



**HAL**  
open science

## Seasonal variation of giant gourami (*Osphronemus goramy*) spawning activity and egg production in aquaculture ponds

Jacques Slembrouck, Otong Zenal Arifin, Simon Pouil, Jojo Subagja, Akhmad Yani, Asependi Asependi, Anang Hari Kristanto, Marc Legendre

### ► To cite this version:

Jacques Slembrouck, Otong Zenal Arifin, Simon Pouil, Jojo Subagja, Akhmad Yani, et al.. Seasonal variation of giant gourami (*Osphronemus goramy*) spawning activity and egg production in aquaculture ponds. *Aquaculture*, 2020, 527, pp.735450. 10.1016/j.aquaculture.2020.735450 . hal-03163603

**HAL Id: hal-03163603**

**<https://hal.inrae.fr/hal-03163603>**

Submitted on 3 Jun 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     **Seasonal variation of giant gourami (*Osphronemus goramy*) spawning activity and egg**  
2                                   **production in aquaculture ponds**

3

4    Jacques Slembrouck<sup>a\*</sup>, Otong Zenal Arifin<sup>b</sup>, Simon Pouil<sup>a</sup>, Jojo Subagja<sup>b</sup>, Akhmad Yani<sup>c</sup>,  
5    Asependi Asependi<sup>c</sup>, Anang Hari Kristanto<sup>b</sup>, Marc Legendre<sup>a</sup>

6

7    <sup>a</sup>     ISEM, Université de Montpellier, CNRS, IRD, EPHE, Montpellier, France

8    <sup>b</sup>     RIFAFE, Bogor, Indonesia

9    <sup>c</sup>     BPPSIGN, Tasikmalaya, Indonesia

10

11    \* Corresponding author:     Jacques Slembrouck

12    E-mail: [jacques.slembrouck@ird.fr](mailto:jacques.slembrouck@ird.fr)

13    Phone: +62 (0) 21 71 79 46 51

14

15    **Jacques Slembrouck** <https://orcid.org/0000-0001-7102-1528>

16    **Simon Pouil** <https://orcid.org/0000-0003-1531-0362>

17    **Marc Legendre** <https://orcid.org/0000-0003-3122-2098>

18 **Abstract**

19 The giant gourami *Osphronemus goramy* Lacépède, 1801, spontaneously spawns in captivity,  
20 making nests for egg deposition when suitable nest supports and nesting material are made  
21 available in rearing facilities. The seasonal variation in reproductive performance of the giant  
22 gourami was characterized during a 20-month experiment in two compartmentalized ponds  
23 (about 550 m<sup>2</sup> each) at a fry production center in West Java, Indonesia. A total of 208 giant  
24 gourami broodfish were introduced in the two experimental ponds, with a sex-ratio of one male  
25 to three females in each of the 52 spawning compartments delimited by vertical nets. Nesting  
26 supports in each spawning compartment were examined every two days for the presence of  
27 eggs resulting from natural reproduction. Three performance indicators were quantified from  
28 the collected nests: spawning frequency (monthly number of spawns per female), effective  
29 fecundity (number of eggs per spawn) and egg quality (estimated from the proportion of clear  
30 living eggs in each spawn). The seasonality of giant gourami reproduction was analyzed as a  
31 function of seasonal variation in rainfall, rearing water temperature and day length. Based on a  
32 total of 413 collected spawns, the multiple linear regression models did not show any significant  
33 relationship between giant gourami spawning frequency and the three environmental variables  
34 studied. In contrast, the number of eggs per spawn was highly and positively related to rainfall  
35 ( $p < 0.0001$ ), moderately and negatively related to water temperature ( $p < 0.001$ ), and weakly  
36 and negatively related to day length ( $p < 0.01$ ). The proportion of clear eggs was a positively  
37 related to day length ( $p < 0.01$ ). Overall, this study represents one of the first comprehensive  
38 datasets on the reproductive phenology of giant gourami, and as such will be helpful in  
39 formulating broodfish management strategies for the species.

40

41 **Keywords:** Reproduction control; Breeding cycle; Natural spawning; Freshwater aquaculture;  
42 Indonesia

## 43 **1. Introduction**

44 Native to Southeast Asia, notably from Indonesia, the Malay Peninsula, Thailand and the  
45 Mekong basin, the giant gourami *Osphronemus goramy* Lacépède, 1801, has been introduced  
46 to several other countries for aquaculture purposes (Welcomme, 1988). This fish is omnivorous,  
47 with a strong vegetarian tendency, and shows relative robustness and adaptability to  
48 unfavorable environmental conditions (aerial respiration), which make it a very attractive  
49 candidate for low-input aquaculture (Caruso et al., 2019). In Indonesia, the giant gourami is  
50 one of the main freshwater commodities of economic importance owing to its high price and  
51 local demand (Rimmer et al., 2013). Since 2000, giant gourami aquaculture production has  
52 grown by a factor of 10 in Indonesia, the main country farming this species (145,000 tons in  
53 2017; FAO, 2019). The Indonesian national production is ensured by approximately 100,000  
54 small-scale fish farmers mainly located on Java Island (79%; BPS, 2013). Although the giant  
55 gourami has been reared for decades and has now reached a significant production level, there  
56 are still important gaps in our knowledge on several aspects of its biology.

