



HAL
open science

Evaluation of a European sea bass (*Dicentrarchus labrax* L.) post-larval tagging method with ultra-small RFID tags

Sara Faggion, Pierre Sanchez, Marc Vandeputte, Frédéric Clota, Alain Vergnet, Marie-Odile Blanc, François Allal

► To cite this version:

Sara Faggion, Pierre Sanchez, Marc Vandeputte, Frédéric Clota, Alain Vergnet, et al.. Evaluation of a European sea bass (*Dicentrarchus labrax* L.) post-larval tagging method with ultra-small RFID tags. *Aquaculture*, 2020, 520, pp.734945. 10.1016/j.aquaculture.2020.734945 . hal-03150884

HAL Id: hal-03150884

<https://hal.inrae.fr/hal-03150884>

Submitted on 7 Mar 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

1 **Evaluation of a European sea bass (*Dicentrarchus labrax* L.) post-larval tagging method with ultra-**
2 **small RFID tags**

3 Sara Faggion¹, Pierre Sanchez^{1,2}, Marc Vandeputte^{1,2}, Frédéric Clota^{1,2}, Alain Vergnet¹, Marie-Odile Blanc¹,
4 François Allal^{1*}

5
6 ¹ MARBEC, Univ Montpellier, CNRS, Ifremer, IRD, Palavas-les-Flots, France

7 ² Université Paris-Saclay, INRAE, AgroParisTech, GABI, 78350, Jouy-en-Josas, France

8
9 *Corresponding author at: Ifremer, MARBEC, Chemin de Maguelone, 34250, Palavas-les-Flots, France.

10 Tel.: +33 4 67 13 04 04. E-mail: francois.allal@ifremer.fr (F. Allal).

11
12 **Abstract**

13 Individual tagging is key to a better understanding of early life stages in fish. Very small RFID transponder
14 microchips (500 x 500 x 100 µm, 82 µg) are now available. The aim of this study was to develop a protocol
15 to tag European sea bass (*Dicentrarchus labrax* L.) larvae from 61 days post-hatching (dph; standard length
16 ~10 mm) to 96 dph (standard length ~28 mm) through intra-coelomic implantation of microchips. The
17 suitability of such a tagging procedure was evaluated, with the purpose of determining the minimal fish age
18 and body size for microchip tagging without adverse effects on survival and growth performance.

19 We produced an experimental population composed by 50:50 normally pigmented larvae and albino larvae
20 through artificial fertilization. Five tagging trials were performed over 35 days, in fish aged 61, 75, 83, 89
21 and 96 dph. Each time, 50 normally pigmented fish were tagged, while 50 albino fish were used as controls.
22 Mortality was recorded daily, while biometric measurements were performed at 75, 83, 89, 96, 103 and 110
23 dph via image analysis.

24 Microchip tagging was possible in larvae from an age of 75 dph (standard length ~20 mm), with satisfactory
25 performance in terms of survival rate (between 84 to 98% 24 hours after tagging) and growth rate, and
26 without significant differences in comparison with the untagged controls. In contrast, tagging before 75 dph
27 is not to be recommended, as the age group 61 dph was the most affected in terms of survival (only 62% of
28 fish survived 24 hours after tagging) and growth rate, showing significant differences compared to the
29 untagged controls. The overall microchip reading success rate for the age groups throughout the experiment
30 was 51.4%, the overall reading success rate at each biometric measurement was 48.2%, probably due to the
31 change in orientation of the microchip inside the fish body cavity.

32 The tagging protocol developed was then overall successful, albeit with a moderate reading success.
33 Precocious tagging could allow the collection of new types of data (individual, longitudinal) related to larval
34 development, behavioral studies, physiological and immunological investigations. Future tests could focus
35 on the effects of tagging on baseline locomotion and behavior, as well as the suitability and the efficiency of
36 intramuscular microchip tagging on larger fish.

37 **Keywords:** larvae, RFID transponder, individual identification, tagging effects, *Dicentrarchus labrax* L.

