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Short-term evaluation of visible implant alpha tags in juveniles of three fish species under laboratory conditions

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Visible implant alpha (VI alpha) tag-induced changes in mortality and condition, as well as tag retention and readability, were examined during a 4-week period for juveniles of three fish species: tiger muskellunge *Esox masquinongy* × *Esox lucius* (91 ± 7 mm total length, L_T, mean ± s.d.), Snake River cutthroat trout *Oncorhynchus clarki behnkei* (84 ± 8 mm) and rainbow trout *Oncorhynchus mykiss* (85 ± 5 mm). Mortality and condition did not differ between tagged fish and control fish for any species and overall tag retention rates were high (92% for *E. masquinongy* × *E. lucius*, 91% for *O. c. behnkei* and 100% for *O. mykiss*). Short-term readability of VI alpha tags was low in juvenile *E. masquinongy* × *E. lucius* and juvenile *O. c. behnkei*. Therefore, it is not recommend to use VI alpha tags in juvenile *E. masquinongy* × *E. lucius* or juvenile *O. c. behnkei* for periods >2 weeks, but VI alpha tags seem to be suitable for juvenile *O. mykiss* for a period of at least 4 weeks.

Key words: condition; mortality; readability; retention; tagging.

INTRODUCTION

Fisheries management decisions are often based on growth, abundance and mortality estimates gained from mark-recapture data (Miranda & Bettoli, 2007). The ability to effectively mark fishes is essential to the accuracy of these estimates. Further, a unique mark is necessary for individual-based information such as growth, condition or movement. Visible implant alpha (VI alpha; Haw *et al.*, 1990) tags have a unique three-digit alphanumeric code that, although internally implanted, is externally visible. This ideally provides the advantages of both internal and external tags (*e.g.* reduced secondary infection risk and easily accessible). Although there is a large body of literature on the retention of VI alpha tags (*e.g.* Table I), there is little information on tag-induced changes in growth, mortality and readability in juvenile fishes. VI alpha tags are probably suitable for individual identification of juvenile fishes because of the tag's small size, ease of application and readability and low cost relative to other uniquely identifiable tags.

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TABLE I. Review of salmonid VI alpha tagging studies. Retention rates and readable rates shown for last check on fish if there were multiple discrete checks

Common name	Scientific name	Type of tag	Retention rate (%)	Readable rate (%)	Fish size	Duration	Reference
Arctic charr	*Salvelinus alpinus*	1·0 × 2·5 mm; soft	68	100	100–150 mm L_F	30–365 days	Rikardsen (2000)
			96	100	150–200 mm L_F		
		1·0 × 2·5 mm; soft	46	100	100–150 mm L_F	25–70 days	
			91	100	150–229 mm L_F		
Arctic grayling	*Thymallus arcticus*	1·0 × 2·5 mm	98	–	137–236 mm L_T	30 days	McMahon *et al.* (1996)
Atlantic salmon	*Salmo salar*	2·0 × 4·0 mm	84	82	100–1301+ g	10 months	Kincaid & Calkins (1992)
		1·0 × 3·0 mm	49	100	21–99 g		
		2·5 × 1·0 × 0·1 mm	74	86·5*	0·9–3·0 kg	6–24 weeks	Treasurer (1996)
			77·3	100*	39·0–67·0 g	6–20 days	
			61·9	90·4*	38–62 g	8–24 weeks	
		Not specified	56, 31	–	23·44 ± 4·38 g (mean ± S.D.)	*c.* 5 months, after 1 sea winter	Moffett *et al.* (1997)
Brook trout	*Salvelinus fontinalis*	3·0 × 1·5 × 0·1 mm	63–100	83–100	211–470 mm L_T	29–100 days	Hughes *et al.* (2000)
		2·5 × 1·0 × 0·1 mm	89–100	94–100	211–470 mm L_T	29–100 days	
		2·5 × 1·0 × 0·1 mm	97–100	74–95	260–355 mm L_T	354–454 days†	
		2·5 × 1·0 × 0·1 mm	75	92‡	197–265 mm L_T	7–251 days	Zerrenner *et al.* (1997)
		2·5 × 1·0 × 0·1 mm	50	–	130–160 mm L_T	Over the course of 1 year	Bryan & Ney (1994)
		2·5 × 1·0 × 0·1 mm	80	–	160–199 mm L_T	Over the course of 1 year	
		2·5 × 1·0 × 0·1 mm	100	–	200+ mm L_T	Over the course of 1 year	
		1·0 × 2·5 mm	59	–	135–231 mm L_T	30 days	McMahon *et al.* (1996)
Brown trout	*Salmo trutta*	2·5 × 1·0 mm; rigid	72·2 ± 5·9 (mean ± S.E.)	–	235–273 mm L_F§	6 months	Summers *et al.* (2006)
		2·5 × 1·0 mm; soft	59·1 ± 6·5 (mean ± S.E.)	–	255–303 mm L_F§	6 months	
Lake trout	*Salvelinus namaycush*	2·0 × 4·0 mm	45	77	100–1301+ g	10 months	Kincaid & Calkins (1992)

