Animal Biotelemetry

Recommendations on size and position of surgically and gastrically implanted electronic tags in European silver eel

Økland and Thorstad

BioMed Central

Økland and Thorstad *Animal Biotelemetry* 2013, **1**:6
http://www.animalbiotelemetry.com/content/1/1/6

Animal Biotelemetry

SHORT COMMUNICATION Open Access

Recommendations on size and position of surgically and gastrically implanted electronic tags in European silver eel

Finn Økland* and Eva B Thorstad

Abstract

Background: Information on European silver eel *Anguilla anguilla* anatomy was collected to gain information on limitations on size and placement of electronic tags.

Findings: To reduce the eel's ability to bite its own sutures, it may be an advantage to make surgical incisions close to the head, but this increases the risk of cutting the liver. Recommended placement of an incision was slightly further from the head than one-fourth of the fish's body length (L_T) to avoid damaging the liver. Long, flexible tags comprising various components can be adjusted to the narrow body cavity and undulating movements of eels. There was space for surgically implanting a 100 mm long tag (11 mm in diameter) in the body cavity of eels with L_T ≥380 mm. During gastric tagging, tag length is limited by stomach length. Silver eels with L_T 380 to 998 mm had stomach lengths of 47 to 185 mm, indicating that there was space for short gastric tags in the smallest eels, but that there was space for relatively long tags in larger eels. The distance from the snout to the start of the stomach constituted 15 to 23% of L_T, indicating how far the transmitter should be inserted during tagging.

Conclusion: This information aids the development of tags and tagging methods that consider the unique morphological and behavioral features of eels.

Keywords: Intraperitoneal implantation, Intragastric insertion, Tagging, Transmitter, Telemetry, Tagging effect

Introduction

The European eel *Anguilla anguilla* population has seriously declined throughout its distribution range during recent decades [1]. A number of causes have been suggested, including changes in ocean currents, climate change, obstructions to migration, habitat loss, parasites, virus infections, contaminants and over-fishing [2-7], and several causes may act in concert. Due to the population decline, the European eel has been included in the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List of threatened species as critically endangered (http://www.iucnredlist.org/apps/redlist/details/60344/0). A European Union (EU) regulation has established measures for the recovery of the European eel, and requires that 40% of the pristine silver eel biomass from each river basin can migrate to the sea [8]. The still unknown reasons for the population decline, and the requirements of the EU regulation, necessitate more information on factors affecting the behavior, habitat use and migrations of the European eel, for example, [9,10].

Electronic tags can be used to obtain information on European eel habitat use and migrations in freshwater and at sea [11,12]. Optimal tagging methods are required to meet the ethical standards for use of research animals and to ensure that tagged fish exhibit a representative behavior. There are numerous tagging effect studies in other fishes, but few on eels [13]. Unique morphological, physiological and behavioral features of eels necessitate explicit evaluation and adjustment of handling and tagging methods. In anguilliform fishes, the physical dimensions or volume of a tag may be more important than that of mass [14], due to the narrow body cavity and anguilliforme swimming undulations.

* Correspondence: finn.okland@nina.no
Norwegian Institute for Nature Research (NINA), P.O. Box 5685 Sluppen, NO-7485 Trondheim, Norway

There are three main methods for attaching large, electronic tags to fish, which are: 1) external attachment, 2) surgical implantation in the body cavity, and 3) gastric insertion via the mouth [13,15,16]. External attachment may be less suited for European eels due to their habitat use, as they are known to bury and hide in mud, gravel, vegetation and among stones and other structures [17]. This hiding behavior may increase the chances of losing external tags in eels and eel-like fishes [18,19]. However, external tagging methods have been developed for external attachment of pop-up satellite archival transmitters to record silver eel ocean migrations [19,20]. The present study focusses on surgical implantation and gastric insertion of tags.