38
39 **1. Introduction**

40 Individual identification and monitoring of an animal within a population through a proper tagging method is
41 increasingly used in aquaculture research. This is especially the case for selective breeding targeting different
42 production traits such as growth, feed efficiency and disease resistance (Das Mahapatra et al. 2001, Lind et
43 al. 2012), but also to track escapees (Uglen et al. 2019). More generally, individual identification is

44 increasingly used for the investigation of a wide range of life history related features of aquatic species, such
45 as growth and survival rates. It is also used for fisheries research and to study population dynamics,
46 behavioral dynamics, spatial ecology and responses to environmental changes (Pine et al. 2003).
47 Among the internal tagging methods, Radio Frequency Identification (RFID) electronic tagging using glass
48 Passive Integrated Transponder (PIT) tags or microtags, is widely used due to a series of advantages, such as
49 billions of unique tag numbers, easiness of tagging and reading, high retention rates and limited side effects
50 to the animals carrying the tags. Tagging with standard RFID glass tags (2×12 mm, 33 mg or 1.4×8 mm,
51 100 mg) can be performed in fish with a minimum length of 60 mm or a minimum weight of 3 g (Baras et al.
52 2000; Navarro et al. 2006), while microtags (Nonatec[®], size 1×6 mm, 10 mg) have been shown to be
53 appropriate in fish with a minimum standard length of 36 mm or a body mass of ~ 0.84 g (Cousin et al. 2012;
54 Ferrari et al. 2014). A tagging method for even smaller fish, however, is worth developing, as many
55 biological changes occur during very early life stages. Nevertheless, tagging could have drawbacks and
56 affect fish, particularly when the ratio between tag and body weight is high. Moreover, susceptibility to
57 anesthesia and manipulation, tag retention and recovery ability could differ from species to species and in
58 animals of different ages within the same species, so tagging methods, both in terms of tag choice and
59 tagging procedures, need to be tested carefully.

60 Developing an early tagging method is also interesting from the perspective that the smallest animals that
61 can be tagged may already have body weight considerably higher than hatching body weight. This is
62 particularly true for the European sea bass (*Dicentrarchus labrax* L.), as tagging is possible at around 1 g of
63 mean weight; at this stage, the body weight of the fish has already increased by a factor of nearly 1000
64 compared to body weight at hatching.

65 The application of ultra-small tagging technologies at early stages could then provide new insights into
66 different aspects, such as early growth differentiation between sexes in sea bass (Saillant et al. 2001). In this
67 species, indeed, sex dimorphism for growth has already occurred at the age of 105 dph where tagging with
68 microtags is possible (1024 degree days above 10°C , Ferrari et al., 2014). Post-larval tagging can also be
69 useful for selective breeding for production traits (growth) or efficiency traits (feed efficiency, disease
70 resistance) in many species, since recording early individual performance may enable early selection and
71 thus a reduction in the cost of selective breeding. As fish are normally reared together to ensure identical
72 environmental conditions, the identification of individuals is necessary to correlate individual performance
73 with the family structure, which is one of the main aspect of breeding programs, and in turn allows the
74 correct estimation of breeding values, and genetic and genomic parameters (Herbinger et al. 1999).

75 Despite the availability of tags to track individual organisms, few options are available for tagging small
76 species or early life stages. The miniaturization of technologies has allowed the development of
77 progressively smaller tags, providing the opportunity of the identification and monitoring of very small-
78 bodied organisms, potentially without side effects in terms of survival, growth, behavior and social
79 interactions. Very small RFID transponders characterized by exceptionally small size and weight (500×500
80 $\times 100$ μm , 82 μg) are now available. These microchips have been already tested for biomedical research
81 purposes in laboratory mice (Gruda et al. 2010) and zebrafish (Chen et al. 2013) by subcutaneous injection
82 and for social behavior studies in insects (honeybees, Tenczar et al. 2014; ants, Robinson et al. 2014) by
83 external adhesion, with satisfactory results.

84 In the present study, we developed a protocol to tag European sea bass larvae from 61 dph (or 372 degree
85 days above 10°C) to 96 dph (or 596 degree days above 10°C) through intra-coelomic implantation of
86 microchips. The suitability and the effects of such tagging procedure were evaluated, with the purpose of
87 determining the most precocious age and the minimal body size for microchip tagging without significant
88 side effects in terms of survival and growth performances.