57 The production of giant gourami fry relies on the natural spawning of captive broodfish held in  
58 ponds, but the commercial-scale propagation of the species still needs to be standardized  
59 (Amornsakun et al., 2014a; Arifin et al., 2019; Prakoso et al., 2019). The overall recruitment of  
60 this multiple spawning species (i.e. number of fry produced per broodfish and per spawn) in  
61 the breeding ponds remains generally low, resulting from variable spawning frequency or  
62 success, and variable egg number and quality (Azrita, 2015). Therefore, ensuring a regular and  
63 sufficient supply of fry through reliable production methods remains a major challenge for the  
64 expansion of gourami aquaculture (Amornsakun et al., 2014a, b; Slembrouck et al., 2019).  
65 Among the various biotic and abiotic factors influencing the reproductive performance of  
66 broodfish, the effects of pond management strategies, sex-ratio and duration of egg production  
67 periods were specifically investigated in a recent study (Arifin et al., 2020). Nevertheless, the

68 seasonality of reproduction has also been mentioned as an important limitation to a regular  
69 supply of giant gourami fry (e.g. Arfah et al., 2006; Kristanto et al., 2019; Wijayanti et al.,  
70 2009). In some instances, this seasonality has prompted studies to test hormonal treatments that  
71 induce oocyte maturation and ovulation of giant gourami broodfish (Arfah et al., 2006).  
72 Nevertheless, to our knowledge, an accurate description of the seasonal variation in  
73 reproductive performance of captive giant gourami broodfish is still lacking in the scientific  
74 literature. Such information would help to rationalize and optimize hatchery operations, as in  
75 many intensively farmed finfish species (Migaud et al., 2013). Because there are considerable  
76 interspecific variations in the patterns of reproductive seasonality (Wootton and Smith, 2014;  
77 Paugy et al. 2017), such investigation would also be useful to further document the influence  
78 of the environment on the reproductive phenology of freshwater tropical fishes for which, with  
79 the exception of some families (mostly cichlids and clariids), availability of accurate datasets  
80 remains limited.

81 The objective of the present study was to assess seasonal fluctuations in the reproduction of  
82 giant gourami (spawning frequency, number of eggs in a spawn and egg quality), based on  
83 nearly two years of follow-up in ponds at the Tasikmalaya Center for the Development of Giant  
84 Gourami Culture (BPPSIGN), the largest giant gourami fry production center in the West Java  
85 Province, Indonesia. The seasonality of giant gourami reproduction was analyzed in function  
86 of seasonal variation in rainfall, rearing water temperature and day length, three environmental  
87 parameters considered as major cues for the reproductive phenology of most tropical fishes  
88 (Lowe-McConnell, 1979; Legendre and Jalabert, 1988; Paugy et al., 2017).

## 89 **2. Materials and Methods**

### 90 **2.1. Experimental facilities and pond water quality**

91 This study was carried out at the BPPSIGN Tasikmalaya Center (7°19'37.992"N,  
92 108°6'101.155"E; altitude 489 m). The experiment was performed over a period of 20 months  
93 from May 2016 to December 2017. Experimental structures were two earthen-bottom ponds of  
94 527 and 563 m<sup>2</sup> in surface area with vertical concrete banks and an average water depth of 0.6  
95 m. The two ponds were divided into spawning compartments of about 20 m<sup>2</sup> each (52  
96 compartments in total), delimited with nets embedded in the sediment and held vertically on  
97 bamboo poles. Ponds were supplied from a conduit carrying spring water from the Galunggung  
98 Mountain located less than 10 km from the BPPSIGN Center.

99 Before starting the experiment, the spawning ponds were dried, cleaned, rid of all other species  
100 and limed before being refilled. Pond water pH, dissolved oxygen, conductivity, and turbidity  
101 were measured at quarterly intervals between 07:00 and 08:00 AM with direct measurements  
102 using a multi-parameter probe (HI 9829 Hanna). Water concentration in ammonia (NH<sub>3</sub>), nitrite  
103 (NO<sub>2</sub><sup>-</sup>) and nitrate (NO<sub>3</sub><sup>-</sup>) was measured at the same time using spectrophotometry analysis  
104 (Hanna HI83399). The average and range of variation of these parameters are provided in  
105 Table 1 and indicate that the pond water quality remained stable during the experiment and  
106 within appropriate standards for tropical freshwater fish (Colt, 2006).