One particular challenge when tagging eels is that they are able to turn their heads and bite their own incisions and sutures [personal observations, 21]. During surgical implantation, it may, therefore, be an advantage to place the incision as close to the head as possible to reduce this behavior. However, this increases the risk of cutting and damaging the liver with the scalpel during surgery, which may cause heavy bleeding [personal observation]. Information on the position of the liver is, therefore, needed for optimal placement of the incision. A second challenge is that the length of the body cavity limits the length of transmitters that can be surgically implanted. This is particularly an issue when developing long and flexible tags, for example, the modified G5 data storage tags, Cefas Technology Limited (CTL), UK., which consist of an electronic unit and three floats mounted on a titanium wire, the present model being 14 cm long in total [22,23]. Data on the length of the body cavity provides information on how long such tags can be for silver eel of different body lengths.

Gastric insertion of tags requires the tag to be inserted via the mouth down the pharynx and into the stomach. The stomach length, therefore, limits the possible tag length. Furthermore, information on the position of the stomach is needed when inserting the tag, because the tag has to be inserted far enough to be placed in the stomach, but without rupturing the stomach wall or causing other physical damage to the fish.

The aim of this study was to collect anatomical measurements of length of the body cavity, distance from snout to the end the liver, length of the stomach and distance from the snout to the start of the stomach in European silver eel to provide recommendations on tag sizes and positions of surgically- and gastrically-implanted tags.

Methods

European silver eel (migration stage V [24]) were captured in a Wolf trap [25] close to the sea in the River Imsa in southern Norway, during downstream migration in October 2008, 2009 and 2010. The following measurements were collected from dead fish: fish body length (L_T), length of body cavity, distance from snout to the end of the liver, distance from snout to the start of the stomach (that is, distance from snout to where the gall bladder is attached to the stomach), and distance from snout to the end of the stomach (defined here as the distance from the snout to where the stomach was too small for a 11 mm diameter tag, which is the diameter of the commonly available archival or acoustic tags, including the G5 tag). L_T and one or several of the other measurements were taken for each individual, but not all measurements were taken for all individuals as measurements were done in connection with other studies. The total sample size was 95 eels, but the sample size for three of the analyses is lower (34 to 58 eels, see the Results section). The measurements are presented as a function of L_T. Different models were tried for the relationship between L_T and the other measurements. The model that according to the r^2-values best described each of the relationships is presented.

Findings

The distance from the snout to the end of the liver (L_{EL}) varied between 81 mm and 207 mm for silver eel between 380 mm and 931 mm body length (L_T) (Figure 1). The relationship between L_{EL} and L_T was best described by a linear regression model ($L_{EL} = 0.22L_T + 5.41$, $r^2 = 0.92$, $n = 34$).

Length of the body cavity (L_{BC}) varied between 115 mm and 252 mm for silver eel between a body length (L_T) of 380 mm and 931 mm (Figure 2). The relationship

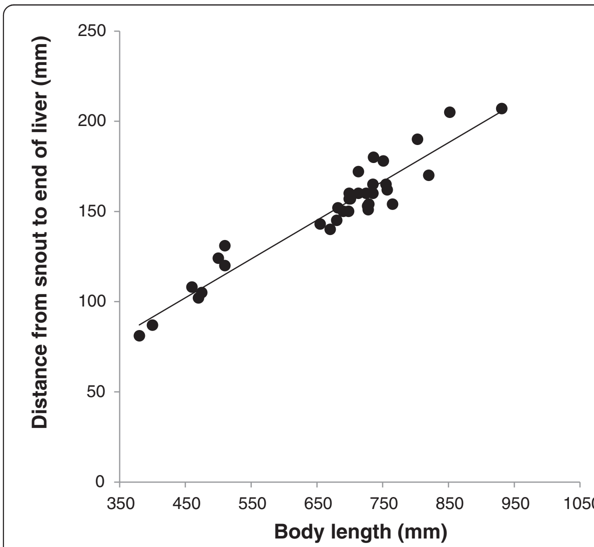

Figure 1 Relationship between distance from the snout to the end of the liver (L_{EL}) and total body length (L_T). The line shows the linear regression model (n = 34).