TABLE I. *Continued*

Common name	Scientific name	Type of tag	Retention rate (%)	Readable rate (%)	Fish size	Duration	Reference
		1·0 × 3·0 mm	41	0	21–99 g		
Rainbow trout	*Oncorhynchus mykiss*	1·0 × 2·0 mm	82||	97¶	140–240 mm L_T	10–120 days	Mourning *et al.* (1994)
		Three sizes**	95·8**	–	149–280 mm L_T**	22–44 weeks**	Haw *et al.* (1990)
		1·5 × 3·5 mm; soft	58·9	–	197·5 ± 21·1 mm L_T (mean ± S.D.)	25 days	Isely & Grabowski (2004)††
		1·5 × 3·5 mm; soft	82·6	100	201 ± 49·7 mm L_T	25 days	Isely *et al.* (2004)
		1·0 × 2·5 mm	51	–	153–388 mm L_F	335 days	McMahon *et al.* (1996)
Cutthroat trout	*Oncorhynchus clarki*	1·0 × 2·5 × 0·08 mm	94	99·4	200–307 mm L_F	3–21 months	Blankenship & Tipping (1993)
	Oncorhynchus clarki	1·0 × 2·5 mm	74	–	> 200 mm L_F‡‡	270–430 days	McMahon *et al.* (1996)
		1·0 × 2·5 mm	9	–	150–175 mm L_F §§		
	Oncorhynchus clarki lewisi	2·5 × 1·0 × 0·1 mm	58	95	100–324 mm L_F	1–406 days	Shepard *et al.* (1996)

L_F, fork length; L_T, total length.
*Taken from per cent illegible.
†BKT used in Zerrenner *et al.* (1997).
‡Taken from per cent unreadable, does not include tags only readable under light and magnification (29%).
§Mean length at tagging for different batches.
||Taken from tag loss (calculated for fish alive on sampling date).
¶Taken from per cent unreadable.
**Tags were 0·08–0·18 mm thick, 0·6–1·3 mm wide and 1·5–4·0 mm long and retention rate is combined over three size groups of tags.
††All *Oncorhynchus mykiss* were sneaker males.
‡‡Length at recapture.
§§Estimated length at tagging for recaptures < 200 mm L_F.

The usefulness of VI alpha tags was evaluated in juvenile tiger muskellunge *Esox masquinongy* Mitchill 1824 × *Esox lucius* L. 1758, Snake River cutthroat trout *Oncorhynchus clarki behnkei* Montgomery 1995 and rainbow trout *Oncorhynchus mykiss* (Walbaum 1792). VI alpha tags have not been evaluated in esocids and retention rates vary considerably for salmonids (Table I). Differences in tag-retention rates for salmonids are often attributed to differences in size at tagging with larger fish retaining a greater percentage of tags (Niva, 1995; Shepard *et al.*, 1996; Hughes *et al.*, 2000). Additionally, differences in fish growth, morphology, healing time and other biotic and abiotic influences necessitate the need for species- and size-specific evaluations of tagging effects on fish mortality, growth, tag retention and tag readability. Therefore, the objectives of this study were to (1) determine if VI alpha tagging influenced mortality or condition of fishes and (2) determine retention rates and readability of VI alpha tags.

