Please note that this is an author-produced PDF of an article accepted for publication following peer review. The definitive publisher-authenticated version is available on the publisher Web site

Aquaculture Research
March 2008, Volume 39, Issue 4 : Pages 420-426
http://dx.doi.org/10.1111/j.1365-2109.2007.01828.x
© 2008 Blackwell Publishing, Inc.

The definitive version is available at www.blackwell-synergy.com

Archimer, archive institutionnelle de l'Ifremer
http://www.ifremer.fr/docelec/

Influence of tank volume on vitellogenesis and spawning performances in sea bass Dicentrarchus labrax L.

Vincent Buchet[1, *], Elodie Coquard[1], Armelle Sévère[1] & Hervé Barone[1]

[1] UMR 1067 Nutrition Aquaculture and Genomics of Fish, Ifremer, Plouzané, France

*: Corresponding author : V. Buchet, UMR 1067, Nutrition Aquaculture and Genomics of Fish, Ifremer, BP 70, 29280 Plouzané, France. email address : Vincent.Buchet@ifremer.fr

Abstract:

Sea bass, Dicentrarchus labrax (mean weight: 748±13 g), were maintained before and during vitellogenesis in 1, 3, 8, 16 and 32 m3 tanks, and then they were transferred to 2 m3 tanks, for the spawning season. During the first 2 months of the experiment, the growth rates were significantly lower in smaller tanks (1 m3). In August, the oocyte diameters were significantly lower in smaller tanks (1, 3 and 8 m3) than in larger (16–32 m3) tanks. At the end of the experiment, the fish mean weight in the 1 m3 tanks was significantly lower than in the 3 m3 tanks, but oocyte diameters and plasma oestradiol concentrations were not significantly different between the volumes. This shows a longer acclimation requirement in smaller volume rearing. Although all the females had not spawned, one spawn at least was collected in each volume. The variation in conditioning volume has not blocked the spawning process. The qualitative and quantitative characteristics of spawns were not significantly different between volumes. The conditioning volume of 3 m3 seems to be a minimal volume required to obtain good reproduction of sea bass.

Keywords: Sea bass**,** Reproduction, Vitellogenesis, Aquaculture, Volume

Introduction

For temperate species fish such as the European sea bass, photoperiod and temperature are the main environmental factors controlling the process of sexual maturation and reproduction (Bromage 1995; Carrillo, Zanuy, Prat, Cerda, Ramos, Mananos & Bromage 1995; Mananos, Zanuy & Carrillo 1997; Bromage, Porter & Randall 2001; Rodriguez, Begtashi, Zanuy, Shaw & Carrillo 2001). The salinity, the oxygenation and the water quality play a minor role. Other factors related to the culture conditions, such as tank hydraulics, rearing density or farming manipulations, can also influence the reproduction of numerous species: common carp (Sehgal & Toor 1995), tilapia (Siddiqui, Al-harbi & Hafedh 1997; Ridha & Cruz 1999), *Pagrus auratus* (Cleary, Pankhurst & Battaglene 2000; Schreck, Contreras-sanchez & Fitzpatrick 2001). They can have a limiting or an activating role in the reproduction and they can influence the spawn quality (Bromage 1995). Although investment in rearing structures is an important part of the budget of a hatchery project, very few studies have been carried out on the influence of tank-rearing volume on spawning performance. Nevertheless, it has been reported that tank volume may influence the welfare of the fish. Hence, mortality associated with repeated handlings is lower for turbot (*Scophtalmus maximus* L.) held in small tank volumes ($2m^3$) than those maintained in larger ones ($16m^3$) (Mugnier, Fostier, Guezou, Gaignon & Quemener, 1998). Similarly, a temporary reduction (2 weeks) in the tank volume during the final stages of gametogenesis influences negatively the quality of gametes produced by brown (*Salmo trutta*) and rainbow trout (Oncorhynchus mykiss) (Campbell, Pottinger & Sumpter 1994). Fornies, Mananos, Carrillo, Rocha, Laureau, Mylonas, Zohar and Zanuy (2001) showed that the quality of the spawns of sea bass held individually in a $2m^3$ tank is lower than that of fish held in$15m^3$ tanks. However, in his study, the fish densities and sex ratios were different. Thus, it is difficult to differentiate the respective effects of density and volume on the quality of gametes and the survival rates of the progeny.