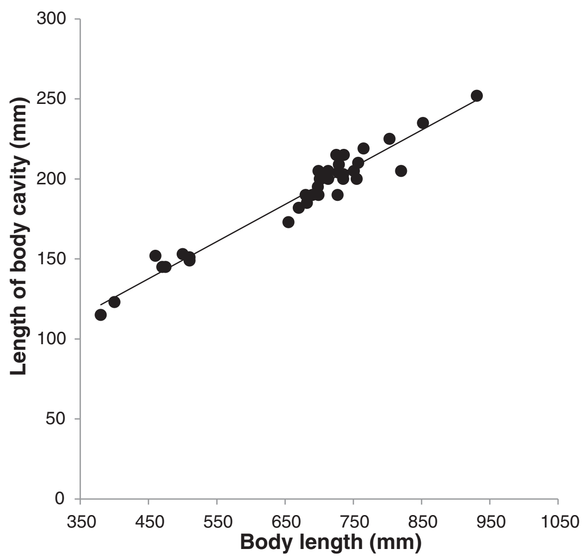

Figure 2 Relationship between length of the body cavity (L_{BC}) and total body length (L_T). The line shows the linear regression model (n = 34).

between L_{BC} and L_T was best described by a linear regression model ($L_{BC} = 0.23L_T + 33.14$, $r^2 = 0.95$, $n = 34$).

Stomach length (L_S) varied between 47 mm and 185 mm for silver eel between 380 mm and 998 mm body length (L_T) (Figure 3). The relationship between L_S and L_T was best described by an exponential regression model ($L_S = 21.32e^{0.0019LT}$, $r^2 = 0.62$, $n = 58$).

Distance from the snout to the start of the stomach (L_{SS}) varied between 67 mm and 190 mm for silver eel between 380 mm and 998 mm L_T (Figure 4). The relationship

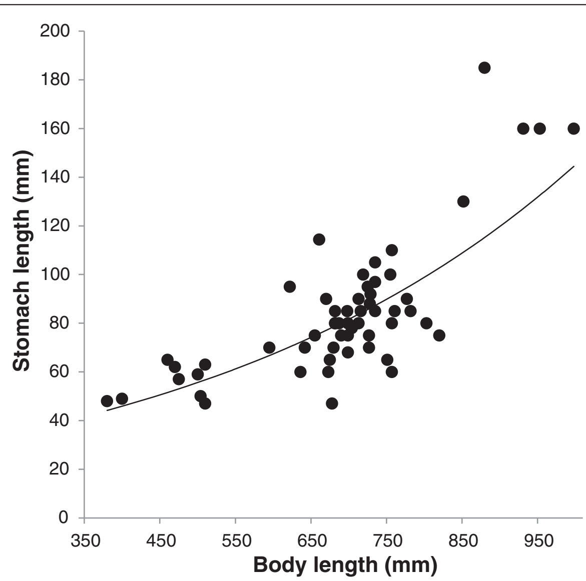

Figure 3 Relationship between stomach length (L_S) and total body length (L_T). The line shows the exponential regression model (n = 58).

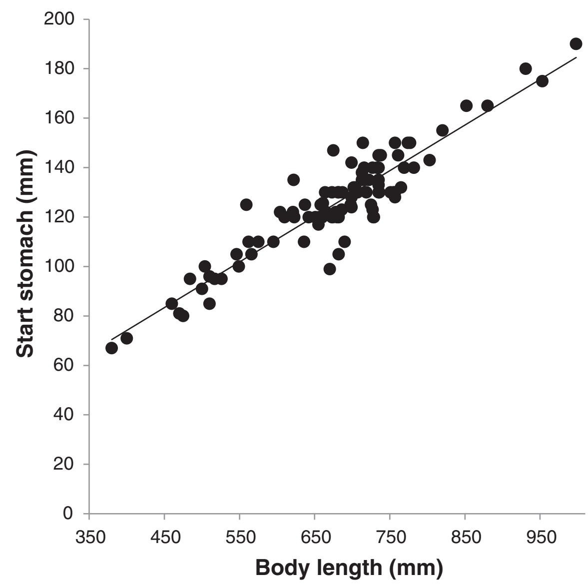

Figure 4 Relationship between distance from the snout to the start of the stomach (L_{SS}) and total body length (L_T). The line shows the linear regression model (n = 95).

