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Abstract

Data collected from wildlife telemetry studies relies on tagging and attachment having minimal impacts on behaviour. Though a widespread technique, relatively few studies evaluate the impacts of differing tagging methods on both welfare and behaviour. Here we use tracking data, collected for other aims, to investigate the impact of inter-peritoneal surgical implantation of acoustic transmitters on the health and behaviour of common bream, *Abramis brama* (L.). In five separate capture events, the behaviour in terms of distances moved and linear range of newly tagged fish (n=61) were compared to previously tagged fish (n=55) present in the same river at the same time. In the first 5 days post-tagging, newly tagged fish moved significantly further than previously tagged fish. Despite this difference, the linear ranges moved by the two groups of fish were equivalent. During 6-10 days post tagging there was no significant differences between the two groups. Thus, the tagging procedure had short term, but not long term behavioural impacts. In addition, a number of tagged fish were recaptured between 51 and 461 days post-surgery. Recaptured fish appeared to have clean, well-healed incisions and exhibited ‘normal’ behaviour in that they were caught alongside a large number of conspecifics. Three recaptured tagged fish were translocated ~35 km downstream, to ascertain how translocation would affect their behaviour. The translocated fish had a greater linear range than control fish, with all three fish returning to the site of capture within 6 to 24 days, suggesting that common bream can exhibit site fidelity.

Key words: aquatic telemetry; surgical implantation; effects of tagging; translocation; *Abramis brama* (L.).

1. Introduction

The development of electronic tags has been one of the most important advances in the study of freshwater fish behaviour and ecology (Lucas & Baras 2001; Cooke *et al*. 2013). Tag implantation into the peritoneal cavity is commonly used in long-term tracking studies of fishes (Lucas & Batley 1996) and regularly used for cyprinid species (*e.g.* Lucas & Batley 1996; Huber & Kirchhofer 1998; Lyons & Lucas 2002; Winter & Fredrich 2003; Fredrich *et al.* 2003; Kuliskova *et al*. 2009; Gardner *et al*. 2013). Such telemetry studies commonly rely on three assumptions: 1) fish condition and mortality are not altered by the tagging procedure or transmitter presence; 2) transmitters are retained for the duration of the observation period; and 3) tagged individuals accurately represent the population being observed (*i.e.* they behave normally; Smith *et al*. 1998; Ramstad & Woody 2003; Neely & Steffensen 2010). Taylor *et al.* (2011) suggests the best approach to evaluate potential tagging effects is to use multiple endpoints that evaluate lethal and sub-lethal effects (*e.g.* healing, swimming activity, and performance; Cooke *et al.* 2011) and that field validations are necessary to ensure that data are relevant to field scenarios (Cooke *et al.* 2011).

Assessment of the effects of surgical implantation of transmitters on the behaviour of tagged fish has previously been carried out by observations of fish in captivity prior to release. In addition, examination of recaptured fish (post-release) can determine the degree of healing and the effects of tag implantation on fish condition (*e.g.* weight). However, there is a paucity of data on the effects of tag implantation on fish behaviour in the wild. Unusual long-distance movements have been observed during the first few days of release following transmitter implantation in largemouth bass *Micropterus salmoides* (L.) (Mesing & Wicker 1986) and dace *Leuciscus leuciscus* (L.) (Clough & Beaumont 1998), but without a suitable control population in the watercourse, it is difficult to ascribe this behaviour as a direct effect of the capture, handling and surgical procedure.

Here, we present the results of a study in which the immediate post-surgery spatio-temporal behaviour of common bream *Abramis brama* (L.) was compared to that of other common bream that had been tagged between 55 and 378 days previously. The study had other primary objectives (see Gardner *et al*. 2013 & 2015)., However, it also presented the opportunity to analyse the short-term effects of capture, handling and tagging on the behaviour of the bream via a comparison of the movements of the two groups of bream. In recapturing a sample of tagged individuals, incision wound healing could also be assessed. In addition, a small group of recaptured fish were translocated downstream and their behaviour compared to those that were not recaptured nor translocated. A detailed description of the tagging protocol is reported in response to calls for greater scrutiny of the methods used in order to compare, replicate and interpret the growing literature on fish telemetry studies (Thiem *et al*. 2011).

2. Material and methods

2.1 Study area

The study area was a continuous open reach of approximately 40 km of the non-tidal lower River Witham and associated tributaries in Lincolnshire, UK, see Gardner *et al*. (2013 & 2015) for further details.

2.2 Sampling procedures

In total, eighty-three adult common bream were caught by either rod and line, seine netting or electrofishing from the River Witham, and tagged in seven batches between

November 2006 and February 2009 (see summary in Table 1). Fish were retained overnight; on one occasion in net cages placed in the river (the site was secure), or more commonly in holding tanks on shore between capture and tagging. After surgery, all fish were released at the site of capture.

Coded acoustic transmitters of two types: Vemco (Nova Scotia, Canada) V9-2L (cylindrical with dimensions of 29 mm by 9 mm diameter, weight in air of 4.7 g, weight in water 2.9 g and with operational life of 80-330 days) and V13-1L (cylindrical with dimensions of 36 mm by 13 mm diameter, weight in air of 11.0 g, weight in water 6.0 g and with operational life of 526-621 days) were implanted into the body cavity. The tag weight in air would represent 0.16-0.57% of the fish's weight out of water.

2.3 Tag implantation protocol

The procedure described was regulated and licensed in the UK by the Home Office under the Animals (Scientific Procedures) Act 1986, and was performed under project licence number PPL 80/2016. The surgery itself took place within the shelter of a mobile laboratory under conditions that were as aseptic as possible in-the-field.