107

### 108 **2.2 Fish maintenance and assessment of reproductive performance**

109 The mature broodfish (n = 208) used in this study were descendants of giant gourami belonging  
110 to the "Galunggung" strain (Arifin et al., 2018). The females were 3-5 years old and weighed  
111 ~3 kg, whereas males were 5-7 years old and weighed ~4 kg. Identification of fish sex and  
112 assessment of their sexual maturity were done on the basis of morphological criteria, milt  
113 emission following gentle abdominal massage or examination of oocytes obtained by

114 intraovarian biopsies as described by Slembrouck et al. (2019). One sexually mature male and  
115 three sexually mature females were placed in each of the 52 spawning compartments of the two  
116 experimental ponds.

117 The giant gourami is a nest builder; therefore, nest supports and nesting material were provided  
118 in each compartment for spawning. Nest supports were baskets made of braided bamboo strips  
119 (total length: 25 cm, including an opening of about 30 cm in diameter), attached to bamboo  
120 stakes, and placed about 15 cm below the water surface with the opening positioned slightly  
121 downward (angle of about 30°). Plant fibers from palm trees (*Arenga* sp.) were piled on a  
122 bamboo table positioned at the surface of the water in the middle of every compartment, so that  
123 the broodfish could easily grasp the fibers with their mouths and build their nests (see Arifin et  
124 al., 2020, for picture of the nest supports).

125 Every two days, all nest supports were examined and closed nests containing eggs were  
126 collected, transferred to the hatchery, then immersed in a water tank to release the eggs by  
127 carefully opening the palm fiber material as detailed in Arifin et al. (2020). All the eggs from  
128 each nest were manually counted, separating live (transparent/clear) eggs from dead  
129 (opaque/white) eggs. During the experiment, reproductive performance was assessed by  
130 monitoring spawning frequency (the number of spawns per female per month), the number of  
131 eggs in a spawn (i.e., numbers of eggs in a nest) and egg quality (estimated by the proportion  
132 of clear eggs in each spawn). In some instances, the eggs were newly hatched at the moment of  
133 nest collection; however, this had no or little incidence on the evaluation of progeny number  
134 and spawn quality because white (dead) eggs take more than one day to break up and newly  
135 hatched larvae, unable to swim, remain inside the nest.

136 During the egg production periods, the broodfish were fed with leaves of elephant ear plants  
137 (*Alocasia macrorrhizos*) and commercial floating pellets (32% proteins, 5% lipids) distributed  
138 at a daily feeding rate of 2% and 1% of fish biomass, respectively. The egg production periods

139 lasted for 3 or 7 months depending on spawning compartments, two durations that lead to  
140 equivalent results in terms of egg production over the long term (Arifin et al., 2020). Between  
141 two successive egg production periods, the broodfish were reconditioned for 1 month  
142 (separating males and females in different ponds and using reverse daily feeding rates of  
143 elephant ear leaves and floating pellets). The broodfish fish were examined every three months  
144 and weighed with a digital scale for adjustment of feeding rations.

145

### 146 **2.3. Monitoring of environmental conditions**

147 Throughout the 20-month experiment, fluctuations of three environmental parameters were  
148 considered: rainfall, pond water temperature and day length. Pond water temperature was  
149 monitored continuously using a data logger (Onset HOBO) placed in the center of the ponds at  
150 20 cm depth. A rain gauge was installed in the immediate vicinity of the ponds to record the  
151 daily rainfall and the information related to day length was collected from Time and Date  
152 (2019).

153

### 154 **2.4. Data treatment and statistical analysis**

155 Prior to statistical analysis, fish reproduction and environmental data were compiled and, for  
156 each pond and each variable, monthly means of the recorded values were calculated. Statistical  
157 analyses were then performed on these average monthly values.

158 The non-significance of the variable “pond”, initially included in general linear models (GLM)  
159 with quantitative environmental variables was confirmed. Then, stepwise multiple linear  
160 regression models (MLR) were used to test for relationships between female spawning  
161 frequency, egg numbers or clear egg proportion in spawns and environmental variables  
162 (rainfall, water temperature and day length). The assumptions underlying the MLR were  
163 checked by visual observation of the model residuals and by statistical analysis (Goldfeld-



164 Quandt test, Rainbow test and Shapiro-Wilk test). Variance inflation factors (VIF) were used  
165 to estimate collinearity of the explanatory variables, with VIF values close to 1 indicating the  
166 absence of strong multi-collinearity (Hair et al., 2010). Statistical analyses were performed  
167 using R freeware version 3.5.2 using the packages “car”, “lmtest” and “stats” (R Development  
168 Core Team, 2019).