between L_{SS} and L_T was best described by a linear regression model ($L_{SS} = 0.18L_T + 0.32$, $r^2 = 0.86$, $n = 95$).

Discussion

The results of this study provide useful information on eel anatomy for surgical and gastric implantation of tags in European silver eel. The results showed that the distance from the snout to the end of the liver constituted approximately one-fourth to one-fifth of the total body length of the fish (L_T), indicating that optimal placement of the incision is slightly further from the head than one-fourth of L_T to avoid damaging the liver. Further, the results showed that there was space for a 100 mm long tag (11 mm diameter) to be surgically implanted in all measured eels (that is, ≥380 mm L_T). However, a 150 mm long tag could only be surgically implanted in silver eel longer than L_T 550 mm. The narrow body cavity of eels limits the diameter of the tags that can be used. A previous study demonstrated that only silver eels >67 cm L_T had a body cavity large enough to accommodate a 13 mm tag [23].

Surgical implantation of tags into the body cavity seems to be a suitable tagging method for European eel. Tag expulsion of surgically implanted tags may occur, but seems not to be a major problem based on studies of European eel and American eel *Anguilla rostrata* [21,23,26,27]. In American eel, critical swimming velocity was not affected by surgically implanted tags [27]. Slow healing of the incision, inflammations and muscle necrosis at the incision does, however, appear to be a challenge, and previous studies have recommended closing the incisions using cyanoacrylate adhesive and a biological bandage made from the eel's own fin [21,26]. The risk with this method is that the cyanoacrylate may be shed relatively fast and the incision be left open [28]. It has later been recommended to close surgical incisions in European eel with monofilament sutures [23].

Gastric insertion of tags may decrease feeding and growth in tagged fish because the tag may block feed intake, the stomach volume available for ingesting feed is reduced, and the fish may feel satiated due to the mass and volume of the tag in the stomach [16]. However, a European silver eel has ceased feeding at this life stage [29], and there is no risk of affecting the feed intake. This may, therefore, be a suitable tagging method for this life stage in European eel. The metamorphosis from yellow eel to silver eel is a gradual process involving morphological and physiological changes, including regression of the alimentary tract as they cease feeding [24,29,30]. The question was, therefore, how much the alimentary tract was regressed and whether gastric insertion of tags was possible in silver eel at this stage. The length of the stomachs varied between 47 mm and 185 mm, indicating that there was space for short gastric tags in the smallest silver eels, but that there was space for relatively long tags in larger eels. Hence, the stomach was still sufficiently large for gastric insertion of tags at this stage. The results showed that the distance from the snout to the start of the stomach constituted 15 to 23% of L_T, and indicated how far the transmitter should be inserted during the tagging procedure.

We know no published studies of the effects of intragastric insertion of tags in European eel. In a tagging effect study in American silver eel *Anguilla rostrata*, it was found that intragastrically inserted tags did not significantly impair swimming capacity or growth of the fish [27]. However, regurgitation was an issue because 28% of eels regurgitated their tags. The authors speculated that silver eel with degenerated alimentary tracts are less likely to regurgitate tags than yellow eel with functioning alimentary tracts [27]. At the same time the authors were worried that a degenerated alimentary tract may be more susceptible to puncture during transmitter insertion. Still, they did not find evidence of damage to the gut wall [27]. Hence, intragastric insertion of tags may be a quick and suitable tagging method in European silver eel, but more knowledge is needed on regurgitation rates and how to keep these as low as possible, and on the susceptibility of damaging the gut wall during tagging.

