Bulgarian Journal of Agricultural Science, 21 (Supplement 1) 2015, 12–16
Agricultural Academy

TAG RETENTION, GROWTH RATE, AND SURVIVAL OF JUVENILE PIKE TAGGED WITH VISIBLE IMPLANT ELASTOMER AND CODED WIRE TAGS

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Abstract

SZCZEPKOWSKI, M., Z. ZAKĘŚ, B. SZCZEPKOWSKA, I. PIOTROWSKA, M. KOZŁOWSKI, K. WUNDERLICH and A. KAPUSTA, 2015. Tag retention, growth rate, and survival of juvenile pike tagged with visible implant elastomer and coded wire tags. *Bulg. J. Agric. Sci.,* Supplement 1, 21: 12–16

The aim of the study was to determine the effectiveness of tagging of juvenile pike with visible implant elastomer (VIE) and coded wire (CWT) tags. Three size groups of juvenile pike were tagged with average body weights of 2.7 g (group I), 5.2–6.2 g (group II), 13.5–16.9 g (group III). After tagging, the fish were reared in RAS for 48 (group I) or 28 days (groups II and III). Tagging with VIE had no impact on the basic rearing indicators of juvenile pike in groups I and II, but differences were noted among the largest pike individuals (group III). Final body weights and lengths were higher in the control group ($P < 0.01$). The survival of the fish was also higher in the untagged fish at 96.7%, while that in the tagged fish was 91.3% ($P < 0.05$). At the end of the experiment the visibility of elastomer tags was 100% in all groups studied. Tagging with CWT had no impact on the rearing indicators measured in any of the groups. CWT retention depended on the size of the tagged fish; in groups I and II it was 65.0 and 56.5%, respectively, and was statistically significant lower than in group III (the largest fish tested), in which it was 98.6% ($P < 0.05$). The results indicate that VIE tags are suitable for short-term studies for pike above 2.7 g. High effectiveness with CWT was only achieved in pike weighing more than 10 g.

Key words: coded-wire tags, pike, tag retention, visible implant elastomer tags

Introduction

Tagging is one of the most important ways of making it possible to identify individual fish or groups of them. Many tagging methods have been developed based on mutilating body parts (usually fins), fluorescent dyes, and external and internal tags (Bergman et al., 1992), among others. The different methods differ in many aspects, including tag durability, which is the period during which the fish can be identified effectively. In some instances, tagging procedures can directly impact fish growth, survival, and behavior (Soula et al., 2012).

One of the important applications of tagging is to evaluate the effectiveness of stocking. Effective technologies for producing stocking material have been developed for many species, and these materials can potentially be used to stock open waters. Pike, (*Esox lucius* L.), is one such species. It inhabits a wide range of territory that includes North America and Eurasia (Crossman, 1996), and it is a significant species in both commercial and recreational fisheries. Recently developed rearing technology that uses formulated feed permits rearing pike of various sizes in recirculating aquaculture systems (RAS) (Wolnicki and Górny, 1997; Kucska et al., 2005; Szczepkowski, 2009). There is, however, a decided

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lack of information regarding the effectiveness of stocking material produced in this type of system.

The aim of the study was to determine the effectiveness of tagging juvenile pike reared in RAS with elastomer and magnetic tags and the impact of the implant procedure on the growth rate and survival of fish.

Materials and Methods

The material used for tagging was obtained through the artificial reproduction of wild pike spawners from Mazurian lakes in northeastern Poland in the pre-spawning season. Egg incubation and larval rearing were conducted in RAS, according to methods described previously (Szczepkowski, 2009). The fish were fed commercial formulated feed exclusively from the beginning of exogenous feeding (Szczepkowski, 2009).

Tagging procedure and fish rearing

Two tagging methods were applied: coded wire or magnetic tags (CWT; Northwest Marine Technology, Shaw Island, WA, USA (NMT)) and visible implant elastomer tags (VIE; NMT). The CWT was inserted with an automatic Mark IV Injector (Northwest Marine Technology, USA). These tags are small pieces of wire with a diameter of 0.25 mm and a length of 1.6 mm. VIE tags are made of a liquid polymer with a hardening medium that is implanted using a Manual Elastomer Injector equipped with a 0.3 ml syringe. Pink fluorescent dye was chosen for the study. Both CWT and VIE tags were implanted in the muscle of the left gill cover near the eyeball. Immediately prior to tagging, the fish were anesthetized by immersion in a Propiscin (IFI Olsztyn, Poland) anesthetic solution at a concentration of 1 ml l^{-1} water. Tagging was done in batches of 50 specimens: applying VIE tags to one group lasted about 10 min, while that with CWT lasted about 5 min. The tagging manipulation time (anesthetizing, measuring, tagging) and that of the control group (anesthetizing and measuring) were similar. The period under which the fish were anesthetized did not exceed 5–6 min.