A specially constructed operating table was used to secure and restrain the fish in an upside-down position with the incision site clearly accessible. The mobile laboratory and operating table were washed and disinfected before any procedures were started. Surgical equipment was sterilised in 97 % ethanol and then rinsed with sterile water or saline solution. Prior to the procedure the activated tag was tested in water with a hydrophone. Tags were then sterilised with a 25% Dettol™ solution, rinsed with sterile water or saline solution and stored in a sterile swab. A 60 litre anaesthetic bath (Tricaine methanesulphonate MS-222; 50 mg/L; see Carter *et al.*

2011), and a similar sized recovery tank, both with aeration were clearly labelled. The anaesthetic bath was tested with a single fish (which was not used again for subsequent anaesthesia and tagging) until anaesthesia was reached (indicated by loss of the righting reflex and a slowed operculum rate, which did not stop). The test fish was allowed to fully recover before any fish to be tagged were anaesthetised.

All surgeries were conducted by a single surgeon (CG). The surgeon and assistant thoroughly cleaned their hands with an alcohol-based hand wash and maintained as aseptic a procedure as was possible under field conditions. The surgeon wore sterile surgical gloves, changing them between fish, or after coming into contact with anything away from the surgical area. Fish were firstly weighed, measured, their sex determined, primarily by the presence of tubercles and also by vent & body morphology (Kennedy & Fitzmaurice 1968), and a scale sampled from the mid-flank above the lateral line, for subsequent age determination. The fish was then placed into the aerated anaesthetic bath. When anaesthesia was reached the fish was removed from the bath, inverted and secured in the operating table between wet smooth foam padding with Velcro™ straps and transferred to the mobile laboratory. During the surgery an assistant monitored the operculum movement throughout. If a problem with the fish's health or well-being was encountered during the procedure then the team had the option to administer an overdose of anaesthetic in-line with Schedule 1 of the Animals (Scientific Procedures) Act 1986.

The incision site was on the ventral surface of the fish, anterior of the pelvic fins and associated muscle blocks. Using tweezers, a line of 4 to 6 scales were removed from the incision site and another scale removed midway and perpendicular to the incision site to allow suture entry. The site was then swabbed with an iodine based antiseptic (Betadine™). An incision was made with a sterile scalpel and was kept to the minimum length required, approximately 20-30 mm. The incision was begun just in front of the pelvic muscle blocks, where the body wall thins, and extended towards the pectoral fins. The incision was made slowly by dragging the scalpel lightly. An assistant used sterile tweezers to hold the incision open while it was being cut allowing the surgeon to see when the incision breached the body cavity and thus avoided making an incision that was too deep, potentially damaging vulnerable internal organs. A sterilised tag was inserted into the incision using a sterile, gloved hand and/or sterile tweezers. The incision was closed with a single suture (Ethicon PDS*II Polydioxanone violet monofilament absorbable W9125; Ethicon, Piscataway, NJ, U.S.A.). One scale had already been removed to allow suture entry and another 1-2 scales were removed with tweezers to achieve suture exit. The suture was secured with a surgeon's knot and excess suture material trimmed with sterile scissors, 5-10 mm from the knot.

The site was swabbed again and G7 wound sealer (Lincolnshire Fish Health, UK) was applied and allowed to at least partly dry for a few seconds. The site was then liberally covered with Orabase™ (Squibb & Sons, Uxbridge, UK) protective paste to provide a temporary barrier and G7 wound sealer reapplied on top of the Orabase™, to prevent the Orabase™ barrier dissolving too quickly when fish were returned to the water. The whole procedure took approximately three to four minutes.

Following surgery, the fish was removed from the operating table and immediately placed in the aerated recovery tank where it was supported by hand in an upright position. An antibiotic injection of 1 ml Baytril at 2.5% directly behind the dorsal fin was given while fish were recovering, although antibiotic use post-surgery has been questioned by Mulcahy (2011). The injection was made on the same line as the erect last dorsal ray between the two main muscle blocks. This site reduces possible scale damage and reduces post-injection leakage of antibiotic. Once each fish was deemed recovered, which took no more than 5 minutes, it was removed to a separate retention net in the river for further observation. Fish were retained in this way for an hour after the last fish was tagged, to ensure they had regained balance and were actively swimming, then collectively released as a group.

2.4 Recapture and translocation of tagged fish

After release, the movements of the common bream were monitored in the lower River Witham, Lincolnshire between Short Ferry (53°13'38"N; 0°21'23"W) and Boston (52°58'53"N; 0°1'46"W). Tracking results were obtained from up to twenty-six fixed (marginal, maintained at approximately mid-water depth, a metre below the surface) VR2 and VR2W acoustic receivers (Vemco, Nova Scotia, Canada) which were positioned ~2-3 km apart, as described by Gardner *et al*. (2013).

Fish were recaptured both intentionally, for translocation and unintentionally, during fishing operations to capture new fish for tagging. When new fish were required for tagging, mobile tracking with a VR100 mobile receiver (Vemco, Nova Scotia, Canada) was undertaken to find areas where tagged fish were present and fishing for fresh fish was concentrated in these areas. Common bream are a shoaling species (Backiel & Zawiska 1968) and thus tagged fish were likely to be associated with untagged fish. Recaptured tagged fish were isolated and identified with the VR100 mobile receiver in separate bank side tanks and identification confirmed by the presence of surgery incisions. The incision site was inspected and photographed to determine the extent of post-surgical healing. All fish were returned to the river alive.

On 16 March 2010 three fish (tag numbers: 12255, 12257& 12266) were caught by wrap-around seine netting (35 m by 3 m pull down and 50 m by 3 m wrap; Coles *et* *al.* 1985) in the Sincil Dyke, close to Short Ferry (53°12'49"N; 0°20'50"W) when three separate single haul nettings covered a length of drain of ~1 km. Fish were placed in large plastic bags (60 cm by 100 cm) containing approximately 20 L of water, bags were sealed at the top and the air space filled with oxygen. These fish were then translocated ~35 km downstream by road and released as a group so their spatio-temporal behaviour could be compared with ‘control’ (not captured nor translocated) tagged fish that were present in the river.