Abbreviations

EU: European Union; L_{BC}: length of body cavity; L_{EL}: distance from the snout to the end of the liver; L_S: stomach length; L_{SS}: distance from the snout to the start of the stomach; L_T: total body length; IUCN: International Union for the Conservation of Nature and Natural Resources.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

FØ designed the data collection and collected the data. FØ and EBT together analyzed the data and drafted the manuscript. Both authors read and approved the final manuscript.

Acknowledgements

The study was funded by Grant Agreement GOCE-2008212133 (EELIAD) of the European Union FP7 research program on Environment (including climate change) and prepared under project number 212133. We thank the staff at the NINA Research Station at Ims for providing assistance during experiments. We thank David Righton and three anonymous reviewers for providing comments that improved the manuscript.

Received: 26 October 2012 Accepted: 25 February 2013
Published: 6 May 2013

References

1. ICES: **Report of the 2012 session of the joint EIFAC/ICES working group on eels.** *ICES CM 2012/ACOM* 2012, **18**:1–824.
2. Feunteun E: **Management and restoration of European eel population (*Anguilla anguilla*): an impossible bargain.** *Ecol Eng* 2002, **18**:575–591.
3. Dekker W: **Worldwide decline of eel resources necessitates immediate action.** *Fisheries* 2003, **28**:28–30.
4. Knights B: **A review of the possible impacts of long-term oceanic and climate changes and fishing mortality on recruitment of anguillid eels of the northern hemisphere.** *Sci Total Environ* 2003, **310**:237–244.
5. Durif CM, Gjøsæter J, Vøllestad LA: **Influence of oceanic factors on *Anguilla anguilla* (L.) over the twentieth century in coastal habitats of the Skagerrak, southern Norway.** *Proc R Soc B Biol Sci* 2011, **278**:464–473.
6. Geeraerts C, Belpaire C: **The effects of contaminants in European eel: a review.** *Ecotoxicology* 2010, **19**:239–266.
7. Kettle AJ, Vøllestad LA, Wibig J: **Where once the eel and the elephant were together: decline of the European eel because of changing hydrology in southwest Europe and northwest Africa?** *Fish Fish* 2011, **12**:380–411.
8. European U: **Council Regulation (EC) No 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel.** *Off J Eur Union* 2007, L **248**:17–23.
9. Pedersen MI, Jepsen N, Aarestrup K, Koed A, Pedersen S, Økland F: **Loss of European silver eel passing a hydropower station.** *J Appl Ichtyol* 2012, **28**:189–193.
10. Simon J, Berends K, Dörner H, Jepsen N, Fladung E: **European silver eel migration and fisheries-induced mortality in the Havel river system (Germany).** *River Res Appl* 2013, **28**:1510–1518.
11. Aarestrup K, Thorstad EB, Svendsen JC, Jepsen N, Koed A, Pedersen MI, Økland F: **Survival and progression rates of large European silver eel in late freshwater and early marine phase.** *Aquat Biol* 2010, **9**:263–270.
12. Davidsen JG, Finstad B, Økland F, Thorstad EB, Mo TA, Rikardsen AH: **Early marine migration of European silver eel (*Anguilla Anguilla*) in northern Norway.** *J Fish Biol* 2011, **78**:1390–1404.
13. Cooke SJ, Woodley CM, Eppard MB, Brown RS, Nielsen JL: **Advancing the surgical implantation of electronic tags in fish: a gap analysis and research agenda based on a review of trends in intracoelomic tagging effect studies.** *Rev Fish Biol Fish* 2011, **21**:127–151.
14. Moser ML, Ogden DA, Sandford BP: **Effects of surgically implanted transmitters on anguilliform fishes: lessons from lamprey.** *J Fish Biol* 2007, **71**:1847–1852.
15. Jepsen N, Thorstad EB, Baras E, Koed A: **Surgical implantation of telemetry transmitters in fish: how much have we learned?** *Hydrobiologia* 2002, **483**:239–248.
16. Bridger CJ, Booth RJ: **The effects of biotelemetry transmitter presence and attachment procedures on fish physiology and behaviour.** *Rev Fish Sci* 2003, **11**:13–34.
17. Deelder CL: **Synopsis of biological data on the eel *Anguilla anguilla* (Linnaeus, 1758).** *FAO Fish Synop* 1984, **80**(revision 1):1–73.
18. Broadhurst BT, Ebner BC, Clear RC: **Radio-tagging flexible-bodied fish: temporary confinement enhances radio-tag retention.** *Mar Freshwater Res* 2009, **60**:356–360.

