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External attachment of data storage tags increases probability of being recaptured in nets compared to internal tagging

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Sea running Arctic charr *Salvelinus alpinus* and anadromous brown trout (sea trout) *Salmo trutta* (420–2030 g) tagged with externally attached data storage tags (DST) had a higher total recapture rate (39 of 44, 89%) due to entanglement in bag nets at sea (90% of all recaptures), compared with internally tagged fish (12 of 18, 67%) that were mostly trapped when returning to their home river (75% of all recaptures). The internally tagged fishes therefore spent longer time at sea before recapture (median 33 days) than externally tagged fishes (median 8 days), and more DST-data were collected. Therefore, in areas with high net fishing intensity, external tagging increases the chances of recapture, but less data may then be recorded by the tags due to a generally shorter period of data sampling.

Key words: archival tag; migrations; radio transmitter; tag effects; telemetry.

Until recent technical developments, little has been known about the movements, physiology and behaviour of long-distance migratory fishes. By continuously recording depth, temperature and light, the data storage (DST) tag is one of the developments that opens up a new array of possibilities to investigate physiological adaptations, behaviours and movements of individual fish (Metcalfe & Arnold, 1997; Moore *et al*., 2000; Åkesson, 2002). For retrieving data from the DST-tag, however the fish has to be recaptured. Maximizing the recapture rate is therefore crucial for ensuring a successful study (Moore *et al*., 2000).

The aim of this study was to examine if choosing either an external or internal tagging method would affect the chance of recapturing a DST-tagged fish. The life history of anadromous Arctic charr *Salvelinus alpinus* (L.) and anadromous brown trout, sea trout, *Salmo trutta* L. often involves annual migration between salt and fresh water (Klemetsen *et al*, 2003; Rikardsen *et al*. 2004*a*). DST-tags

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are therefore well suited for analysing marine migration behaviour in these species, since the fishes can be easily trapped and recaptured when returning to fresh water (Rikardsen, 2000). Both species commonly feed in the littoral zone at sea during summer (Pemberton, 1976; Lyse *et al.*, 1998; Rikardsen *et al.*, 2000; Rikardsen, 2004; Rikardsen & Amundsen, 2005), making them accessible for both angling and gillnetting.

The present study with DST-tagging of Arctic charr and sea trout in the Alta Fjord in northern Norway (70° 05′ N; 22° 55′ E) demonstrated an increased chance of being entangled in a fisherman's nets and recaptured when tagged with externally attached DST-tags compared to tags internally implanted in the body cavity. The Alta Fjord holds large populations of Atlantic salmon *Salmo salar* L., Arctic charr and sea trout (Rikardsen *et al.*, 2004*b*; Rikardsen & Amundsen, 2005), and there is an extensive bag net fishing for returning Atlantic salmon along the coastline of the fjord. A fish trap is located near the mouth of the Hals River in the Alta Fjord, capturing all descending and ascending fishes (Finstad & Heggberget, 1993).

A total of 33 descending adult Arctic charr (430–230 g, mean 900 g) and 29 sea trout (660–1850 g, mean 1050 g) were trapped in the Hals River and tagged with either of two DST-tag models (DSTmilli: 13 × 39 mm, 9 g in air; CTD-tag: 15 × 46 mm, 19 g in air; Star Oddi, Iceland, Table I). Tag mass in air was on average 1·4% (range 0·5–2·4%) of the body mass (M_B) of the fish. Similar tag: fish mass relationships did not affect the swimming capacity or food consumption of Atlantic salmon (Thorstad *et al.*, 2000; Robertson *et al.*, 2003). Both tags recorded temperature and pressure (depth), while the CTD-tag additionally recorded salinity. The DSTmilli was attached to the fishes both internally and externally, while the CTD-tag had to be attached externally for salinity measurements.