The definition of the ‘control’ group used throughout the study warrants some comment; previously tagged fish were used as a ‘control’ group to compare with newly captured, tagged / translocated and released fish. A more appropriate control would be previously tagged fish recaptured but released at the same site and their behaviour compared with recently tagged (or translocated) and released fish. However, in this case it would not be clear if the difference in behaviour between the two groups was due to recapture itself (which is stressful) rather than the capture, handling and surgery / tag insertion (or translocation) which collectively is a distinct but also stressful event. Recapture of previously tagged fish was very difficult in such a large waterbody, thus it was considered that previously tagged fish still at liberty would act as a reasonable proxy for a control group.

2.5 Data handling and statistical analysis

Data were downloaded to a laptop using VR2PC and VUE software packages (Vemco, Nova Scotia, Canada). Allocation of a km value (measured using ArcMap v9.1 Geographic Information System, ESRI Ltd, Redlands, CA, USA) upstream of the tidal limits at Boston for each receiver allowed the movements of individual fish to be quantified.

There were five tagging events when 'new' fish were tagged while previously tagged fish were also being tracked in the river, allowing the behavioural effects of capture, handling and tagging to be compared between these two groups; newly tagged and previously tagged (details of each tagging event are presented in Table 1). The effects of the single translocation event of three fish were also compared.

Two methods of quantifying the spatio-temporal behaviour of the tracked fish were used. The cumulative distance moved between the receivers visited by an individual fish gave the total distance moved (TDM) in km. The longitudinal distance between the most upstream and downstream detections (Young 1999; Ovidio *et al*. 2000) gave the linear range (LR) in km, with positive values indicating ranges upstream and negative values indicating ranges downstream.

We analysed the TDM and the LR by newly tagged and previously tagged fish over two periods; the first 5 days (120 h) following release and the second 5 days (120.1 – 240 h) after release. Fish that were not detected during any period were omitted from that part of the analysis. The movement data did not fit a normal distribution, possibly because of the discrete intervals of transmitters in the river. Data instead fitted an overdispersed Poisson distribution. We analysed movement data using a Poisson GLMM with type (newly tagged/previously tagged) as a fixed factor and fish ID and tagging event as random factors. To account for overdispersion, we fitted an individual-level random effect. We then tested whether fish moved upstream or downstream using a binomial GLMM with the same fitted fixed and random effects. Using just newly tagged fish, we tested whether capture method impacted movements. Again, we used Poisson and binomial GLMMs with method (electrofishing, seine netting, rod and line) as a fixed factor and tagging event as a random effect. We fitted an individual level random effect to account for overdispersion. All models were conducted using the *glmer* function from the lme4 package (Bates *et al*. 2014) in R version 3.03 (R core team 2014).

For the translocation analysis, Mann-Whitney U tests were used to analyse differences in TDM and LR between the two groups during the consecutive five day periods following translocation, as data were not normally distributed, these analyses were performed with Minitab® v15.1.1 (Minitab Inc., PA, USA).

3. Results

All eighty-three common bream made a full recovery post-surgery and swam away strongly on release. Another fish implanted was euthanised under Schedule 1 of the Animals Scientific Procedures Act (1986) after it failed to fully recover from anaesthesia; although a post-mortem revealed no surgical complications. Individual fish were tracked from 40-629 days (mean 266.0 ± SD 146.7; see Gardner *et al*. 2013). Subsequent analysis of tracking data showed no evidence of tag expulsion and survival rates of 100% were experienced for fish that stayed within the study area in the short term, with all fish released showing upstream movements (indicative of an alive fish) for at least two months, usually substantially more, post-surgery.

3.1 Recaptured fish

In total, eight (~10%) of the eighty-three tagged common bream were recaptured during the study. A single haul seine netting on 30 November 2007 resulted in 990 adult common bream with masses between ~2-3 kg. The netting recaptured four tagged bream, three 51 days post-surgery and one 275 days post-surgery. One fish was recaptured 76 days post-surgery by electro-fishing in the Sincil Dyke on 24 February 2009. One fish 384 days post-surgery and two fish 461 days post-surgery were recaptured during nettings on 16 March 2010, which resulted in 1,270 adult common bream between ~1-3 kg.

Recaptured fish appeared to be behaving naturally, in that they were associated with numbers of untagged fish, sometimes in very high densities. Physically they exhibited clean healing and tissue regeneration (Figure 1), although in one case there was some haemorrhaging around the incision site. There was no evidence of the tag expulsion process described by Jepsen *et al*. (2008). All recaptured fish where visually inspected and appeared to be in no worse a physical condition than when they were tagged. All three fish recaptured 51 day post-surgery and the single fish recaptured 76 days post-surgery still had sutures present. All four fish recaptured 275-461 days post-surgery displayed clean healing and suture absorption, with a small scar being the only evidence of the surgical procedure. This indicates that the sutures were absorbed in line with the manufacturers' specifications, which state that absorption is minimal until about the 90 days post-surgery.