89 **2. Materials and Methods**

90 *2.1. Production and rearing of the experimental fish*

91 All procedures were conducted in accordance with the guidelines for animal experimentation established by
92 the European Union (Directive 2010-63-EU) and the corresponding French legislation. The experiment was
93 approved following evaluation by the Ethical Committee n° 036, under authorization number
94 APAFIS#19713-2019010917222576v3 delivered by the French Ministry of Higher Education, research and
95 Innovation.

96 The fish used in the experiment were produced in the experimental facilities of IFREMER in Palavas-les-
97 Flots (France). Artificial fertilization was performed as a full factorial mating scheme using the eggs of two
98 albino dams homozygous for recessive albinism (*a/a*) and the cryopreserved sperm of five sires which were
99 heterozygous (*a/+*) at the same locus (and thus normally pigmented). This specific mating scheme allowed
100 for the production of normally pigmented (*a/+*) larvae and albino (*a/a*) larvae in equal proportions (50:50).

101 2.2. *Microchips, ID reader and software*

102 Microtransponder tags (“p-Chips[®]”) were obtained from PharmaSeq, Inc. (Monmouth Junction, New Jersey).
103 Each microchip measures 500 x 500 x 100 µm (Fig. 1) and carries a specific serial number (ID). When the
104 chip is stimulated by a diode laser (660 nm, 60 mW average power) of an ID reader (“wand”), the photocells
105 embodied in the microchip provide power and synchronization signals for the electronic circuits of the chip.
106 Then, when the on-chip antenna contained by the chip itself is stimulated by the laser light, the chip
107 transmits the ID at 1MHz through a variable magnetic field. Subsequently, the signal is decoded by a field
108 programmable gate array (FPGA), that is part of the wand itself, and eventually through a reader software
109 (www.pharmaseq.com; Jolley-Rogers et al., 2012).

110 2.3. *Implantation protocol*

111 The intra-coelomic implantation was performed using a stereomicroscope. Each sterilized injector (2¼” x 4”
112 sterilization pouch) pre-loaded with the microchip (Fig. 1) was settled on a micromanipulation arm and
113 connected to a piston fixed on a specifically designed and 3D-printed mounting stand. The pressure exerted
114 on the piston caused the subsequent pressure of the injector plunger and the ejection of the microchip from
115 the needle. This mechanism allowed great precision during the tagging operations, avoiding the direct
116 manipulation of the fish and minimizing abrupt movements, which may cause injuries to the larvae.

117 Fish were prepared for the manipulation in iso-osmotic seawater, to equilibrate internal and external ion
118 concentration (the iso-osmotic salinity is between 10.2 and 11.6‰: Varsamos et al., 2001) and anesthetized
119 with MS-222 (Sigma-Aldrich, 0.07 g/l in iso-osmotic seawater; Chatain and Corraoa, 1992). Each fish was
120 gently placed on a microscope slide covered with dampened absorbent paper and put under the
121 stereomicroscope. The microchip was then injected after the insertion of the needle into the peritoneal cavity
122 of the fish, on the left side (Fig. 1; Supplementary video 1). The whole procedure (preparation in iso-osmotic
123 sea water, anesthesia, tagging) lasted on average 10 minutes for each fish. After tagging, the fish were
124 transferred in a tank of iso-osmotic 0.2 µm filtered and sterilized seawater for recovery (to avoid osmotic
125 stress and prevent infections) and they were allowed to rest for 2 hours before being returned to their rearing
126 tank. The temperature of the water was controlled throughout the entire manipulation in order to avoid
127 temperature shocks, and care was taken to limit the time the fish were kept inside the anesthetic bath and out
128 of the water. Control fish received the same treatment (anesthesia and manipulation out of the water), except
129 for the needle insertion or microchip tagging.

130 Five tagging trials were performed over 35 days, in fish aged 61, 75, 83, 89 and 96 (days post-hatching) dph.
131 Each time, 50 randomly chosen normally pigmented (*a/+*) fish from the stock rearing tank were tagged,
132 while 50 randomly chosen albino (*a/a*) fish from the stock rearing tank were used as controls (total number
133 of tagged fish: 250; total number of untagged controls: 250). After each tagging trial, tagged fish and
134 untagged controls were mixed and transferred to an empty tank, to allow the discrimination of fish tagged on
135 a given day and to easily estimate the mortality per group in case of microchip loss or reading failure. The
136 conditions (temperature and salinity) were strictly identical in all rearing tanks.