169

### 170 **3. Results**

171 At the BPPSIGN Tasikmalaya Center, day length varied annually between 11 h 41 min and 12  
172 h 33 min, and pond water temperature ranged from 22.6°C to 32.7°C. The cumulative monthly  
173 rainfall ranged from 5 to 528 mm during the experiment, from May 2016 to December 2017.  
174 Overall, the monthly mean of the pond water temperature showed limited variation (between  
175 25.4°C and 28.0°C), whereas the monthly rainfall was much lower during the second than  
176 during the first half of the experimental period (from 331 to 528 mm vs. 0.5 to 288 mm,  
177 respectively; Figure 1A).

178 During this 20-month period, as determined from the 413 spawns collected in the two  
179 experimental ponds (206 and 207 spawns per pond), the reproduction of giant gourami occurred  
180 continuously. Because no effect of the duration of egg production periods (successive periods  
181 of 3 or 7 months) was detected for any variable (spawning frequency, egg number and quality),  
182 the data were pooled for analyses. The mean monthly spawning frequency of giant gourami  
183 varied between 0.07 and 0.26 spawn female<sup>-1</sup> month<sup>-1</sup> without a clear seasonal rhythm in the  
184 intensity of spawning activity (Figure 1B). The mean monthly number of eggs per spawn  
185 collected from the nests varied between 2020 and 5920 eggs spawn<sup>-1</sup> and peaked (more than  
186 4000 eggs spawn<sup>-1</sup>) during the period between July and November 2016 (Figure 1B). The mean  
187 monthly proportion of clear (live) eggs in the spawns varied between 79 and 96% (Figure 1B).

188 The MLR did not reveal any significant relationship between giant gourami spawning  
189 frequency and any of the environmental variables (Table 2). Observed monthly variation in  
190 spawning frequency had no clear seasonal rhythm; it was not related to simultaneous variations  
191 in rainfall, water temperature or day length. In contrast, variation in the number of eggs  
192 produced per spawn was clearly related to variation in environmental variables (multiple  $R^2 =$   
193  $0.71$ ;  $p < 0.0001$ ). Egg number was highly and positively related to rainfall (t-value =  $7.777$ ,  $p$   
194  $< 0.0001$ ), moderately and negatively related to water temperature (t-value =  $-4.387$ ,  $p = 0.001$ ),  
195 and weaker and negatively related to day length (t-value =  $-2.983$ ,  $p < 0.01$ ) (Table 2). For  
196 egg quality, as evaluated through the proportion of clear eggs, there was a positive but relatively  
197 weak relationship with day length (t-value =  $3.126$ ,  $p < 0.01$ ), but not with rainfall or water  
198 temperature.

199

#### 200 **4. Discussion**

201 In the present study, giant gourami clearly reproduced all year round in the ponds at the  
202 BPPSIGN Tasikmalaya Center. No clear seasonal rhythm was revealed in the spawning  
203 frequency of broodfish, which was not related to concurrent variations in rainfall, water  
204 temperature or day length. Although the spawning activity of the giant gourami is often  
205 considered as continuous all year round (Bhimachar et al., 1944), seasonal variations in the  
206 spawning frequency have been noted, depending on the region or authors (Arfah et al., 2006;  
207 Bhimachar et al., 1944; Wijayanti et al., 2009), but relationships between these variations and  
208 environmental variables were not documented. In a recent study performed in the West Java  
209 Province, targeted questionnaires and interviews also highlighted that fish farmers from Bogor  
210 districts report seasonal variation in the reproductive intensity of their giant gourami broodfish,  
211 with rain events (possibly together with associated variation in water temperature) leading to a  
212 reduction in spawning frequency (Kristanto et al., 2019). In the same study, farmers from the

213 Tasikmalaya district observed no clear seasonality in giant gourami spawning activity, which  
214 the present investigation confirms. In contrast to spawning frequency, the number of eggs  
215 collected from the nests were strongly related to environmental factors; it was positively related  
216 to rainfall, intermediately and negatively related to water temperature and weakly, and  
217 negatively related to day length. To our knowledge, such temporal variation in egg number and  
218 their strong relationship with rainfall and water temperature has not been reported previously  
219 in the giant gourami. However, seasonal variation in fecundity is known to occur in several  
220 tropical species reproducing all year round. In the African catfish *Heterobranchus longifilis*,  
221 maximal egg production is observed during the rainy season, whereas in the lagoon tilapias  
222 *Sarotherodon melanotheron* and *Tilapia guineensis*, fecundity is highest during the hot, dry  
223 season (Legendre, 1992). In *Oreochromis niloticus*, the peak of fecundity corresponds with  
224 maximum resource availability and flooding imminence (Duponchelle et al., 2000). Tropical  
225 fish species are generally very plastic and can allocate resources to reproduction according to  
226 rainfall regimes (Chellappa et al., 2009). In the present study, the giant gourami egg quality  
227 was positively, although weakly, related to day length. Prayogo et al. (2018) claimed that  
228 experimentally controlled long photoperiods (18L-6D) have a positive effect on the expression  
229 levels of vitellogenin genes. It is well known that fish vitellogenins are critical for providing an  
230 adequate nutritional reserve for embryonic development and are also involved in other complex  
231 functions that influence egg quality (Reading et al., 2018). Nevertheless, further studies are  
232 needed to better understand the mechanisms underlying the positive influence of day length  
233 observed here on giant gourami egg quality.