Finally, very few studies have focused on only the effect of tank rearing volume on reproductive performances. Okumura, Okamoto, Oomori and Nakazono (2002) showed that water height and pond volume could limit the emergence of reproductive behaviour preceding spawning of *Epinephelus akaara*. Ambali and Little (1996) have shown that for the same condition of

biomass, the production of eggs of *Oreochromis niloticus* per m2 is inversely proportional to the size of the reproduction ponds. The spawns of zebra fish (*Danio rerio*) maintained in volumes of 200 or 100mL represent, respectively, 48% and 26% of the production obtained with breeders maintained in aquariums of 3.5 L (Goolish, Evans, Okutake & Max 1998). The objective of this experiment was to estimate the influence of tank volume during gametogenesis on individual spawning performances of the European sea bass, firstly, by follow-up of the effects on the gonadic development and on the plasmatic E2 profiles and, secondly, by comparing these observations with the quantitative and qualitative characteristics of the individual spawns observed during the reproductive season. This would allow showing a correlation between the reduction in the tank volume and the decrease in the spawn performances and also determination of the minimum volume that blocks the reproduction. The present study was conducted on sea bass *Dicentrarchus labrax* that spawns spontaneously in captivity and due to its economic importance for European aquaculture.

Materials and Methods

Fish and rearing conditions

The European sea bass *Dicentrarchus labrax L.* used in this experiment were hatched at the Ecloserie Marine de Gravelines (France) and reared in our experimental facilities for 3 years. During six months preceding the experiment, fishes were maintained in 6 tanks of 3 m^3 of volume. The experiment was divided into two phases: the first, “conditioning period”, which was squared with the whole gametogenesis and the second, “spawning period”, which starts at the end of vitellogenesis and covers the duration of the spawning period.

Sexually mature sea bass (mean weight: 748 +/- 13g) were randomly distributed in 1, 3, 8, 16 and 32m^3 tanks (3 tanks for "1m^3 condition" and 1 tank for the other conditions), at the density of 3 fishes per m^3 and a sex ratio of 2 males: female during the conditioning period (from the end March to end December). Each tank of 1, 3, 8, 16 and 32 m^3 contained 3, 9, 24, 48 and 96 fishes respectively. Under-skin magnetic tags implanted in gill cover individually identified the fish. Breeders were maintained under natural photoperiod and water temperature of the roadstead of Brest (latitude 48°21’N). At the end of the first period, the females were considered

ripe when mean diameter of oocyte reached 800-900µm. The males were selected based on their ripeness characters (spontaneous sperm release). Each selected female was transferred into spawning tank for an individual monitoring at same sex ratio than previously (2 males: female). 3 spawning tanks were brought into second phase for each conditioning volume (3 replicates), according to the method used by Suquet, Normant, Gaignon, Quéméner and Fauvel (2005). Egg collectors allowed us to collect both floating and sinking eggs from each spawning device. Spawns occurred spontaneously.

The conditioning (1, 3, 8, 16 and 32 m^3) and spawning (2m^3) tanks were supplied with running seawater to a flow corresponding to 30% of the volume of each tank per hour. The oxygen level was maintained around 80% of the saturation. During the conditioning period, fish were fed "ad libitum", every day, with commercial feed (Neo Repro, Le Gouessant® - Lamballe - France, pellet diameter 9mm). During the spawning period, a small quantity of food was provided to avoid a weight loss and keep the tanks clean when the temperature exceeds 12 °C.

Studied parameters

Every month (from March to December), during the “conditioning period”, all the fish of all experimental units were caught and anesthetized with ethylene glycol monophenylether (200ppm). Growth was estimated by individual weighing of all fish. From these, Specific growth rate (SGR, $\%day^{-1}$) was calculated as: $100 \times (\ln w_f - w_i)\ day^{-1}$, where w_i and w_f are the initial and final mean wet body weight respectively. Oocyte development was monitored by biopsy. Biopsies were carried out in all females of 1, 3 and 8 m^3 tanks and at 8 randomly chosen females of the other experimental units (16 and 32 m^3). The diameter of the forty largest oocytes was recorded. Plasma levels of steroid hormones, estradiol (E2), were monitored during gametogenesis. E2 was quantified using a homologous enzyme-linked immunosorbent assay (ELISA) based on the procedure described by Nash, Davail-Cuisset, Bhattacharyya, Suter, Le Menn & Kime (2000). Measurements of steroid levels were performed in the same females as the determination of oocyte diameter.