137 2.4. *Survival, microchip retention and reading, and growth monitoring*

138 Rearing tanks were monitored daily throughout the experiment to record mortality. Biometric measurements
139 were performed at 75, 83, 89, 96, 103 and 110 dph. During each biometric measurement, the fish were
140 anesthetized as described above (paragraph 2.3) and the microchip ID of each experimental fish was read. As
141 the reading process should be fast and the handling of such small-bodied fish should be minimized, the
142 attempt of microchip reading lasted a maximum of 30 seconds per fish.
143 The fish (tagged and untagged controls) were then individually placed over a light table (Ultra Slim Light
144 Box, Microlight) to increase the contrast, and a digital picture of each fish was taken using a stand with a
145 digital camera (12.2 megapixel), using a graduated ruler as a reference. Finally, the fish were placed in 0.2
146 μm filtered and sterilized seawater to recover before being returned to their rearing tank.
147 Image analysis was performed with the ImageJ software 1.51 (Rasband, 1997-2018), allowing the measure
148 of the standard length of each fish (the caudal fin was not taken into account). The graduated ruler taken on
149 each picture with the fish has permitted to convert all measurements from pixels to mm.
150 During each biometric measurement (75, 83, 89, 96, 103 and 110 dph), 50 fish from the stock rearing tank
151 were randomly chosen and measured to monitor the survival and the growth of normally pigmented fish and
152 albino fish, and check that (a/a) and (a/+) fish from the same genetic background have similar survival and
153 growth rates (Supplementary material 1).

154 2.5. Data analysis

155 The number of survived animals belonging to the tagged fish group and the untagged controls group, both
156 after the implantation of the microchip and at the end of the experiment, were compared using a χ^2 test.
157 The standard length of the tagged fish and the untagged controls in each tagging group and at each biometric
158 measurement were analyzed for normality using the Shapiro-Wilk test and for homoscedasticity using
159 Bartlett's test. These tests indicated that in general the data did not conform to the assumption of normality or
160 homoscedasticity, even after transformation (log or square root). The Wilcoxon-Mann-Whitney non-
161 parametric test was then used to compare the standard length of the tagged fish and of the untagged controls
162 at each biometric measurement and for each tagging group (one test per tagging group at each biometric
163 measurement).
164 All the tests were performed in R version 3.5.0, package *stats* (R Core Team, 2018) and the significance
165 threshold was p -value < 0.05 .

166 3. Results

167 3.1. Survival rate

168 No significant differences in survival rate were detected between tagged fish and untagged controls across
169 the groups that were tagged on days 75, 83, 89 and 96 post-hatching. However, among the fish tagged on day
170 61 post-hatching, tagged fish had a lower survival than untagged controls. The increased mortality due to
171 tagging in this group occurred immediately after microchip implantation, within the first 24 hours after
172 tagging ($\chi^2 = 8.914$, p -value = 0.003; Table 1). After that, no fish mortality connected to tagging was
173 registered.
174 Fish mortality was also registered throughout the experimental trial, but no differences in survival rate were
175 observed between tagged and untagged fish of each group at the end of the experiment (Table 1).
176 The youngest group subjected to the microchip implantation showed the lowest survival rate (62%), with 31
177 fish surviving out of 50 fish tagged, whereas the other age groups showed rather higher survival rates,
178 ranging from 82% to 98%, with a minimum of 41 to a maximum of 49 surviving fish out of the total (Table
179 1).

180 3.2. Microchip retention and reading

181 Tag loss was difficult to discriminate from reading failure. The overall microchip reading success rate for the
182 age groups throughout the experiment was 51.4%, the overall reading success rate by biometric measurement
183 (average at each date without taking into account the age at tagging) was 48.2%. The lowest mean value was

184 observed in tagging age group 61 dph (42.9%), while the highest mean value was observed in tagging age
185 group 89 dph (58.4%). The biometric measurement performed at 103 dph had the highest tag reading success
186 rate (54.1%), whereas the first biometric measurement performed at 75 dph resulted in the lowest tag reading
187 success rate (38.7%; Table 2). However, this latter percentage refers to only tagging age group 61 dph, which
188 was in general the group with the worst performance.