234 As a whole, the present study provides the first detailed long-term investigation on the seasonal  
235 variation of the spawning performance of captive giant gourami. We found no clear spawning  
236 rhythms in this species in the environmental conditions of the Tasikmalaya area. On the same  
237 location and using identical rearing procedures, it was observed that a same female spawns in

238 average every 5 months and that spawning frequency was strongly influenced by broodfish sex-  
239 ratio (Arifin et al, 2020). In Tasikmalaya ponds, fluctuations of environmental parameters were  
240 limited (particularly temperature) and, as a matter of fact, remained during the whole study in  
241 a range favorable to giant gourami gametogenesis and spawning. Nevertheless, in other areas,  
242 several studies (*op. cit.*) reported the occurrence of seasonal variation in giant gourami  
243 reproduction, probably as a consequence of a locally less stable environment. Further  
244 investigation conducted in such area with the same methodology as in the present study would  
245 provide complementary view on the environmental control of giant gourami reproductive  
246 phenology. By contrast to spawning frequency, the number of eggs per spawn showed greater  
247 sensitivity to environmental changes and was strongly related to variations of environmental  
248 variables (particularly rainfall and, to a lesser extent, water temperature and day length). Egg  
249 quality was also affected by day length. These findings should be taken into consideration when  
250 establishing egg production plans in commercial hatcheries. For instance, egg production  
251 periods of 6–7 months separated by resting/reconditioning periods of 1 month are  
252 recommended in the management of giant gourami spawning ponds (Arifin et al., 2020). As far  
253 as possible, it is therefore recommended for optimizing egg production to synchronize the  
254 broodfish resting/reconditioning periods with the periods of the year during which rainfall and  
255 broodfish fecundity are at their lowest.

256

## 257 **Acknowledgements**

258 The authors acknowledge Maman Sudirman and the technicians of the West Java Center for  
259 the Development of Giant Gourami Culture (BPPSIGN) for sharing their experience and for  
260 their assistance throughout this study. This is a publication ISEM no. XXX-XXX.

261

262 **References**

- 263 Arfah, H., Maftucha, L., Carman, O., 2006. Induced spawning of giant gourami *Osphronemus*  
264 *gouramy* Lac. by Ovaprim. Jurnal Akuakultur Indonesia 5, 103-112.  
265 <https://doi.org/10.19027/jai.5.103-112>.
- 266 Amornsakun, T., Kullai, S., Hassan, A., 2014a. Some aspects in early life stage of giant  
267 gourami, *Osphronemus goramy* (Lacepède) larvae. Songklanakarin J. Sci. Technol. 36,  
268 493-498.
- 269 Amornsakun, T., Kullai, S., Hassan, A., 2014b. Feeding behavior of giant gourami,  
270 *Osphronemus gouramy* (Lacepède) larvae. *Songklanakarin J. Sci. Technol.* 36, 261-264.
- 271 Arifin, O.Z., Imron, I., Asependi, A., Hendri, A., Muslim, N., Yani, A., 2018. Intraspecific  
272 hybridization between two populations of Galunggung giant gourami (*Osphronemus*  
273 *goramy*, Lacepède, 1801) (in Indonesian). *J. Ris. Akuakultur* 12, 315-323.
- 274 Arifin, O.Z., Prakoso, V.A., Kristanto, A.H., Pouil, S., Slembrouck, J., 2019. Effect of  
275 stocking density on growth, food intake and survival of giant gourami (*Osphronemus*  
276 *goramy*, Lacepède) larvae. *Aquaculture* 509, 159-166.  
277 <https://doi.org/10.1016/j.aquaculture.2019.05.010>.
- 278 Arifin, O.Z., Slembrouck, J., Subagja, J., Pouil, S., Yani, A., Asependi, A., Kristanto, A.H.,  
279 Legendre, M., 2020. New insights into giant gourami (*Osphronemus goramy*)  
280 reproductive biology and egg production control. *Aquaculture* 519, 734-743.
- 281 Azrita, H.S., 2015. Morphological character among five strains of giant gourami,  
282 *Osphronemus goramy* Lacepède, 1801 (Actinopterygii: Perciformes: Osphronemidae)  
283 using a truss morphometric system. *Int. J. Fish Aquat. Stud.* 2, 344-350.