During the spawning period, presence of spawn was checked every morning. The determination of eggs viability was made at the “4 cells stage”, using 3 samples of 15 ml for each spawn. Eggs

and oocytes were sorted according 3 criteria: live and considered as fertilized eggs (floating eggs and visible cells), dead (sinking eggs) or not fertilized (floating eggs but invisible division of cells). 3 samples by spawn were placed in cylindro-conical incubators of 1liter in volume with a renewal rate of 300% per hour. The water temperature was the same as in the spawning tanks. Each day, the dead eggs were collected. At hatching, measurements on larvae were realized under weak anaesthesia with ethylene glycol monophenylether. The following parameters were evaluated:(1) Number of spawns by female, (2) fecundity; number of eggs by spawn and relative fecundity; total number of eggs / weight of female, (3) viability rate (%); 100 x (number of live eggs/total number eggs), (4) fertilization rate (%); 100 x (number of fertilized eggs/ total number of eggs), (5) egg diameter (mm); evaluated on 40 eggs fertilized without apparent abnormality in cells division. Values obtained for the spawns were means of 3 incubators. (6) Length of larvae (mm); mean total length of forty larvae alive and without skeletal malformations. (7) Hatching rate (%); 100 x (number of larvae / number of eggs incubated). (8) Malformation rate (%): 100 x (malformed larvae/larvae) and non-lethal malformation rate (%): 100 x (malformed alive larvae /larvae). A skeletal malformation is considered as non-lethal, if it allows the survival of larvae.

Statistical analysis

All results are expressed as mean ± SE. Data were compared using one-way ANOVA using STATISTICA for Windows. Significant ANOVAs were followed by a post hoc multiple comparison test (Newman-Keuls). Differences were considered to be significant at $P<0.05$. Before ANOVA analysis, data expressed in % were arc sinus square-root transformed.

Results

The minimal value of oxygen saturation observed in the $3m^3$ tank during the conditioning period (75.2% air saturation) remains superior to the minimum required for the well-being of sea bass. This deficit (-13%) compared with the other conditions was measured for approximately 2

144 months. During the spawning period, the oxygen saturation rate remained above the minimum
145 required for the well being of fish (> = 79%).
146
147 Conditioning period
148 Temperature ranged from 9.1℃ (8th December) to 20. 1℃ (27th August) for all tanks. From
149 March to August, the specific growth rate (SGR (%day^{-1}) in the 1m^3 tank was significantly lower
150 (0.07 ± 0.02, P<0.05) than in other tanks (3, 8, 16 and 32 m^3) with a SGR equal to 0.17 ± 0.01,
151 0.14 ± 0.01, 0.17 ± 0.01, 0.18 ± 0.01 respectively. Although after August this difference
152 disappeared, the Specific Growth Rate of fishes from this condition remained significantly lower
153 (0.11 ± 0.01% day^{-1}) (P<0.05) than the fishes of other tanks, 0.2 ± 0.01, 0.16 ± 0.01, 0.19 ±
154 0.01, 0.19 ± 0.01 % day^{-1} for respectively 3, 8 16 and 32 m^3 tanks, for the whole conditioning
155 period. This is illustrated by the evolution of weight of fishes in the different conditions during the
156 conditioning period (Fig 1).
157 At the end of August, the mean oocytes diameter of females from 16 and 32 m^3 were
158 significantly larger than for the females of 1, 3 and 8 m^3 tanks (Fig 2). This difference
159 disappeared progressively and at the end of the conditioning period, no significant difference
160 persisted (Table 1 and Fig 2).
161 Whatever the sampling date considered, the comparison of the mean concentration of E2,
162 connected with volume, does not show any significant difference; for example the E2
163 concentration at the end of conditioning period (ng.ml^{-1}) was 0.57 ± 0.2, 1.79 ± 0.14, 1.05 ±
164 0.33, 1.27 ± 0.15, 1.06 ± 0.18 for respectively 1, 3, 8, 16 and 32 m^3. The mean plasma
165 concentration E2 of all females shows a significant peak in early October (Fig 3).
Figure 1 166
Figure 2 167
Figure 3 168
169
170 Spawning period
171 During this period, the temperatures ranged from 9.4 to 13.5℃. Fishes were transferred in the
172 spawning units on 20th December. The first spawn occurred on 7th February and the last one

on 9th April. For the twice-spawning females, the spawning period lasted between 17 and 27 days (Table I). The lowest fecundity per spawn was observed for the three females (n° 2, 5 and 15) conditioned in $1m^3$, which showed the lowest total fecundity with only a spawn. The best spawn fecundity and total fecundity were observed for two-spawning females (n° 11 and 14). After statistical analysis, no relation was identified between rank of the spawn and the fecundity, for the twice-spawning females.

The eggs viability rate was included between 50 and 98.2%, except for a spawn with a nil viability rate (female n° 8). 7 of 13 spawns showed a viability rate superior to 80%. No relation was identified between conditioning volume and viability rate and between rank of spawn and viability rate.