189 3.3. Growth monitoring

190 The standard body length of the tagged fish and untagged controls was significantly different in tagging age
191 group 61 dph, starting from the second biometric measurement performed at 83 dph until the end of the
192 experiment. Significant differences in growth were initially detected in tagging age group 83 dph, but in this
193 case, the untagged fish were smaller compared to the tagged ones. However, the body length became
194 homogenous thereafter, and no differences in the body length were found during the fourth and the fifth
195 biometric measurements performed at 103 and 110 dph. For the other groups, no growth differences were
196 observed between tagged and untagged fish (Table 3).

197 4. Discussion

198 Our experiment revealed that the microchip intra-coelomic implantation was effective in sea bass larvae
199 from an age of 75 dph (459 degree days above 10°C) or from a standard length of ~20 mm and a body
200 weight of ~0.11 g. On average, fish of 75 dph or more were not affected by the tagging procedure, showing
201 satisfactory performances in terms of survival rate, growth rate and microchip reading success rate.

202 The group subjected to the earliest microchip implantation (61 dph) was the most affected in terms of
203 survival and growth rate. We can hypothesize that the very small size of the fish at this age (standard length
204 ~10 mm) combined with their developing and thus fragile body may be a reason that explains the higher
205 susceptibility of this group to the procedures of anesthesia, handling and needle insertion. In bigger fish
206 subjected to PIT-tagging, mortality caused by the manipulation and tag insertion was detected up to 10 days
207 after tagging (Dare 2003). In our experiment, we observed mainly a non-recovery immediately after
208 microchip implantation, then a low mortality rate up to 24 hours after tagging. After 24 hours, no fish
209 mortality imputable to the tagging process was registered.

210 Significant differences in standard length were initially detected between tagged fish and untagged controls
211 in the 83 dph age group, but with tagged fish longer than controls, which was not expected. This could be
212 attributable to a stochastic sampling effect. These differences disappeared after 14 days and were not
213 detected later on.

214 When we recovered the microchips from the dead fish, we were also able to estimate the retention rate of the
215 tags, which was in general moderately high (76.2%), but the average microchip reading success was lower
216 (~50%). Apart from a certain proportion of reading failure imputable to tag loss, the main explanation could
217 be the change in orientation of the microchip inside the body cavity after tagging. Baras et al. (2000) has
218 already described different orientations of tags and changes of orientation throughout time for PIT-tagged
219 Eurasian perch (*Perca fluviatilis*), that could affect the detection of the tag itself. The microchip technology is
220 rather different compared to PIT-tag or microtag technologies, even if they are all RFID transmission
221 protocols. The microchip relies on the laser light stimulation of both the photocells embodied in the chip and
222 the antenna that transmits the ID; both components are situated to one side of the chip, thus a change of
223 orientation of the microchip inside the coelomic cavity of the fish can prevent the laser light to reach the
224 photocells and to stimulate the antenna, making the reading of the chip difficult or even impossible.

225 The implantation of the microchip in the fish dorsal muscle (as tested on zebrafish; Chen et al. 2013) may
226 avoid or limit chip displacement or orientation change, but this implies the utilization of larger-sized fish
227 (standard length > 30 mm), reducing the comparative advantage of the microchip compared to microtags
228 which can be used at a minimum standard length of 36 mm (Cousin et al. 2012; Ferrari et al. 2014).

229 Using the microchip technology tested in this study, we showed that it is now possible to individually
230 monitor fish from an extremely early life stage, allowing for the study of many biological, physiological or

231 behavioral aspects, and the tagging protocol that was developed was overall successful. Anyway, tag
232 implantation should imply minimal or no stress to the fish (Bridger and Booth, 2003) in terms of growth
233 patterns, but also in terms of baseline locomotion and behavior. Further investigations related to the possible
234 effects on swimming behavior due to the procedure and the presence of the tag inside the fish coelomic
235 cavity could be interesting, as Ferrari et al. (2014) found some differences in swimming activity between
236 tagged and untagged controls (105 dph sea bass juveniles). However, they detected such differences only in
237 the period immediately following tag implantation, when tagged fish showed hyperactive behavior compared
238 to the controls. The analysis of the behavioral adaptability to the tagging procedure could be noteworthy,
239 mainly because the fish in our experiment underwent to the tagging process at a younger age and at a smaller
240 size compared to the experiment of Ferrari et al.