284 Bhimachar, B.S., David, A., Muniappa, B., 1944. Observations on the acclimatization, nesting  
285 habits and early development of *Osphronemus gorami* (Lacepède). Proc. Natl. Acad.  
286 Sci. India Sect. B Biol. Sci. 20, 88-101.

287 BPS., 2013. Number of non-ornamental fish farms by region and fish species (in Indonesian).  
288 <https://st2013.bps.go.id/dev2/index.php/site/tabel?tid=57&wid=3200000000> (accessed  
289 13 September 2019).

290 Caruso D., Arifin, Z.O., Subagja, J., Slembrouck, J., New, M., 2019. *Osphronemus goramy*.  
291 Cultured Aquatic Species Information Programme. In: FAO Fisheries and Aquaculture  
292 Department [online]. Rome.

293 Chellappa, S., Bueno, R.M.X., Chellappa, T., Chellappa, N.T., Val, V.M.F.A., 2009.  
294 Reproductive seasonality of the fish fauna and limnoecology of semi-arid Brazilian  
295 reservoirs. *Limnologica* 39, 325-329. <https://doi.org/10.1016/j.limno.2009.06.003>.

296 Colt, J., 2006. Water quality requirements for reuse systems. *Aquacult. Eng.* 34, 143-156.

297 Duponchelle, F., Cecchi, P., Corbin, D., Nunez, J., Legendre, M., 2000. Variations in  
298 fecundity and egg size of female Nile tilapia, *Oreochromis niloticus*, populations from  
299 man-made lakes of Côte d'Ivoire. *Env. Biol. Fish* 57, 155-170.  
300 <https://doi.org/10.1023/A:1007575624937>.

301 FAO, 2019. FishStatJ: software for fishery statistical time series. FAO, Roma.

302 Hair, J.F. Jr, Black, W.C., Babin, B.J., Anderson, R.E., 2010. Multivariate data analysis, 7th  
303 edition. Prentice Hall, Upper Saddle River, NJ.

304 Kristanto, A.H., Slembrouck, J., Subagja, J., Pouil, S., Arifin, O.Z., Prakoso, V.A., Legendre  
305 M., 2019. Egg and fry production of giant gourami (*Osphronemus goramy*): Rearing  
306 practices and recommendations for future research. *J. World Aquacult. Soc.* 51, 119-  
307 138. <https://doi.org/10.1111/jwas.12647>.

308 Legendre, M., 1992. Aquaculture potentialities of cichlids (*Sarotherodon melanotheron*,  
309 *Tilapia guineensis*) and clariids (*Heterobranchus longifilis*) autochthonous from  
310 lagoons of Ivory Coast (in French). ORSTOM, Marseille, France. 83 p. + annex.

311 Legendre, M., Jalabert, B., 1988. Physiology of reproduction, in: Lévêque, C., Bruton, M.N.,  
312 Ssentongo, G.W. (Eds.), Biology and ecology of African freshwater fishes (in French).  
313 ORSTOM, Marseille, France, pp 153-175.

314 Lowe-McConnell, R.H., 1979. Ecological aspects of seasonality in fishes of tropical waters.  
315 Symp. Zool. Soc. Lond. 44, 219-241.

316 Migaud, H., Bell, G., Cabrita, E., McAndrew, B., Davie, A., Bobe, J., Herráez, M.P., Carrillo,  
317 M., 2013. Gamete quality and broodstock management in temperate fish. Rev.  
318 Aquacult. 5, 194-223. <https://doi.org/10.1111/raq.12025>.

319 Paugy, D., Lévêque, C., Duponchelle, F., 2017. Reproduction, in: Paugy, D., Lévêque, C.,  
320 Otero, O. (Eds.), The inland water fishes of Africa: Diversity, ecology and human use.  
321 IRD Editions/Mrac, Marseille, France, pp. 189-217.

322 Prakoso, V.A., Pouil, S., Prabowo, M.N.I., Sundari, S., Arifin, O.Z., Subagja, J., Affandi, R.,  
323 Kristanto, A.H., Slembrouck, J., 2019. Effects of temperature on the zootechnical  
324 performances and physiology of giant gourami (*Osphronemus goramy*) larvae.  
325 Aquaculture 510, 160-168. <https://doi.org/10.1016/j.aquaculture.2019.05.047>.

326 Prayogo, N.A., Siregar, A.S., Sukardi, P., Nugrayani, D., Ekasanti, A., Riviani, Bessho, Y.,  
327 2018. Identification and expression of vitellogenin gene in the gouramy (*Osphronemus*  
328 *goramy*) under photoperiod manipulation. E3S Web Conf. 47, 1-10.  
329 <https://doi.org/10.1051/e3sconf/20184702001>.