MATERIALS AND METHODS

TAGGING METHODS

VI alpha tag-induced changes in mortality and condition, and tag retention and readability, were examined during a 4-week period for juvenile *E. masquinongy* × *E. lucius* ($n = 143$), *O. c. behnkei* ($n = 69$) and *O. mykiss* ($n = 48$; Table II). Each species of fish was held in two round fibreglass recirculating tanks (1·2 m diameter × 0·9 m depth). Tanks were exposed to a light regime consisting of 12L:12D. Fishes were allowed to acclimate to the laboratory environment until initial mortalities were reduced or until logistics allowed tagging.

Fishes were tagged with VI alpha tags (1·2 mm x 2·7 mm; Northwest Marine Technology, Inc.; www.nmt.us). Prior to tagging, fishes were anaesthetized with tricaine methanesulphonate (MS-222; Haw *et al.*, 1990; Kincaid & Calkins, 1992), and total length (L_T; mm) and mass (M; g) were measured. Fishes were assigned one of the three treatments: (1) green postorbital tag, (2) yellow postorbital tag or (3) control. Controls were subjected to identical handling protocols as tagged fishes, including being held out of water for the approximate time required to tag fishes but were not injected with the needle, that is controls were included to account for confounding responses due to handling. Control fishes were also marked with a fin clip to distinguish control fishes from tagged fishes that did not retain their tag. Removal of fins has been shown to have no effect on growth or survival of marked fishes (Gjerde & Refstie, 1988). Tags were inserted on the fish's left side by right-handed taggers (insertion point was dorsal to tag once implanted). Tags were inserted into the lightly pigmented postorbital area in all species (Haw *et al.*, 1990). Yellow tags were more easily seen than green tags following the first trial using *E. masquinongy* × *E. lucius*. Therefore, only yellow tags were used for the *O. c. behnkei* and *O. mykiss* trials.

Immediately following tag injection, readability of tag numbers was rated on a scale of 1–4. A tag on which all numbers were easily read without the use of a ultraviolet light (Northwest Marine Technology, Inc.) was given a rating of 1. A tag on which numbers were only partially readable or not readable but became fully readable with the use of a light was given a rating of 2. A tag on which numbers were only partially readable or not readable and became partially readable but not fully readable with the use of a light was given a rating of 3. A tag that was visible, but on which no numbers were readable with or without the use of a light was given a rating of 4. Fish with an initial tag readability of 3 or 4 (*i.e.* poor initial insertion) were excluded from further analysis.

All fishes were allowed to recover in a small holding tank following the initial tag readability assessment, placed in a salt bath for 1–2 min and randomly assigned to one of two round fibreglass tanks (1·2 m diameter × 0·9 m depth). Retention and readability were checked on two separate days after tagging at *c.* 14 and 28 days. On these days, fishes were again anaesthetized with MS-222, L_T and M were measured, and presence and readability of tags were recorded. Mortality was recorded daily.

TABLE II. Number, total length (L_T; mean ± S.D.), mass (M; mean ± S.D.) and retention rate (R; %) of control, tagged and tagged fishes that expelled their tags (Exp), at each stage of the experiment (initial tagging date, week 2 and week 4) for juvenile *Esox masquinongy* × *Esox lucius*, *Oncorhynchus clarki behnkei* and *Oncorhynchus mykiss*