The fishes were anaesthetized using clove oil (Iversen *et al.*, 2003). For internal tagging, the fish was placed with the ventral side up on a partly submerged V-shaped surgical table. A 2 cm incision was made on the ventral surface posterior to the pelvic girdle using a scalpel. The DST-tag was inserted through the incision and pushed into the body cavity above the pelvic girdle. The internal tag was equipped with an identification tube that was pushed through the body wall using a hollow needle. A knot was made outside on the tube to prevent it from sliding back into the body cavity. The incision was closed using two or three independent absorbable silk sutures (3/0 Ethicon). The external tags were attached to the fish below the dorsal fin. Two hollow needles were pushed through the dorsum of the fish 1·5–2·0 cm below the dorsal fin. The spacing between the needles matched the length of the tag. A plastic back plate was used on the opposite side to prevent erosion of the flesh by the attachment wire. Handling time was 3–5 min and recovery time 5–10 min for both methods. Prior to each incision, the surgical equipment was rinsed in 96% ethanol.

The fishes were tagged during 29 May –5 June in 2002–2004 (Table I). Hence, all groups of fishes were released at the same time each year. The fishes were captured in the trap 1–7 days prior to tagging and kept in a freshwater tank. After tagging, the fishes were kept in the tank for observation 24 h before release below the trap. All returns of tags from fishermen were rewarded.

TABLE I. Number of fishes recaptured by different fishing methods (bag nets, angling and fish trap) for externally (EXT) and internally (INT) tagged fishes with data storage tags (DSTmilli or CTD-tag)

Tagging	Year	Species	Data storage tag	Number tagged	Mean size		Number of recaptures			
					L_F (mm)	Mass (g)	Bag nets	Angling	Fish trap	%
EXT	2002	Arctic charr	milli	7	427	702	6	1		100
		Sea trout	milli	7	529	1309	7			100
	2003	Arctic charr	CTD	5	495	1127	3	2		100
		Arctic charr	milli	1	520	1101	1			100
		Sea trout	CTD	6	505	1055	5		1	100
	2004	Arctic charr	CTD	7	511	1163	5			71
		Arctic charr	milli	2	490	852	2			100
		Sea trout	CTD	6	507	1139	4			67
		Sea trout	milli	3	434	733	2[2]			67
	Total			44	491	1020	35	3	1	89
INT	2002	Arctic charr	milli	4	474	907		1	3	100
		Sea trout	milli	1	585	1621			1	100
	2003	Arctic charr	milli	3	391	511			1	33
		Sea trout	milli	4	470	887		1	2	75
	2004	Arctic charr	milli	4	431	688		1	2[1]	75
		Sea trout	milli	2	497	980				0
	Total			18	475	932	0	3	9	67

[1]one fish had lost the internal tag in the gillnet.
[2]one tag was found entangled in the gillnet without the fish.
L_F, fork length.

In total, 82% (51 of 62) of the tagged fishes had been recaptured by December 2004 (85% of the Arctic charr and 79% of the sea trout) (Table I). There were no differences between the two species in recapture rates (Fisher's exact tests, externally tagged fishes $P = 1{\cdot}0$, internally tagged fish $P = 0{\cdot}63$). Sample sizes were too small to include year as a factor in this analysis, but there was not a large variation among years in number of fish tagged of each species (Table I), such that this was not thought to bias the results. In total, 89% (39 of 44) of the externally tagged fishes were recaptured, while 67% (12 of 18) of the internally tagged fishes were recaptured (Table I). The proportion recaptured was significantly higher for externally than for internally tagged fishes in 2003 (Fisher's exact test, $P = 0{\cdot}036$), whereas no differences were found in 2002 and 2004 ($P = 1{\cdot}0$ and $0{\cdot}36$, respectively).

Both externally tagged Arctic charr and sea trout were most frequently recaptured in bag nets along the shoreline in the Alta Fjord (Table I). Of the 39 externally tagged fishes that were recaptured, 90% (35 fish) were recaptured in bag nets, 8% (three fishes) by angling in the sea and 2% (one fish) in the trap in the Hals River (Table I). In contrast, none of the 12 recaptured internally tagged fishes were recaptured in bag nets, but 75% (nine fishes) in the fish trap in the Hals River and 25% (three fishes) by angling in the sea (Table I). The proportion recaptured in bag nets was significantly higher for externally than for internally tagged fishes (Fisher's exact tests, Arctic charr $P < 0{\cdot}001$, sea trout $P < 0{\cdot}001$). Sample sizes were too small to include year as a factor in this analysis, but the trend was consistent among years (Table I). Moreover, if combining species and analysing years separately, the results were the same ($P = 0{\cdot}001$–$0{\cdot}003$). There was no difference in body mass between fishes recaptured in bag nets and those recaptured in the trap (*t*-test, $P = 0{\cdot}22$).