3.2 Effects of capture, handling and tagging procedure

There was a lot of variability between results from individual fish in some cases, hence the relatively large standard errors (Figures 2 & 3). In the first 5 days (120 h) following release the newly tagged fish moved significantly further than fish previously tagged and already in the river (Poisson GLMM: Estimate = 0.67 ± 0.21, Z = 3.12, P = 0.002; Figure 2), but the linear range they covered did not differ significantly (Poisson GLMM: Estimate = 0.30 ± 0.22, Z = 1.38, P = 0.169; Figure 3). There was no significant difference in the proportion of fish moving upstream or downstream (Binomial GLMM: Estimate = 0.17 ± 0.48, Z = 0.36, P =0.721; total n = 87, control upstream n = 20, control downstream n = 11, newly tagged upstream n =

40, newly tagged downstream n = 16), although when fish that did not register either an upstream or downstream movement (*i.e.* linear distance = zero) were included in the analysis, newly tagged fish tended to move upstream more often (Binomial GLMM: Estimate = 1.11 ± 0.41, Z = 2.76, P = 0.006; total n = 116, control upstream n = 20, control downstream n = 11, control non-movers n = 24, newly tagged upstream n = 40, newly tagged downstream n = 16, newly tagged non-movers n = 5). By contrast, newly tagged fish did not move significantly further than previously tagged fish already in the river at 6-10 days (120.1 – 240 h) post-release (Poisson GLMM: Estimate = 0.17 ± 0.43, Z = 0.40, P = 0.689: Figure 2), nor did the linear range they moved differ significantly (Poisson GLMM: Estimate = 0.16 ± 0.36, Z = 0.434, P = 0.665; Figure 3). There was no significant difference in the proportion of fish moving upstream or downstream (Binomial GLMM: Estimate = -0.52 ± 0.62, Z = -0.84, P = 0.401; total n = 55, control upstream n = 20, control downstream n = 9, newly tagged upstream n = 15, newly tagged downstream n = 11). This result did not change when fish that did not register either an upstream or downstream movement were included in the analysis (Binomial GLMM: Estimate = -0.36 ± 0.48, Z = -0.80, P = 0.421; total n = 105, control upstream n = 20, control downstream n = 9, control non-movers n = 29, newly tagged upstream n = 15, newly tagged downstream n = 11, newly tagged non-movers n = 21).

Method of capture had a significant effect on total distance moved in the first 5 days (120 h) following release by the newly tagged fish (Table 2). Fish caught by seine netting (P = 0.039) moved significantly further than those caught by electrofishing, whilst there was a marginally non-significant tendency for rod caught fish to move further (P = 0.069). Similarly method of capture had a significant effect on the linear range (Table 2), with rod caught fish (P = 0.001) having larger linear ranges than those caught by electrofishing, and a non-significant tendency for seine net caught fish to have larger linear ranges (P = 0.155). Method of capture did not impact the direction fish moved within the first 5 days post-release (Table 2).

By contrast, method of capture had no significant effect on the total distance moved 6-10 days post-release (Table 3), though fish caught by seine net had a marginally non-significant tendency to move less (P = 0.073). Similarly, method of capture had no significant effect on the linear ranges of newly tagged fish (Table 3), or the direction fish moved (Table 3).

3.3 Effects of translocation

Following translocation all three fish returned to the Sincil Dyke 6-24 days after being released ~35 km downstream (Figure 4). Individual fish showed considerable variability in their behaviour but there was no significant difference in mean TDM between the translocated and control fish (Figure 5). Mann-Whitney U tests revealed no significant effect on TDM in any five day period following translocation, Table 4. However, the translocated fish ranged over longer distances upstream as they returned to the Sincil Dyke, while the control fish slowly ranged downstream (Figure 6). Mann-Whitney U tests revealed significant differences in LR in every concurrent five day period (Table 4).

4. Discussion

4.1 Recaptured fish

Whenever surgery is involved fish will be subjected to disturbance and post-surgical healing rates vary according to species, age, the size of the incision and associated trauma, and water temperature (Lucas & Baras 2001). Although the survival of tagged fish is often not the best measure of the impact of the surgical procedure on fish (Jepsen *et al*. 2008), it remains the simplest to measure without invasive or destructive techniques. Although the sample size here was relatively small and may not be random or representative, all recaptured fish in this study were alive and showed advanced healing and no suture loss after 51 days with water temperatures between 4-14 ºC. The four fish recaptured 275-461 days post tagging showed complete external recovery, with the incision site hard to identify and no signs of sutures, being absorbed in line with the manufacturer’s specifications. Retention of sutures until healing is advanced is preferable to premature loss which may increase tag loss and mortality risk (Jepsen *et al*. 2002).

Efforts to recapture tagged fish often resulted in the capture of large numbers of untagged conspecifics, indicating tight shoaling behaviour (as described by Backiel & Zawiska 1968; Phillips & Rix 1985; Borcherding *et al*. 2002.). The observation of tagged fish with other untagged conspecifics (*e.g.* Clough & Ladle 1997; Clough & Beaumont 1998; Jepsen & Berg 2002), and of tagged fish engaged in migration (*e.g.* Baras 1997) and spawning (*e.g.* Lucas & Batley 1996) have been interpreted to indicate ‘normal’ behaviour by the tagged fish. However, few studies have quantified the effects of tagging on behaviour (see review by Bridger & Booth 2003).

4.2 Effects of capture, handling and tagging procedure

The tagging procedure was designed with the highest regard for fish welfare and animal ethics, aseptic techniques, incision dressing and antibiotics were employed as a ‘belt and braces’ approach to safeguard against post-operative infection, despite recent evidence that such measures do not increase post-operative survival (see Jepsen *et al*. 2013). This approach was adopted following advice from the regulator. This subject has been cause for recent debate and some now consider it important to discourage researchers from taking unnecessary precautions unless there are specific (documented) problems with infections (see Jepsen *et al.* 2013, 2014a, 2014b). However, the use of aseptic techniques has also been championed (see Mulcahy 2013 & 2014) as standard best practice.