	Initial		Week 2			Week 4		
	Control	Tagged	Control	Tagged	Exp	Control	Tagged	Exp
E. masquinongy × *E. Lucius*								
Days since tagging	–	0	–	14	14	–	26	26
Number of fish	70	73	70	66	4	52	54	5
L_T (mm)	91·0 ± 9·0	91·0 ± 7·0	105·7 ± 10·1	107·14 ± 8·5*	*	118·4 ± 10·4	119·9 ± 9·3*	*
M (g)	3·9 ± 1·2	4·0 ± 1·0	5·8 ± 1·8	6·1 ± 1·5*	*	8·1 ± 2·3	8·5 ± 2·1*	*
R (95% C.I.)	–	–	–	94 (85–98)	–	–	92 (81–97)	–
O. c. behnkei								
Days since tagging	–	0	–	15	15	–	28	28
Number of fish	34	35	34	32	3	34	31	3
L_T (mm)	85·8 ± 6·7	84·1 ± 8·1	90·0 ± 7·0	89·7 ± 9·3	83·3 ± 9·0	91·4 ± 6·8	92·5 ± 9·8	84·0 ± 10·4
M (g)	6·6 ± 1·8	6·3 ± 2·1	7·0 ± 1·9	7·2 ± 2·6	5·7 ± 2·1	7·2 ± 1·8	7·9 ± 2·9	5·3 ± 2·3
R (95% C.I.)	–	–	–	91 (75–98)	–	–	91 (75–98)	–
O. mykiss								
Days since tagging	–	0	–	14	14	–	28	28
Number of fish	23	25	23	25	0	23	25	0
L_T (mm)	86·1 ± 7·2	85·0 ± 4·9	101·8 ± 8·4	100·5 ± 5·8	–	112·4 ± 8·4	110·9 ± 5·6	–
M (g)	7·9 ± 2·1	7·7 ± 1·4	12·3 ± 2·9	12·0 ± 2·0	–	15·3 ± 3·2	15·2 ± 2·5	–
R (95% C.I.)				100 (83–100)			100 (83–100)	

*Three control fishes did not retain their mark making it impossible to distinguish them from tagged fish that expelled their tags; thus, neither group was included in L_T, M or condition analysis.

DATA ANALYSIS

Mortality rate was calculated as $M_t = \left[\left(n_0 - n_t\right) n_0^{-1}\right] 100$, where n_0 is the number of fish alive at the start of the experiment and n_t is the number of fish alive at time t of the experiment (Miranda & Bettoli, 2007). Ninety-five per cent confidence intervals (95% C.I.) were calculated following methods in Fleiss *et al.* (2003) for proportions assuming a binomial distribution. Mortality of tagged and control fishes was compared using χ^2-tests of the number of fishes alive at each check. Condition [Fulton's condition factor; Anderson & Neumann (1996)] of tagged and control fishes was compared at each check using t-tests. Fishes that expelled tags and survived until being checked for tags were included in the analyses as tagged fishes.

Tag-retention rate was calculated as $R_t = [(n_t)(n_0 - d_t)^{-1}]100$, where n_0 is the number of tagged fish at the start of the experiment, n_t is the number of live fish that retained their tags at time t and d_t is the number of dead fish that retained their tags at time t. Retention rate, as calculated here, assumes that tagged fish that died prior to a check would have retained their tags until the next check had they lived. Therefore, tag-retention rate may overestimate the actual per cent of retained tags.

Tag readability was calculated as the percentage of tags that were fully visible at each time period. Tags with a readability rating of 1 or 2 were considered fully visible as fishes in these two categories could be uniquely identified. The 95% C.I. for tag retention and readability were calculated following the methods in Fleiss *et al.* (2003) for proportions assuming a binomial distribution.

RESULTS

MORTALITY AND CONDITION

Mortality rate 4 weeks after tagging was 19% (95% C.I. = 11–30%) for tagged fish and 26% (95% C.I. = 17–38%) for control fish for the *E. masquinongy* × *E. lucius* trial, 3% (95% C.I. = 0–17%) for tagged fish and 0% (95% C.I. = 0–13%) for control fish for the *O. c. behnkei* trial and 0% (95% C.I. = 0–17%) for tagged fish and 0% (95% C.I. = 0–18%) for control fish for the *O. mykiss* trial. Mortality did not differ between tagged fish and control fish over the course of the study for *E. masquinongy* × *E. lucius* ($\chi^2 = 0{\cdot}25$, d.f. = 2, $P > 0{\cdot}05$), *O. c. behnkei* ($\chi^2 = 0{\cdot}01$, d.f. = 2, $P > 0{\cdot}05$) or *O. mykiss* ($\chi^2 = 0{\cdot}00$, d.f. = 2, $P > 0{\cdot}05$).