Two of the fishes lost their tag most likely due to entanglement in nets. One external tag was found entangled in the bag net, but the fish had disappeared and was not recaptured. An internally tagged fish was recaptured in the fish trap without the tag, but with injuries from a gillnet. It is most likely that the knot on the identification tube had been hooked in the net and the tag been dragged out, because the hole for the tube was tired up.

Time from release to recapture was significantly shorter for externally than for internally tagged fishes (Mann-Whitney *U*-test, 2002: $P = 0{\cdot}01$; 2003: $P = 0{\cdot}07$; 2004: $P = 0{\cdot}003$; all data combined: $P < 0{\cdot}001$; Fig. 1). Median time to recapture in nets for externally tagged fishes was 8 days (0·4–360·0 days). In contrast, median time for internally tagged fishes recaptured in the fish trap when returning to their home river was 33 days (18–400 days).

This study documents that the probability of being captured in nets was considerably higher for externally tagged than for internally tagged Arctic charr and sea trout, probably due to the external tag being hooked and entangled in the net. As a consequence, the externally tagged fishes were mainly captured in bag nets during feeding in the fjord, whereas the internally tagged fishes were not vulnerable to these fishing methods and were usually not recaptured until they returned to fresh water and were caught in the fish trap in their home river. Thus, the fishes with internal tags spent a longer time before they were recaptured, and data from a longer time period could be retrieved. A significantly smaller proportion of the internally tagged fishes, however, was

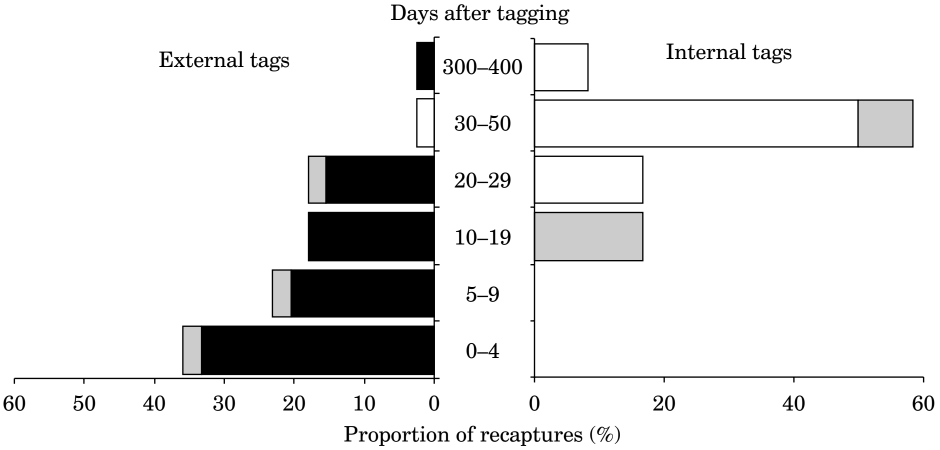

FIG. 1. Proportion (%) of externally and internally tagged fishes that were recaptured at different time periods in bag nets (■), by angling at sea (■) or in the fish trap when returning to fresh water (□).

recaptured in one of the three study years. Therefore, in areas with high net fishing intensity, external tagging increases the chances of recapture, but fewer data may then be recorded by the tags due to a generally shorter period of data sampling.

When choosing a tagging method, other factors, such as the danger of fouling of external tags, should also be taken into consideration (Thorstad *et al*., 2001). No significant signs of fouling, however, were seen on any of the tags recaptured in the present study (only a thin layer of algae on some tags), which may be due to the low sea temperatures (averages between 6 and 11° C at 3 m depth in June and July) and the relatively short time period the fishes had been in the sea (up to 48 days). No reports of inflammation or other adverse effects of the tags on the fishes were received for any of the tagging methods during the study period. The results in this study are also relevant for telemetry tags such as radio transmitters and acoustic transmitters, since the DST-tags are similar in shape, size and attachment method.

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