In this study the capture, handling and tagging procedure appeared to impact behaviour for the first 5 days post-tagging, detectable at the resolution of the tracking undertaken. These differences had disappeared at 6–10 days post-surgery. Similarly temporary effects of tagging have been observed elsewhere. Robertson *et al*. (2003) recorded negative effects on growth up to day 36 of a 45 day experiment assessing the impacts of tagging on wild Atlantic salmon *Salmo salar* (L.) parr implanted with dummy transmitters and observed in flow-through aquaria.

It is important to know if tagging disrupts behaviour in order to validate the data collected and conclusions drawn. For example, in a study of dace in the River Frome, UK, 88% of tagged fish moved upstream immediately after release, with some making large excursions on the day of release and three fish moving so far that they were lost outside of the study area (Clough & Beaumont 1998). In response to such reports, some studies have either not recorded data from the period immediately after tagging (*e.g.* one week by Allouche *et al.* 1999) or excluded it from analyses to mitigate against the effects of tagging and handling on fish behaviour (Winter 1996).

Mesing & Wickler (1986) report unusual long-distance movements in largemouth bass during the first days of release after transmitter implantation. By contrast, Lyons & Lucas (2002) observed no large movements (> 100m) of tagged common bream in the River Trent, UK during the first hour after release. It is possible the effect of surgery on behaviour is taxon specific and may reflect differences in ecology, such as the likelihood of predation. For instance, dace in the river Frome are common prey of pike (Masters *et al*. 2003). Alternatively, differences between studies may reflect differences in the spatial resolution of the tracking devices used, such that small changes in behaviour may not be picked up by static receivers positioned several km apart.

Capture by seine net and rod and line had the most effect on TDM and LR after 0-5 and 5-10 days, it might be that electrofishing is less disruptive than these other two methods. Disruption of an entire school of shoaling fish may elicit this response, with released fish trying to relocate their school.

4.4 Effects of translocation

Translocation did not significantly affect the activity levels of the fish, as determined by the mean total distance moved (although this may reflect the low statistical power associated with the movement of just 3 fish). However, linear ranges were significantly greater in the translocated fish as they appeared to display site fidelity, moving upstream towards the original capture site.

How fish navigate in complex habitats is still unclear, although it is likely to involve several mechanisms (see Hasler & Wisby 1958; Malinin 1970; Carlson & Haight 1972; Mesing & Wicker 1986; Hert 1992; Baras 1997, Odling-Smee & Braithwaite 2003). Fourteen radio tagged brown trout (*Salmo trutta* L.) were displaced over 0.8 to 3.6 km upstream and downstream in the river Eden, Scotland. Twelve of these fish subsequently returned to the areas from which they were taken, seemingly to follow specific orientation cues (*e.g.* olfactory) rather than searching at random (Armstrong & Herbert 1997).

Here data lend support for the notion that fish are capable of relocating by directed movements using specific orientation cues, rather than by accident or a random search pattern. Prior to translocation all fish were relatively sedentary in the Sincil Dyke, and had been for some time. Following translocation, once fish had returned 'home', they tended to remain in relatively localized areas of the channel. The preceding tracking data of the fish allows some assessment of each fish's 'familiar area' (the zone through which the fish could remember having moved; Bovet 1992). Interestingly the fish that took the longest to return 'home' had prior knowledge of the lower river where it was translocated. Therefore, this fish could be using olfactory beacons (the presence or absence of familiar odours emanating from the familiar area; Halvorsen & Stabell 1990), or any of a range of other potential cues, such as visual and olfactory landmarks, or areas of distinct water flow patterns (Armstrong & Herbert 1997). By contrast, the other two translocated fish had not experienced the lower river in the preceding ~15 months and may have no experience of its visual and olfactory landmarks to use as navigational aids, and were the quickest to return 'home'.

In conclusion, this study detected short term impacts of capture, handling and tagging procedure on the behaviour of bream with newly tagged fish moving greater distances in the first five days post-operation, these differences had become non-significant during the 6-10 day period. Recaptured fish had clean healing incisions and appeared to be exhibiting 'normal' behaviour in that they were part of large shoals of common bream. Translocated fish appeared to exhibit site fidelity, moving quickly back to the site of capture.

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Figure Captions

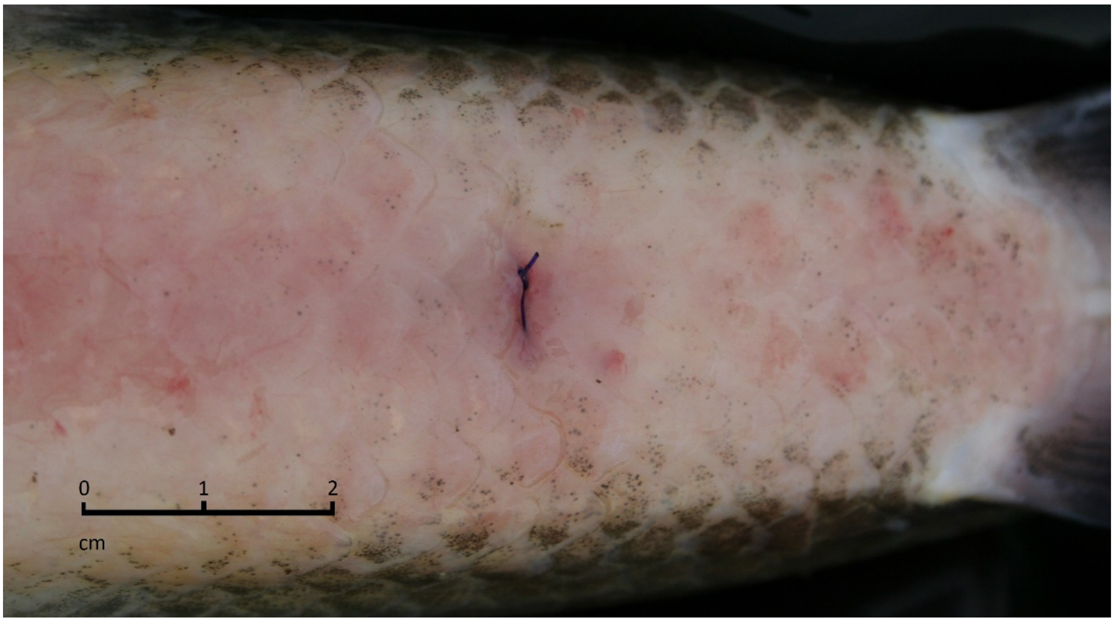

Figure 1. Incision site of fish 6073 - 51 days post tagging. Note the very clean advanced healing and incision closure, suture still present.