330 R Development Core Team, 2019. R: A language and environment for statistical computing.  
331 R Foundation for Statistical Computing, Vienna.

332 Reading, B.J., Andersen, L.K., Ryu, Y.W., Mushirobira, Y., Todo, T., Hiramatsu, N., 2018.  
333 Oogenesis and egg quality in finfish: Yolk formation and other factors influencing  
334 female fertility. *Fishes* 3, 45. <https://doi.org/10.3390/fishes3040045>.

335 Rimmer, M.A., Sugama, K., Rakhmawati, D., Rofiq, R., Habgood, R.H., 2013. A review and  
336 SWOT analysis of aquaculture development in Indonesia. *Rev. Aquac.* 5, 255-279.  
337 <https://doi.org/10.1111/raq.12017>.

338 Slembrouck, J., Arifin, O.Z., Pouil, S., Subagja, J., Yani, A., Kristanto, A.H., Legendre, M.,  
339 2019. Gender identification in farmed giant gourami (*Osphronemus goramy*): A  
340 methodology for better broodstock management. *Aquaculture* 498, 388-395.  
341 <https://doi.org/10.1016/j.aquaculture.2018.08.056>.

342 Time and Date, 2019. Weather in Tasikmalaya, Java, Indonesia.  
343 <https://www.timeanddate.com/worldclock/indonesia/tasikmalaya> (accessed 12  
344 September 2019).

345 Welcome, R.L., 1988. International introductions of Inland aquatic species. *FAO Fish. Tech.*  
346 *Pap.* 294, Roma, Italy, 318 p.

347 Wijayanti, G.E., Soeminto, Simanjuntak, B.I., 2009. Reproductive hormone profiles and  
348 gametogenesis in female giant gourami (*Osphronemus gouramy*) (in Indonesian). *Jurnal*  
349 *Akuakultur Indonesia* 8, 77-89.

350 Wootton, R.J., Smith, C., 2014. *Reproductive Biology of Teleost Fishes*. Wiley Blackwell,  
351 Chichester, West Sussex, UK. 496 p.