Immediately following tagging the fish with CWT, the presence of the tags was tested using a Quality Control Device (NMT). The effectiveness of the VIE tags was verified with a UV flashlight (NMT). The tagged fish were those in which the presence of a tag was confirmed. Three size groups of juvenile pike were tagged with either CWT or VIE tags, as follows:

– group I – mean body weight 2.7 g, age 46 days post hatch (DPH) (VIE, CWT) (number of fish – 1350 individuals, of which 450 were tagged with VIE, 450 with CWT, and 450 individuals were the control group and were not tagged);

– group II – mean body weight range from 5.2 g, age 55 DPH (CWT) to 6.2 g, age 66 DPH (VIE) (number of fish – 1350 individuals, of which 450 were tagged with VIE, 450 with CWT, and 450 individuals were the control group and were not tagged);

– group III – mean body weight from 13.5 g, age 87 DPH (VIE) to 16.9 g, age 95 DPH (CWT) (number of fish – 900 individuals, of which 300 were tagged with VIE, 300 with CWT, and 300 individuals were the control group and were not tagged).

Fish from each of the size classes – individuals tagged with CWT or VIE and the control group – were divided into three replicates of equal number and stocked into tanks made of artificial material with volumes of 1m^3 each in a RAS. The stocking density was 150 individuals per 1 m^3 in groups I and II and 100 individuals per 1 m^3 in group III. The water temperature was maintained within the range of 18.0–22.5°C. The oxygen content at the rearing tank outflow did not decrease below 6.5 mg l^{-1}, the content of total ammonia nitrogen (CAA = $NH_4^+ + NH^3$) did not exceed 0.2 mg l^{-1}, and water pH ranged from 7.1 to 7.8. The rearing period was 48 days in group I and 28 days in groups II and III.

The fish were fed 24 h per day by an automatic band feeder (FIAP, Fishtechnik GmbH, Ursensollen, Germany) with commercial salmonid feed (Skretting, France): group I received Nutra 1.5 (52% protein, 20% fat, 19.9 MJ kg^{-1} digestible energy, 1.5 mm granule size), and groups II and III received E-Stella 1P (47% protein, 14% fat, 18.4 MJ kg^{-1} digestible energy, 3 mm granule size). The daily feed ration was 5% of the fish biomass in group I, 4.5% of that in group II, and 2% of that in group III.

Measurements, calculations, and statistical analysis

At the beginning and the end of each experiment, the body weight (to the nearest 0.1 g) and body length Lc (to the nearest 1 mm) of 60 individuals from each experimental variant were measured. Fish mortality was monitored daily throughout rearing. The data collected were used to calculate the following rearing indicators:

– specific growth rate, SGR (% d^{-1}) = 100 × (ln final body weight (g) – ln initial body weight (g)) × rearing period^{-1} (days),

– Fulton condition coefficient, CF = 100 × (body weight (g) × body length Lc^{-3} (cm)),

– feed conversion ratio, FCR = weight of feed consumed (g) × (final stock biomass (g) – initial stock biomass (g))$^{-1}$,

– stock survival, S (%) = 100 × (final abundance (indiv.) × initial abundance^{-1} (indiv.)),

– tag retention; R (%) = 100 × (number of fish with tags on the final day of the experiment (indiv.) × total number of fish on the final day of the experiment^{-1} (indiv.)).

These results were analyzed statistically using Statistica 5.0 PL. Simultaneously, variance was verified with Levene's test. Percentage data were transformed with the *arcsin* function. Single factor analysis of variance (ANOVA) and Tukey's test (HSD) ($P \leq 0.05$) were used to determine significant differences between the groups of fish analyzed. Mean values from the replicates were used in the calculations.

Results

Tagging with elastomer tags (VIE) did not impact on the basic rearing indicators of juvenile pike in groups I and II (Table 1; $P > 0.05$).

Differences were noted, however, among the largest pike studied (group III). The final body weights and body lengths were noted in the control group ($P < 0.05$). Fish survival was also the highest in the groups of untagged fish at 96.7%, while in the tagged fish it was 91.3% ($P < 0.05$). A high feed conversion ratio was noted in group III of 2.12 in the control group and 3.10 in the tagged fish group. Short-term VIE tag retention in all of the pike size groups studied was 100% (Figure 1).

For the fish tagged with CWT, no differences were noted in rearing indicator values among the different size groups of tagged and untagged fish (Table 2). Fish survival was high and exceeded 96%. The FCR value was low and did not exceed 1.3 (group II; Table 2). CWT retention depended on fish size (Figure 1). In groups I and II tag retention was 65.0 and 56.5% respectively, and was statistically significantly lower than that in group III (the largest fish studied) which was 98.6% ($P < 0.05$).