There were no differences in initial condition of tagged fish and control fish for *E. masquinongy* × *E. lucius* ($t_{stat} = -1{\cdot}19$, d.f. = 140, $P > 0{\cdot}05$), *O. c. behnkei* ($t_{stat} = 0{\cdot}56$, d.f. = 67, $P > 0{\cdot}05$) or *O. mykiss* ($t_{stat} = -0{\cdot}91$, d.f. = 46, $P > 0{\cdot}05$). There were also no differences in condition of tagged fish and control fish for *E. masquinongy* × *E. lucius* ($t_{stat} = -1{\cdot}01$, d.f. = 101, $P > 0{\cdot}05$), *O. c. behnkei* ($t_{stat} = -1{\cdot}44$, d.f. = 66, $P > 0{\cdot}05$) or *O. mykiss* ($t_{stat} = -1{\cdot}72$, d.f. = 46, $P > 0{\cdot}05$) after 4 weeks. Note that for the *E. masquinongy* × *E. lucius* trial, three control fish did not retain their fin clip making them inseparable from tagged fish that expelled their tags. Therefore, for the *E. masquinongy* × *E. lucius* trial, these three fish and those that expelled tags ($n = 5$) were not included in condition analysis.

RETENTION AND READABILITY

Overall retention rates were 92% (95% C.I. = 81–97%) for *E. masquinongy* × *E. lucius*, 91% (95% C.I. = 75–98%) for *O. c. behnkei* and 100% (95% C.I. = 83–100%) for *O. mykiss* (Table II). Retention from the initial tagging date to week 2 was lower than from week 2 to week 4 for all trials. The number of tags that were fully visible

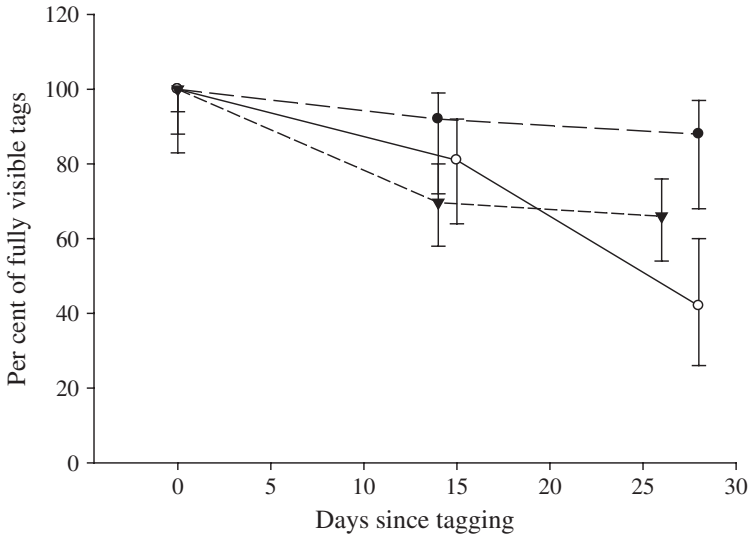

FIG. 1. Per cent of VI alpha tags (± 95% C.I.) that were fully visible throughout the study for *Oncorhynchus mykiss* (●), *Oncorhynchus clarki behnkei* (○) and *Esox masquinongy* × *Esox lucius* (▼).

decreased through time for all trials (Fig. 1). After 4 weeks, 66% (95% C.I. = 54–76%) of tags were fully visible for *E. masquinongy* × *E. lucius*, 42% (95% C.I. = 26–60%) for *O. c. behnkei* and 88% (95% C.I. = 68–97%) for *O. mykiss*.

