedures on swimming performance of wild and hatchery-reared Atlantic salmon smolts. *Transactions of the American Fisheries Society* **126,** 707–714.

Smith, L. S. & Newcomb, T. W. (1970). A modified version of the Blazka respirometer and exercise chamber for large fish. *Journal of the Fisheries Research Board Canada* **27,** 1321–1324.