Discussion

Both elastomer and magnetic tags are currently used in studies of various fish species (Thomassen et al., 2000;

Table 1

Rearing indicators of three size groups of juvenile pike tagged with VIE (mean value ± SD. n = 3) (for explanation of groups see Materials and methods section)

Indicator	Group I		Group II		Group III	
	VIE	Control	VIE	Control	VIE	Control
Initial body weight (g)	2.8 ± 0.0	2.8 ± 0.0	6.2 ± 0.2	6.2 ± 0.2	13.4 ± 0.7	13.6 ± 0.3
Final body weight (g)	19.1 ± 0.3	17.4 ± 0.9	10.8 ± 0.2	10.8 ± 0.3	18.7 ± 0.2^{a}	20.5 ± 0.2^{b}
Initial body length lc (cm)	6.8 ± 0.0	6.8 ± 0.0	9.0 ± 0.1	9.0 ± 0.1	11.7 ± 0.2	11.7 ± 0.1
Final body length lc (cm)	13.2 ± 0.1	12.8 ± 0.2	11.1 ± 0.1	11.1 ± 0.0	13.5 ± 0.0^{a}	13.8 ± 0.0^{b}
Initial condition coefficient K ( )	0.89 ± 0.01	0.90 ± 0.01	0.86 ± 0.01	0.84 ± 0.01	0.83 ± 0.02	0.84 ± 0.02
Final condition coefficient K ( )	0.80 ± 0.00	0.82 ± 0.01	0.81 ± 0.02	0.79 ± 0.02	0.76 ± 0.01	0.78 ± 0.01
Specific growth rate SGR (% d^{-1})	3.98 ± 0.03	3.79 ± 0.11	1.94 ± 0.07	1.99 ± 0.22	1.20 ± 0.19^{a}	1.43 ± 0.07^{b}
Feed conversion ratio FCR ( )	0.75 ± 0.01	0.83 ± 0.05	1.15 ± 0.08	1.28 ± 0.10	3.10 ± 0.49	2.12 ± 0.38
Survival (%)	97.6 ± 1.4	99.8 ± 0.2	94.8 ± 1.3	90.5 ± 2.1	91.3 ± 0.7^{a}	96.7 ± 1.3^{b}

Values marked with letter indexes within fish size groups differ significantly statistically ($P \leq 0.05$).

Table 2

Rearing indicators of three size groups of juvenile pike tagged with CWT (mean value ± SD. n = 3) (for explanation of groups see Materials and methods section)

Indicator	Group I		Group II		Group III	
	CWT	Control	CWT	Control	CWT	Control
Initial body weight (g)	2.8 ± 0.0	2.8 ± 0.0	5.3 ± 0.1	5.1 ± 0.2	16.9 ± 0.2	16.9 ± 0.3
Final body weight (g)	15.0 ± 0.3	17.4 ± 0.9	11.4 ± 0.4	11.6 ± 0.6	27.6 ± 1.1	25.4 ± 2.0
Initial body length lc (cm)	6.8 ± 0.0	6.8 ± 0.0	8.2 ± 0.1	8.1 ± 0.1	12.5 ± 0.1	12.4 ± 0.1
Final body length lc (cm)	12.3 ± 0.1	12.8 ± 0.2	10.8 ± 0.1	10.9 ± 0.2	14.4 ± 0.1	14.1 ± 0.3
Initial condition coefficient K ( )	0.89 ± 0.01	0.90 ± 0.01	0.94 ± 0.01	0.94 ± 0.01	0.87 ± 0.01	0.88 ± 0.01
Final condition coefficient K ( )	0.79 ± 0.01	0.82 ± 0.01	0.88 ± 0.01	0.87 ± 0.01	0.90 ± 0.01	0.88 ± 0.01
Specific growth rate SGR (% d^{-1})	3.49 ± 0.06	3.79 ± 0.11	2.71 ± 0.18	2.93 ± 0.07	1.74 ± 0.10	1.43 ± 0.25
Feed conversion ratio FCR ( )	0.98 ± 0.03	0.83 ± 0.05	1.26 ± 0.02	1.25 ± 0.12	0.99 ± 0.15	1.07 ± 0.12
Survival (%)	98.4 ± 0.8	99.8 ± 0.2	99.0 ± 0.3	98.7 ± 0.2	96.7 ± 2.6	99.3 ± 0.3

No statistically significant differences were noted among fish tagged with CWT and control fish within size groups ($P > 0.05$).