DISCUSSION

MORTALITY AND CONDITION

VI alpha tags did not influence mortality or condition of juvenile esocids or juvenile salmonids. Few studies have examined the use of VI alpha tags in small-bodied or juvenile fishes; nonetheless, VI alpha tags have no influence on several species of larger salmonids. VI alpha tags did not influence growth (Zerrenner *et al.*, 1997), condition (Bryan & Ney, 1994) or mortality (Zerrenner *et al.*, 1997) of tagged brook trout *Salvelinus fontinalis* (Mitchell 1814), condition of tagged westslope cutthroat trout *Oncorhynchus clarki lewisi* (Richardson 1836) (Shepard *et al.*, 1996), or length and mass (Treasurer, 1996), or mortality (Treasurer, 1996; Moffett *et al.*, 1997), of tagged Atlantic salmon *Salmo salar* L. 1758. VI alpha tags do not appear to influence mortality or condition of tagged fishes in the short term and are probably good candidates for tagging small-bodied fishes if tag retention and tag readability are acceptable.

RETENTION AND READABILITY

Retention rates for juvenile fishes in this study ranged from 91 (75–98%) to 100% (83–100%). Juvenile retention rates of VI alpha tags were similar to or higher than previous studies of similar-sized fishes (Table I), although few studies have looked at retention in fishes <150 mm. For example, retention rates in this study were higher

than predicted for *O. clarki* based on size at tagging. Shepard *et al.* (1996) developed a model for *O. c. lewisi* to predict retention based on length at tagging and determined that the manufacturers recommended minimum length of 150 mm would result in at least 73% tag retention. Additionally, to attain 90% retention, minimum size at tagging would need to be 195 mm (Shepard *et al.*, 1996). In this study, VI alpha tag retention rate was 91% (75–98%) for *O. c. behnkei*, but for much smaller-sized fish ($85 \pm 7{\cdot}4$ mm) than was predicted for *O. c. lewisi* (Shepard *et al.*, 1996). Several factors may explain these differences in retention rates including fish size at tagging, environment and duration of study.

Fish size at tagging is commonly thought to influence VI alpha tag retention rates in salmonids (Kincaid & Calkins, 1992; Bryan & Ney, 1994; Niva, 1995). It has been recommended by both the tag manufacturer and previous studies that VI alpha tags should not be used in fishes <150 mm L_T due to lack of adequate adipose eye tissue, difficulty tagging and low retention rates. Although there was some difficulty in tagging juvenile fishes in the adipose eye tissue in this study, fishes were successfully tagged in the postorbital region.

The influence of size at tagging on retention rates is probably species specific. Retention was higher among larger fish in *O. clarki*, *S. fontinalis* and Arctic grayling *Thymallus arcticus* (Pallas 1776), but retention did not differ between *O. mykiss* <200 and >200 mm L_F (McMahon *et al.*, 1996). Similarly, fork length had a significant influence on tag loss in Dolly Varden *Salvelinus malma* (Walbaum 1792) but not on coastal cutthroat trout *Oncorhynchus clarki clarki* (Richardson 1836) (Frenette & Bryant, 1996). Although evidence of size-dependent retention rates exists, size-dependent differences in tag retention could not be assessed in this study because only similar sized *E. masquinongy* × *E. lucius*, *O. c. behnkei* and *O. mykiss* were examined in each trial.

Environment is thought to play an important role in tag retention and may explain the relatively high retention rates in small fishes in this study. Retention rates are often much higher in laboratory or hatchery conditions relative to natural conditions (McMahon *et al.*, 1996). Tag retention rates were much lower when examined under field conditions (McMahon *et al.*, 1996) than when examined under hatchery conditions (Mourning *et al.*, 1994) for similar sized *O. mykiss*. Retention rates of *S. fontinalis* were also higher in studies in which fish were held in hatchery environments (Zerrenner *et al.*, 1997, Hughes *et al.*, 2000) relative to field conditions (Bryan & Ney, 1994; McMahon *et al.*, 1996), although hatchery fish were slightly larger than those used in field studies (Table I). Still, other species such as *T. arcticus* (McMahon *et al.*, 1996) and *O. clarki* (Blankenship & Tipping, 1993; Frenette & Bryant, 1996; Shepard *et al.*, 1996) have high retention rates when exposed to natural conditions. Retention rates may decline with exposure to natural conditions in some species. Even so, VI alpha tags seem to have suitable short-term retention rates under laboratory conditions for juvenile *E. masquinongy* × *E. lucius*, *O. c. behnkei* and *O. mykiss*.