241 In terms of application, microchip tagging is likely to be interesting in all studies targeted at larvae and
242 small-bodied fish, for which other tagging techniques (PIT-tagging, microtagging) are not suitable. Fish at
243 those very early stages are nowadays studied either as groups or with lethal phenotyping. Individual
244 identification could give access to new types of data (individual, longitudinal) that could both improve our
245 understanding of the processes that happen during larval development and the implementation of behavioral
246 studies of larval stages, as well as physiological and developmental investigations. Potential examples
247 include, the individual susceptibility of early stages to different pathologies, the possible recovery from a
248 pathology and the impact on subsequent growth, as well as immunological studies, individual feeding
249 behavior and coping styles of very small fish. Also, for fish treated as groups with “programming” aimed at
250 eliciting epigenetic mechanisms with long term effect (e.g. Balasubramanian et al. 2016), post-treatment
251 individual tagging could enhance the reliability of later phenotyping by enabling common garden rearing of
252 the treated groups, thus better controlling for environmental effects of the tanks. However, the reading
253 success with the implantation methodology we used remained medium-low (36-62% at a given time point),
254 thus operational use of these microchips will require increased sample sizes. Nevertheless, this remains the
255 only method allowing individual identification of fish larvae with a mean weight of 100 mg, while the
256 alternative microtags tested before were operational only for fish of 590 mg of mean weight (Ferrari et al.
257 2014).

258 Furthermore, intramuscular microchip tagging could be performed also in larger fish, as an alternative to the
259 common tagging techniques, with the advantage of a very small tag to body weight ratio, but the suitability
260 and the efficiency have to be tested.

261

262 **Acknowledgements**

263 We wish to thank Intellibio for providing technical support and instrumentation, as well as the French
264 Ministry of Agriculture for financial support (CRECHE2019 project).

265 **Conflict of interest**

266 The authors declare that they have no conflict of interest.

267 **References**

268 Balasubramanian, M.N., Panserat, S., Dupont-Nivet, M., Quillet, E., Montfort, J., Le Cam, A., Médale, F.,
269 Kaushik, S.J., Geurden, I., 2016. Molecular pathways associated with the nutritional programming of plant-
270 based diet acceptance in rainbow trout following an early feeding exposure. BMC Genomics 17, 449.
271 doi:10.1186/s12864-016-2804-1.

272 Baras, E., Malbrouck, C., Houbart, M., Kestemont, P., Mélard, C., 2000. The effect of PIT tags on growth and
273 physiology of age-0 cultured Eurasian perch *Perca fluviatilis* of variable size. Aquaculture 185, 159-173.

274 Bridger, C.J., Booth, R.K., 2003. The effects of biotelemetry transmitter presence and attachment procedure
275 on fish physiology and behavior. Rev Fish Sci 11, 13-34.

276 Chatain, B., Corraoa, D., 1992. A sorting method for eliminating larvae without functional swimbladders.
277 Aquaculture 107, 81-88.

278 Chen C., Durand E., Wang J., Zon L.I., Poss K.D., 2013. Zebrafish transgenic lines for in vivo
279 bioluminescence imaging of stem cells and regeneration in adult zebrafish. Development 140, 4988-4997.

280 Cousin, X., Daouk, T., Péan, S., Lyphout, L., Schwartz, M.-E., Bégout, M.-L., 2012. Electronic individual
281 identification of zebrafish using radio frequency identification (RFID) microtags. J Exp Biol 215, 2729-
282 2734.

283 Dare, M.R., 2003. Mortality and long-term retention of Passive Integrated Transponder tags by spring
284 chinook salmon. N Am J Fish Manag 23, 1015-1019.