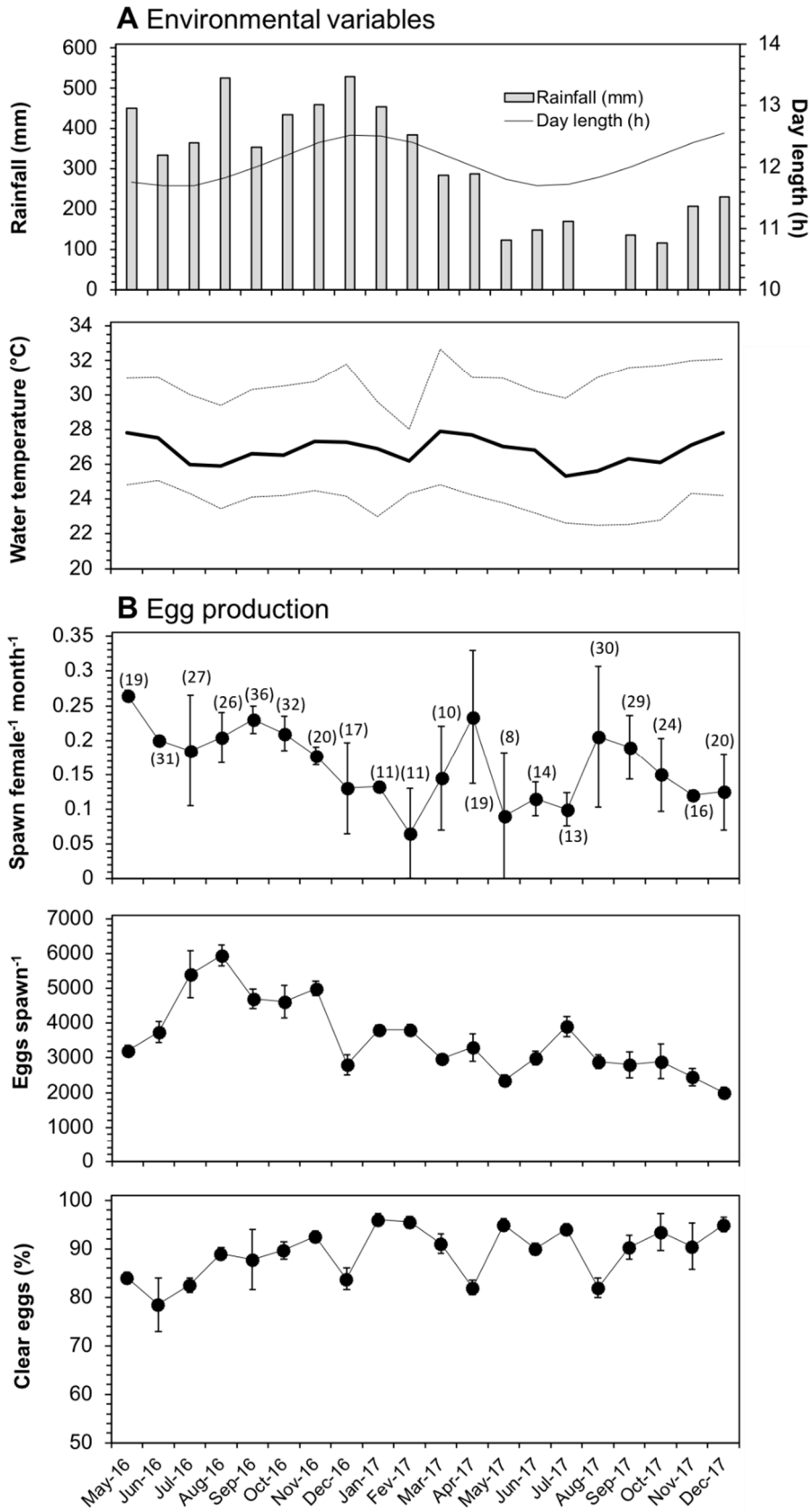
352



353 **Captions to figure**

354

355 **Figure 1.** Mean monthly variation in environmental variables (A) and egg production  
356 characteristics of giant gourami in ponds (B) at the BPPSIGN Tasikmalaya Center. A<sub>1</sub>: rainfall  
357 and day length, A<sub>2</sub>: pond water temperature (mean  $\pm$  extreme instantaneous temperature), B<sub>1</sub>:  
358 female spawning frequency, B<sub>2</sub>: number of eggs in a spawn and B<sub>3</sub>: egg quality according to  
359 the proportion of clear eggs. In graphs B<sub>1</sub>, B<sub>2</sub> and B<sub>3</sub>, vertical bars indicate the range between  
360 the means recorded in the two compartmentalized ponds. Due to the occurrence of periodic  
361 reconditioning periods, the number of females actually involved in reproduction each month  
362 was not constant and varied between 72 and 156 individuals (127 females per month on  
363 average). The total number of spawns collected per month is given in parentheses (graph B<sub>1</sub>).



364 **Figure 1**

365 **Table 1.** Summary of water quality parameters measured in the ponds during the 20-month  
366 experiment.

Parameters <sup>1</sup>	Mean $\pm$ SD (Range)
DO (mg L <sup>-1</sup> )	5.2 $\pm$ 1.3 (3.8-7.3)
pH	7.6 $\pm$ 0.2 (7.5-7.9)
Conductivity ( $\mu$ S cm <sup>-1</sup> )	180 $\pm$ 8 (171-188)
Turbidity (NTU)	9 $\pm$ 3 (9-13)
NH <sub>3</sub> (mg L <sup>-1</sup> )	<0.0065
NO <sub>2</sub> <sup>-</sup> (mg L <sup>-1</sup> )	0.010 $\pm$ 0.005 (0.006-0.020)
NO <sub>3</sub> <sup>-</sup> (mg L <sup>-1</sup> )	0.41 $\pm$ 0.12 (0.26-0.59)

367 <sup>1</sup>DO: dissolved oxygen

368

369 **Table 2.** Results of multiple linear regression models assessing the effects of environmental  
 370 variables (i.e. daily rainfall, water temperature and day length) on the reproductive performance  
 371 (i.e. female spawning frequency, egg number and egg quality) of captive giant gourami  
 372 broodfish.

<b>A - Spawning frequency</b>				
Multiple R <sup>2</sup> : 0.08	Estimate	SD	t-value	p-value
Intercept	0.7356	0.6163	1.194	0.241
Daily rainfall	0.0032	0.0027	1.183	0.245
Water temperature	0.0093	0.0180	0.520	0.606
Day length	-0.0707	0.0459	-1.541	0.132
<b>B - Number of eggs per spawn</b>				
Multiple R <sup>2</sup> : 0.71	Estimate	SD	t-value	p-value
Intercept	34172.81	5151.12	6.634	< <b>0.0001</b>
Daily rainfall	180.07	23.15	7.777	< <b>0.0001</b>
Water temperature	-678.61	154.70	-4.387	< <b>0.001</b>
Day length	-1172.40	393.08	-2.983	< <b>0.01</b>
<b>C - Proportion of clear eggs</b>				
Multiple R <sup>2</sup> : 0.24	Estimate	SD	t-value	p-value
Intercept	14.356	42.061	0.341	0.735
Daily rainfall	-0.217	0.189	-1.148	0.260
Water temperature	-1.678	1.263	-1.328	0.194
Day length	10.034	3.210	3.126	< <b>0.01</b>

373