Study duration may also influence relative retention rates of VI alpha tags. Retention rates usually increase over time due to healing of insertion wounds. Haw *et al.* (1990) determined that insertion wounds healed almost completely by 15 days in *O. mykiss*, resulting in little tag loss thereafter. Similarly, Mourning *et al.* (1994) observed that most healing occurred during the first 30 days after tagging in hatchery *O. mykiss*. Healing time and thus initial rate of tag loss probably differ between species, as Kincaid & Calkins (1992) determined that it took 70 days for complete insertion wound

healing to occur in *S. salar* and lake trout *Salvelinus namaycush* (Walbaum 1792). In this study, the similar or higher observed retention rates in the last 2 weeks of the study relative to the first 2 weeks of the study in all the trials, along with visual inspection, indicates some healing occurred between 15 and 28 days for all species.

Many of the same factors thought to influence tag retention rates, including size at tagging, species-specific characteristics and study duration, may also influence readability of tags. The juvenile fishes examined in this study (with the exception of *O. mykiss*) had low overall tag readability by the end of each trial. Most VI alpha tagging studies on salmonids reported high readability rates in fishes >150 mm (Table I). Conversely, 100% of VI alpha tags in yearling *S. namaycush* were unreadable 294 days after tagging (Kincaid & Calkins, 1992). Surprisingly, few studies have directly examined the relationship between size at tagging and readability. In *S. fontinalis*, size at tagging did not influence tag readability; however, the size of fish examined ranged from 211 to 470 mm (Hughes *et al.*, 2000), much larger than fish used in this study.

Readability varied considerably among species in this study. The most surprising of which was the difference in readability of similar sized juvenile *O. c. behnkei* and juvenile *O. mykiss*. Twenty-eight days after tagging, only 42% (95% C.I. = 26–60%) of *O. c. behnkei* tags were fully visible, whereas 88% (95% C.I. = 68–97%) of juvenile *O. mykiss* tags were fully visible. Size at tagging, environment and study duration were similar for both species, indicating that some inherent difference between the two species (*e.g.* morphology and physiology) caused lower visibility in *O. clarki behnkei*; however, differences in species were not examined directly.

Study duration is particularly influential in readability of VI alpha tags. Readability commonly decreases over time (Mourning *et al.*, 1994; Zerrenner *et al.*, 1997) but can also increase with time (Kincaid & Calkins, 1992). Readability in this study declined over time for all three species due to tissue growth and clouding of tissue over tags. Similarly, 60 days after tagging, 7% of VI alpha tags implanted in hatchery *O. mykiss* were unreadable or readable only with an incandescent light, whereas 120 days after tagging, 14% were unreadable or readable only with a light (Mourning *et al.*, 1994). Kincaid & Calkins (1992) observed opaque guanine platelets that formed a silver layer over VI alpha tags in some *S. salar* and reduced tag readability. In other fishes, readability was reduced by dark, cloudy areas (Kincaid & Calkins, 1992). A portion of these tags became visible by the end of the study due to tissue clearing (Kincaid & Calkins, 1992). Longer studies are needed to determine if readability will continue to decline with time in juvenile fishes, especially if the objective of tagging fishes is to determine long-term changes in individual growth or movement.

VI alpha tags did not influence fish mortality or condition, and tag retention rates were high in juvenile fishes regardless of species. Low short-term visibility in juvenile fish of some species, however, greatly limits the usefulness of this technique. It is not recommended that VI alpha tags be used in juvenile *E. masquinongy* × *E. lucius* or *O. c. behnkei* for periods >2 weeks because of low visibility, but VI alpha tags seem to be suitable for juvenile *O. mykiss* for a period of at least 4 weeks.

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