285 Das Mahapatra, K., Gjerde, B., Reddy, P.V.G.K., Sahoo, M., Jana, R.K., Saha, J.N., Rye, M., 2001. Tagging:
286 on the use of passive integrated transponder (PIT) tags for the identification of fish. Aquac Res 32, 47-50.

287 Ferrari, S., Chatain, B., Cousin, X., Leguay, D., Vergnet, A., Vidal, M.-O., Vandeputte, M., Bégout, M.-L.,
288 2014. Early individual electronic identification of sea bass using RFID microtags: a first example of early
289 phenotyping of sex-related growth. Aquaculture 426-427, 165-171.

290 Gruda M.C., Pinto A., Craelius A., Davidowitz H., Kopacka W., Li J., Qian J., Rodriguez E., Kuspiel E.,
291 Mandecki W., 2010. A system for implanting laboratory mice with light-activated microtransponders. J Am
292 Assoc Lab Animal Science 49, 826-831.

293 Herbinger, C.M., O'Reilly, P.T., Doyle, R.W., Wright, J.M., O'Flynn, F., 1999. Early growth performance of
294 Atlantic salmon full-sib families reared in single family tanks versus in mixed family tanks. Aquaculture
295 173, 105-116.

296 Jolley-Rogers, G., Yeates, D.K., Croft, J., Cawsey, E.M., Suter, P., Webb, J., Morris, R.G., Qian, Z.,
297 Rodriguez, E., Mandecki, W., 2012. Ultra-small RFID p-Chips on the heads of entomological pins provide
298 an automatic and durable means to track and label insect specimens. Zootaxa 3359, 31-42.

299 Lind, C.E., Ponzoni, R.W., Nguyen, N.H., Khaw, H.L., 2012. Selective breeding in fish and conservation of
300 genetic resources for aquaculture. Reprod Dom Anim 47, 255-263.

301 Navarro, A., Oliva, V., Zamorano, M.J., Ginés, R., Izquierdo, M.S., Astorga, N., Afonso, J.M., 2006.
302 Evaluation of PIT system as a method to tag fingerlings of gilthead seabream (*Sparus auratus* L.): effects on
303 growth, mortality and tag loss. Aquaculture 257, 309-315.

304 Pine, W.E., Pollock, K.H., Hightower, J.E., Kwak, T.J., Rice, J.A., 2003. A review of tagging methods for
305 estimating fish population size and components of mortality. Fisheries 28, 10-23.

306 R Core Team (2018) R: A Language and Environment for Statistical Computing. R Foundation for Statistical
307 Computing, Vienna. <https://www.R-project.org>

308 Rasband, W.S., 1997-2018. ImageJ, U. S. National Institutes of Health, Bethesda, Maryland, USA,
309 <https://imagej.nih.gov/ij/>.

310 Robinson E.J.H., Feinerman O., Franks N.R., 2014. How collective comparisons emerge without individual
311 comparisons of the options. Proc Biol Sci 281, 20140737.

312 Saillant, E., Fostier, A., Menu, B., et al. 2001. Sexual growth dimorphism in sea bass *Dicentrarchus labrax*.
313 Aquaculture, 202, 371-387.

314 Tenczar P., Lutz C.C., Rao V.D., Goldenfeld N., Robinson G.E., 2014. Automated monitoring reveals
315 extreme interindividual variation and plasticity in honeybee foraging activity levels. Anim Behav 95: 41-48.

316 Uglem, I., Kristiansen, T. S., Mejdell, C.M., Basic, D. and Mortensen, S., 2019. Evaluation of large-scale
 317 marking methods in farmed salmonids for tracing purposes: impact on fish welfare. Rev Aquacult.
 318 doi:10.1111/raq.12342.

319 Varsamos, S., Connes, R., Diaz, J., Barnabé, G., Charmantier, G., 2001. Ontogeny of osmoregulation in the
 320 European sea bass *Dicentrarchus labrax* L. Marine Biology 138, 909-915.

321
 322
 323
 324
 325

Table 1

327 For each age group, number of survived fish and survival rate (%) of the tagged fish and untagged controls
 328 the day of the microchip implantation/first manipulation, and number of survivor fish and survival rate (%)
 329 from 24 h post-implantation to the end of the experiment.