19. Økland F, Thorstad EB, Westerberg H, Aarestrup K, Metcalfe JD: **Development and testing of attachment methods for pop-up satellite archival transmitters in European eel.** *Anim Biotel* 2013, **1**:3.
20. Aarestrup K, Økland F, Hansen MM, Righton D, Gargan P, Castonguay M, Bernatchez L, Howey P, Sparholt H, Pedersen MI, McKinley RS: **Oceanic spawning migration of the European eel (*Anguilla anguilla*).** *Science* 2009, **325**:1660.
21. Baras E, Jeandrain D: **Evaluation of surgery procedures for tagging eel *Anguilla anguilla* (L.) with biotelemetry transmitters.** *Hydrobiologia* 1998, **371/372**:107–111.
22. Metcalfe JD, Righton DA, Hunter E: **Fish and chips: the development of electronic tags for fish and their application in fisheries research at cefas.** *Defra* 2011:28.
23. Thorstad EB, Økland F, Westerberg H, Aarestrup K, Metcalfe J: **Evaluation of surgicalimplantation of electronic tags in European eel and effects of different suture materials.** *Mar Freshwater Res* 2013, **64**:324–331.
24. Durif C, Dufour S, Elie P: **The silvering process of *Anguilla anguilla*: a new classification from the yellow resident to the silver migrating stage.** *J Fish Biol* 2005, **66**:1025–1043.
25. Wolf P: **A trap for the capture of fish and other organisms moving downstream.** *Trans Am Fish Soc* 1951, **80**:41–45.
26. Winter HV, Jansen HM, Adam B, Schwevers U: **Behavioural effects of surgically implanting transponders in European eel, *Anguilla anguilla*.** In *Aquatic Telemetry: Advances and Applications. Proceedings of the Fifth Conference on Fish Telemetry held in Europe, Ustica, Italy, 9–13 June 2003.* Edited by Spedicato MT, Lembo G, Marmulla G. Rome: FAO/COISPA; 2005:287–295.
27. Cottrill A, Økland F, Aarestrup K, Jepsen N, Koed A, Hunter KJ, Butterworth KG, McKinley RS: **Evaluation of three telemetry transmitter attachment methods for female silver-phase American eels (*Anguilla rostrata* Leseur).** *J Great Lakes Res* 2006, **32**:502–511.
28. Wagner GN, Cooke SJ, Brown RS, Deters K: **Surgical implantation techniques for electronic tags in fish.** *Rev Fish Biol Fish* 2011, **21**:71–81.
29. Pankhurst NW, Sorensen PW: **Degeneration of the alimentary tract in sexually maturing European *Anguilla anguilla* (L.) and American eels *Anguilla rostrata* (LeSueur).** *Can J Zool* 1984, **62**:1143–1149.
30. van Ginneken V, Durif C, Balm SP, Boot R, Verstegen MWA, Antonissen E, van den Thillart G: **Silvering of European eel (*Anguilla anguilla*): seasonal changes of morphological and metabolic parameters.** *Anim Biol* 2007, **57**:63–77.

doi:10.1186/2050-3385-1-6
Cite this article as: Økland and Thorstad: **Recommendations on size and position of surgically and gastrically implanted electronic tags in European silver eel.** *Animal Biotelemetry* 2013 **1**:6.