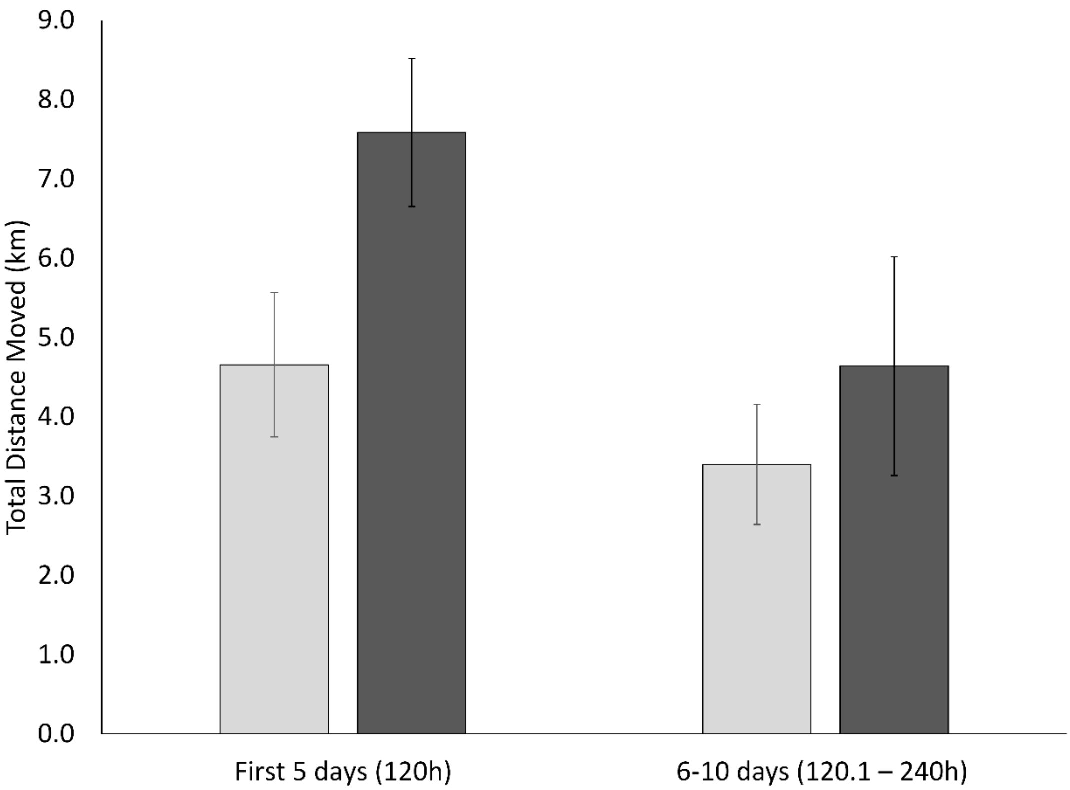

Figure 2. The mean total distance moved TDM (± SE) from five different tagging events over two concurrent five day periods (0-5 days and 6-10 days) post-surgery of

newly tagged fish (light grey bars; 0-5 days n= 61; 6-10 days n= 47) and control previously tagged fish (dark grey bars; 0-5 days n= 55; 6-10 days n= 58).