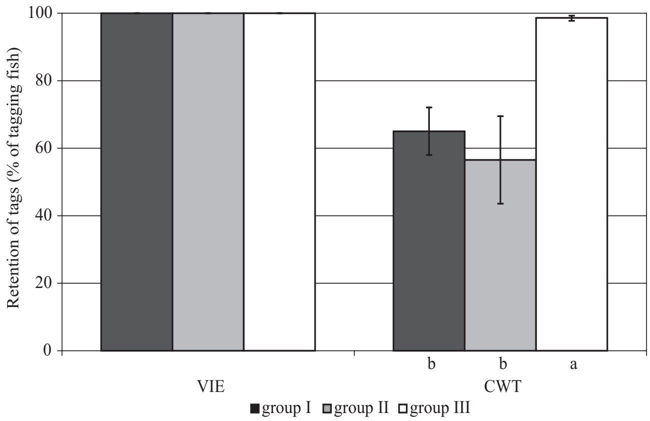

Fig. 1. Retention of CWT and VIE in juvenile pike (mean value ± SD, n = 3) (for explanation of groups see Materials and methods section)

Jepsen et al., 2010). Their small size is an advantage as it allows tagging small fish and makes reading them easy. The results of our experiment demonstrate that tagging with VIE tags and CWT does not impact the growth or survival of juvenile pike weighing no more than 10 g. Similar results were noted in other species tagged with these tags (Olsen and Vøllestad, 2001; Blankenship and Thompson, 2003; Brennan et al., 2005). In the current experiment, a negative impact was noted during VIE tag implantation in the largest pike group tested (body weight above 13.9 g). Soula et al. (2012) confirmed a dependence between mortality and size in fish tagged with VIE tags. Higher mortality was noted among red porgy (*Pagrus pagrus* (L.)) when the fish weighed less than 1 g, while none was noted in larger fish (above 1 g). In this case, mortality could be linked with greater sensitivity to manipulation and to more difficulty in tagging with this type of material. Increased mortality in the present study in the larger fish tagged seems to have been caused by other factors, such as the strong negative reaction of pike this size to any environmental changes and any manipulation, including harvesting (Szczepkowski, 2009). This could also indicate that the tagging procedure, which differed from the way the fish were held during tagging in the other two cases as well as in how they were counted after tagging - in the case of VIE it was done manually, while CWT tags were counted with an automatic counter that is much more disruptive for the fish. It should be mentioned, however, that while tagging pikeperch (*Sander lucioperca* (L.)) of sizes similar to those in the current study with VIE tags and CWT, it was not observed the negative impact of tagging procedure on rearing indicators (Zakęś et al., 2013).

Short-term (28–48 days) tag retention was significantly higher with VIE tags as they were visible in all of the tagged fish. High retention with these tags has been observed in other studies (Goldsmith et al., 2003) as well as decreasing retention over longer periods (Brennan et al., 2005). High VIE tag retention was noted in pike reared in ponds for three and five months following tagging (98–99%, Szczepkowski et al., 2012). It was also noted that as the fish grew, the tags shifted position, which increased the difficulty of reading them.

With CWT tagging, tag losses usually occur immediately after tagging. In eel (*Anguilla anguilla* L.) most tags are lost within two hours of tagging (Thomassen et al., 2000). Brennan et al. (2005) report that CWT retention stabilizes thirty days after tagging and remains at a similar level for the subsequent six months, which indicates that these tags are more suitable for long-term tagging. In our studies we observed a clear difference in CWT retention depending on fish size. Satisfactory retention rates above 90%, which are close to the values observed in other studies (Tipping and Heinricher, 1993; Thomassen et al., 2000; Zakęś et al., 2013), were only noted in our study in fish with body weights above 13 g. The short-term CWT retention rates in the pike groups with lower weights (under 10 g) did not exceed 60–70%. This is probably linked with weak development in the gill cover muscles in which the tags are implanted. It appears that CWT tags should be implanted in another location on the body of pike under 10 g. Numerous studies have shown that the choice of the tag implantation site is significant for its retention. CWT tags were proven to be ineffective when implanted near the nose in eel with 94% losses in the course of one week, but retention was substantially higher (4% loss in the same period) when the tags were implanted in the muscles (Simon and Dörner, 2005). In muskellunge (*Esox masquinongy* Mitch.) passive integrated transponder (PIT) tag retention was higher when implanted in the dorsal muscle than in the cheek (Younk et al., 2010), while CWT retention was higher in the cheek than in the dorsal fin (Tipping and Heinricher, 1993).

The results of our study indicate that VIE are suitable for short-term studies of pike with body weights exceeding 2.7 g. CWT tags are only highly effective in individuals with body weights above 10 g. Using these tags on pike with body weights under 10 g requires further study to determine if there are better, more effective CWT tagging places or implementation methods.

The study was co-financed with European Union funds from the Operational Programme "Sustainable Development of the Fisheries Sector and Coastal Fishing Areas 2007–2013" (Contract No. 00004-61724-OR1400001/09/11) and from statutory topic number S-028 of the Stanisław Sakowicz Inland Fisheries Institute, Olsztyn, Poland.

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