Age at tagging	Survival 24h after microchip implantation/first manipulation			
	Tagged		Untagged controls	
	N	Survived	N	Survived
61 dph	50	31 (62%)	50	50 (100%)
75 dph	50	42 (84%)	50	50 (100%)
83 dph	50	41 (82%)	50	50 (100%)
89 dph	50	49 (98%)	50	50 (100%)
96 dph	50	45 (90%)	50	50 (100%)
Overall	250	208 (83.2%)	250	250 (100%)

Age at tagging	Survival from 24h to the end of the experiment			
	Tagged		Untagged controls	
	N	Survived	N	Survived
61 dph	31	11 (35.5%)	50	24 (48.0%)
75 dph	42	31 (73.8%)	50	44 (88.0%)
83 dph	41	40 (97.6%)	50	48 (96.0%)
89 dph	49	44 (89.8%)	50	48 (96.0%)
96 dph	45	41 (91.1%)	50	49 (98.0%)
Overall	208	167 (80.3%)	250	213 (85.2%)

330 Characters in bold indicate significant differences between tagged and untagged controls (χ^2 test, p -value < 0.05).

331
 332
 333
 334
 335
 336
 337
 338

Table 2

340 Microchip reading success rate (% of total number of fish) at each biometric measurement and for each age
 341 group.

Age at tagging	Reading success rate at a given age						Average success rate by group
	75 dph	83 dph	89 dph	96 dph	103 dph	110 dph	
61 dph	38.7	40.0	46.7	46.7	46.7	38.5	42.9
75 dph	-	61.9	58.3	36.1	58.8	43.8	51.8
83 dph	-	-	41.5	46.3	48.8	50.0	46.6
89 dph	-	-	-	61.2	56.3	57.8	58.4
96 dph	-	-	-	-	60.0	54.5	57.3

							51.4
Average success rate by biometric measurement	38.7	51.0	48.8	47.6	54.1	48.9	48.2

342 **Table 3**
343 Comparison between the standard length (\pm SD, mm) of the tagged fish and the untagged controls, per each
344 age group and per each biometric measurement.

Age at tagging	Age at measurement					
	75 dph	83 dph	89 dph	96 dph	103 dph	110 dph
	Tagged					
61 dph	19.7 \pm 2.3	20.8 \pm 3.1	22.2 \pm 3.6	24.0 \pm 4.0	26.2 \pm 4.5	28.7 \pm 5.5
75 dph	-	23.2 \pm 2.0	25.1 \pm 2.3	27.2 \pm 2.5	30.1 \pm 2.8	33.5 \pm 2.5
83 dph	-	-	26.4 \pm 1.8	28.6 \pm 1.9	31.3 \pm 2.2	34.3 \pm 2.4
89 dph	-	-	-	26.4 \pm 3.2	28.7 \pm 3.4	31.2 \pm 3.2
96 dph	-	-	-	-	30.9 \pm 2.3	33.3 \pm 2.5
	Untagged controls					
61 dph	20.2 \pm 2.2	23.2 \pm 1.8	25.2 \pm 2.2	27.6 \pm 2.5	30.9 \pm 2.8	33.8 \pm 2.9
75 dph	-	23.2 \pm 2.1	25.8 \pm 1.8	28.0 \pm 2.0	31.4 \pm 2.3	34.4 \pm 2.3
83 dph	-	-	25.3 \pm 1.8	27.6 \pm 2.1	30.8 \pm 2.1	33.7 \pm 2.4
89 dph	-	-	-	27.3 \pm 2.0	29.8 \pm 2.1	32.3 \pm 2.3
96 dph	-	-	-	-	31.0 \pm 3.0	33.4 \pm 3.3

345 Characters in bold indicate significant differences between tagged fish and untagged controls (Wilcoxon-Mann-
346 Whitney non-parametric test, p -value $<$ 0.05).

347

348

349

350

351

352

353

354

355 **Fig. 1.** Intra-coelomic implantation of the microchip in a 75 dph larva: a) insertion of the injector needle into
356 the peritoneal cavity of the fish; b) ejection of the microchip (A; indicated by the red arrow) from the injector
357 needle; c) withdrawal of the injector needle.

a**b****c**