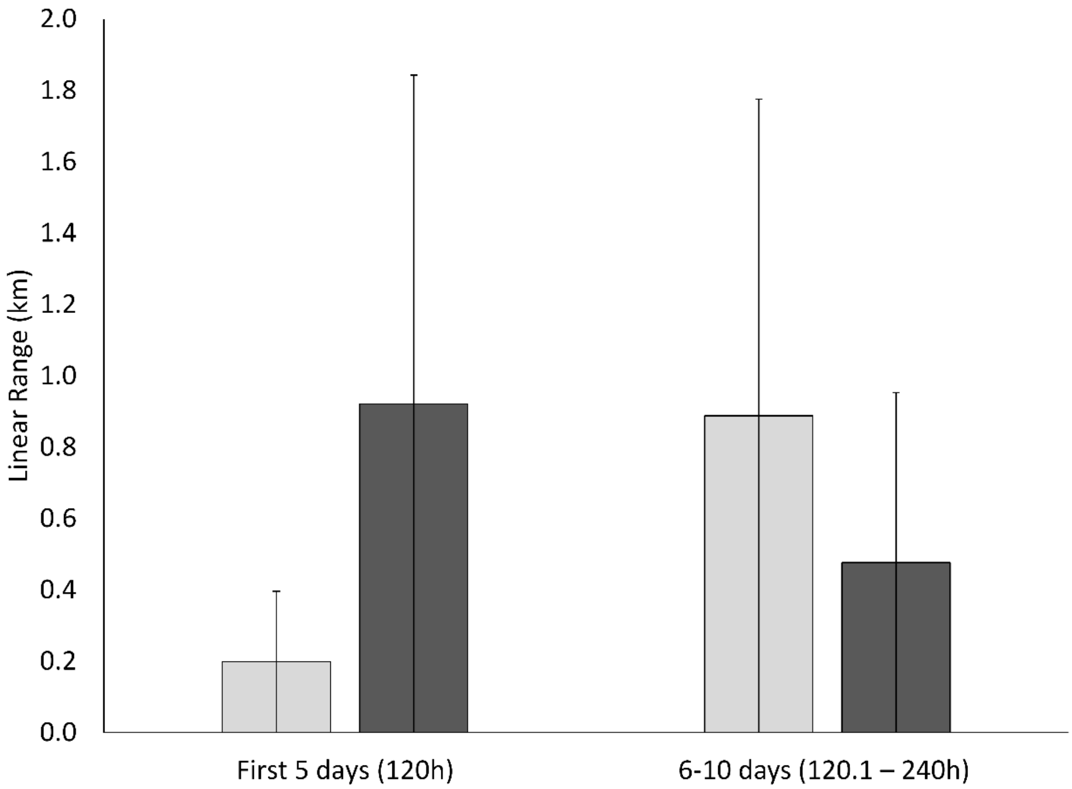

Figure 3. The mean linear range LR (± SE) from five different tagging events over two concurrent five day periods (0-5 days and 6-10 days) post-surgery of newly tagged fish (light grey bars; 0-5 days n= 61; 6-10 days n= 47) and control previously tagged fish (dark grey bars; 0-5 days n= 55; 6-10 days n= 58).

Figure 4. Movement patterns for A; tag ID 12255 (male), B; 12257 (female) and C; ID 12266 (male) showing behaviour before and after translocation. Return journey to Sincil Dyke shown in red, which took 11, 6 and 24 days after release approx. 35km downstream respectively.

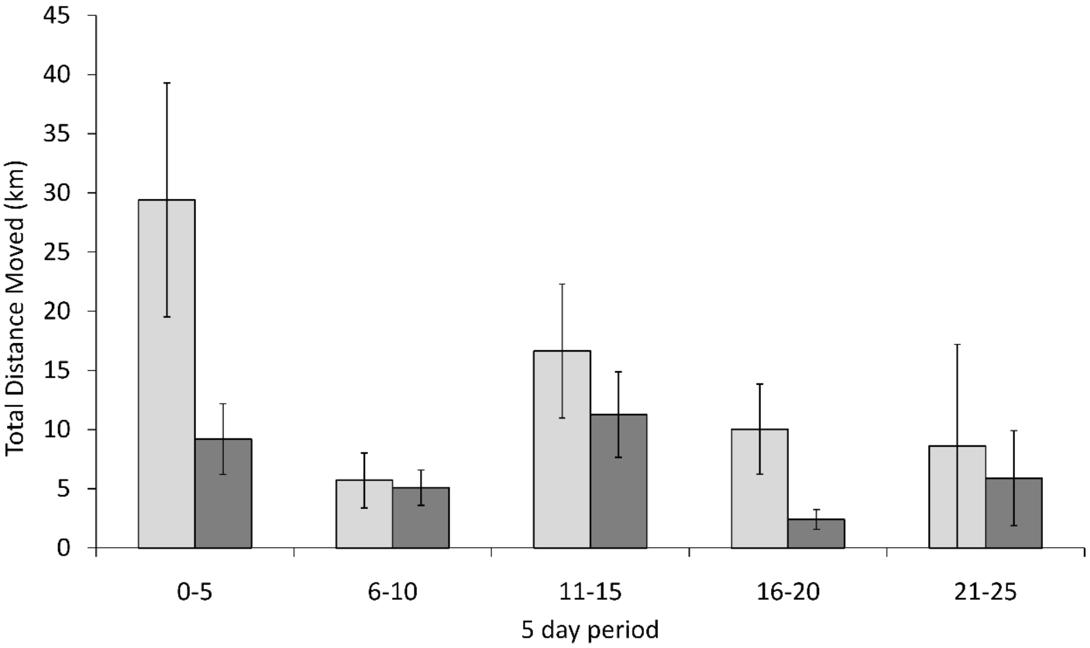

Figure 5. The mean total distance moved TDM (± SE) over five concurrent five day periods up to twenty five days after release for the translocated group (n=3; light grey bars) and non-translocated control group (n=7; dark grey bars).

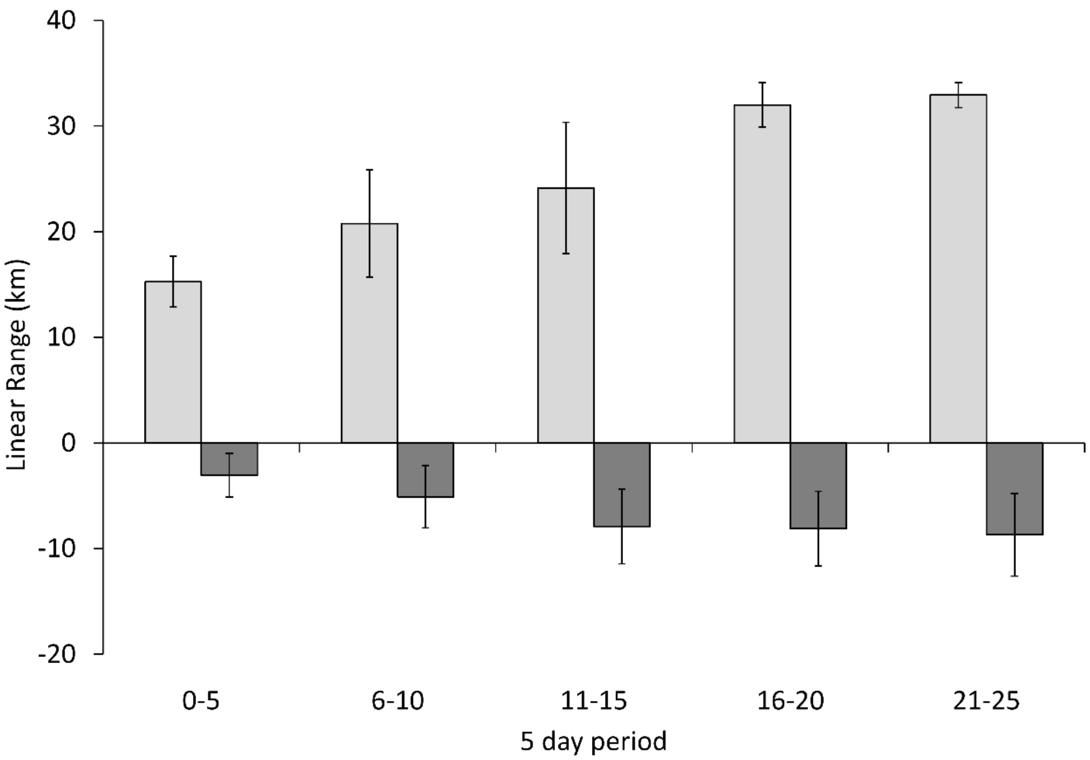

Figure 6. The mean linear range LR (± SE) over five concurrent five day periods up to twenty five days after release for the translocated group (n=3; light grey bars) and non-translocated control group (n=7; dark grey bars).

Table 1 Details of the seven groups of fish that were tagged between 2006 and 2009 and the tagging events used to compare the spatial-temporal behaviour of newly tagged fish with fish that had been tagged previously, which were present in the same waterbody and therefore subject to the same environmental variables.

Group No.	Tagging event No. for effects of tagging analysis (ETA)	Date Tagged	No. of new fish	No. of previously tagged fish used in ETA	Tag Type	Capture Method	Mass mean ± SD [range], (kg)	Fork Length (mean ± SD [range], mm)	Stated Tag Life (days)	No. days Tracked (days)
1	-	21/11/2006	7	-	V9	Electro fishing	2.46 ± 0.34 [1.92-2.94]	480.0 ± 23.4 [440-512]	135-330	108-501
2	1	28/02/2007	7	7	V9	Rod and Line	2.30 ± 0.14 [2.09-2.49]	485.1 ± 17.4 [460-510]	80-330	69-495
3	2	10/10/2007	10	6	V9	Rod and Line	2.31 ± 0.24 [1.92-2.66]	490.5 ± 18.8 [461-520]	210	208-210
4	3	04/12/2007	19	16	V9	Seine netting	2.40 ± 0.25 [1.95-2.91]	485.5 ± 14.7 [458-511]	210	153-210
5	-	01/10/2008	15	-	V13	Electro fishing	2.48 ± 0.21 [1.98-2.83]	486.3 ± 9.79 [468-505]	526-621	202-629
6	4	10/12/2008	13	15	V13	Electro fishing	2.22 ± 0.23 [1.92-2.83]	479.8 ± 16.3 [454-522]	526-621	132-543
7	5	25/02/2009	12	28	V13	Electro fishing	2.34 ± 0.22 [2.04-2.72]	491.1 ± 17.7 [452-518]	526-621	40-534

Table 2 Results of binomial GLMM, using just the newly tagged fish to test whether capture method impacted movements in the first 5 days (120h).

Model	Parameter	Estimate	*Z*	*P*
(a) Total distance moved	Electric fishing	0		
	Rod and line	0.54 ± 0.30	1.82	0.069
	Seine net	0.59 ± 0.29	2.06	0.039
(b) Linear range	Electric fishing	0		
	Rod and line	1.08 ± 0.33	3.28	0.001
	Seine net	0.48 ± 0.33	1.42	0.155
(c) Direction	Electric fishing	0		
	Rod and line	-0.32 ± 0.69	-0.47	0.637
	Seine net	0.38 ± 0.74	0.51	0.613

Table 3 Results of binomial GLMM, using just the newly tagged fish to test whether capture method impacted movements at 6-10 days (120.1 – 240h) post-release.

Model	Parameter	Estimate	*Z*	*P*
(a) Total distance moved	Electric fishing	0		
	Rod and line	0.45 ± 0.79	0.57	0.566
	Seine net	-1.79 ± 0.99	-1.79	0.073
(b) Linear range	Electric fishing	0		
	Rod and line	0.68 ± 0.63	1.09	0.278
	Seine net	-1.25 ± 0.82	-1.54	0.125
(c) Direction	Electric fishing	0		
	Rod and line	0.74 ± 1.07	0.69	0.491
	Seine net	-0.12 ± 1.23	-0.10	0.922

Table 4 Mann-Whitney U tests results for comparisons of TDM and LR between fish captured and translocated ~35 km downstream, and control fish not captured or translocated. * denotes significance at 0.05.

Concurrent five day period	Total Distance Moved	Linear Range
1 (1-5 days)	U = 25, $n_1 = 3$, $n_2 = 7$, $P = 0.0674$	U = 27, $n_1 = 3$, $n_2 = 7$, $P = 0.0227$*
2 (6-10 days)	U = 19, $n_1 = 3$, $n_2 = 7$, $P = 0.6475$	U = 27, $n_1 = 3$, $n_2 = 7$, $P = 0.0227$*
3 (11-15 days)	U = 19, $n_1 = 3$, $n_2 = 7$, $P = 0.6485$	U = 27, $n_1 = 3$, $n_2 = 7$, $P = 0.0227$*
4 (16-20 days)	U = 24.5, $n_1 = 3$, $n_2 = 7$, $P = 0.0855$	U = 27, $n_1 = 3$, $n_2 = 7$, $P = 0.0227$*
5 (21-25 days)	U = 16, $n_1 = 3$, $n_2 = 7$, $P = 1.0000$	U = 27, $n_1 = 3$, $n_2 = 7$, $P = 0.0227$*