All fertilization rates were superior to 98% except for the first spawn of a female from 16 m^3 (86%). The mean eggs diameter of all spawns varied from 1,15 ± 0.005 mm (the first spawn of a female from 16 m^3) to 1,24 ± 0.004 mm (the first spawn of a female from 32 m^3). This spawn had a mean egg diameter that differed significantly ($P< 0.05$) from the other diameters of eggs. There is no relation between the eggs diameter and fecundity rate or the weight of the female. The hatching rates varied from 22% to 92% without relation between this parameter and the volume of conditioning, spawn rank or viability rate.

Hatchings have started from 4 to 6 days after the beginning of the incubation and have happened during one or two days. No difference was showed between the spawns. The malformations rates have moved between 5.3% (female from 8 m^3) and 30% (female from 32 m^3), except the first spawn of the second female from 8 m^3 with a malformations rate significantly different (62%). The non-lethal malformations represented 13 to 95% of the total malformations. There was no relation between malformation rate and the conditioning volume.

Table I

The smallest larva measures 3.30 mm, the greatest: 4.7 mm. The smallest mean length is 3.66 ± 0.03 mm (second spawn of female 3) and the greatest is 4.28 ± 0.03 mm (second spawn of female 14), without significant difference between spawns. At the end of the experiment, the ovarian samples of females showed atretic oocytes. The mean weight loss of the females during the spawning period has been upper to males (respectively 20,8 ± 1,56% et 14,6 ±

0,89%). Furthermore, the spawning females and those, which did not spawn, showed a weight loss of 25.6 ± 1,25% and 15,3 ± 0,75%, respectively.

Discussion

The growth observed for all experimental tanks is very weak during the first two months of the experiment, with some conditions showing a loss of weight (1 and 8 m^3). In the second part of the conditioning period all tanks have similar growth rates.

In addition, the evolution of oocyte diameter shows a significant difference between the smallest volumes (1, 3 and 8 m^3) and the largest, which disappears progressively; in November there is no more difference. The differences of growth or kinetic of maturation observed in the first part of the conditioning period are explained by a more difficult acclimatization phase for the fishes in smallest volumes (1, 3 and 8 m^3), during which a permanent static behavior of the fishes, particularly, in 1 m^3 tanks was observed whereas the other fishes take up rapidly all the available space and show an active swimming behavior. A compensatory growth occurring after a growth depression as described by Arendt (1997) or by Ali, Nicieza and Wootton (2003) could explain this tightening.

The peak of plasma E2 concentrations observed in October corresponds with these obtained during previous studies held on sea bass. (Mananos *et al.* 1997; Prat, Zanuy, Bromage & Carrillo 1999; Asturiano, Sorbera, Ramos, Kime, Carrillo & Zanuy 2000). In the study of Asturiano et al. (2000), this rise appears when oocyte mean diameter reach 650-700 µm, whereas in our study the oocyte diameter reached 400 µm. Moreover, previous study showed the appearance of the E2 peak one or two months before spawn (Mananos *et al.* 1997; Prat *et al.* 1999) or during the spawning period (Prat, Zanuy, Carrillo, De Mones & Fostier 1990); our study shows a peak earlier, four months before spawning period. These high levels of E2 are useful for the preservation of the oocytes viability until the environmental conditions allow the final maturation of oocytes. In our experimental conditions, the fall of the water temperature (under 12°C from November) could explain the delay in the beginning of the spawning period and the lapse of four months between the peak of E2 and the beginning of spawns.

Our study showed that it is possible to obtain spontaneous spawns in small volumes ($2m^3$) in contradiction with Fornies et al. (2001). The results obtained for the relative fecundity (mean of 232000 eggs kg_1) are in agreement with Mananos et al. (1997), who calculated a value of 293000 eggs kg_1. Because at least one female from each conditioning volume has spontaneously spawned, we can conclude that none of the volumes tested blocks the reproduction in the range studied. The low number of spawns obtained and the variability in spawn results does not allow to show a gradual effect of the conditioning volume. One female from the $3m^3$ tank and two females from the $8m^3$ tank had spawned twice and the total fecundities associated are among the four best ones. All the females conditioned in $16m^3$ have spawned, but their fecundities are lesser. Only one female fromthe$1m^3$ tank and one from the $32m^3$ tank had spawned and their fertilities were among the worst ones. The poor results observed for the females from the $32m^3$ tank can be explained by the stress induced by the transfer from a large conditioning volume ($32m^3$) to a small spawning volume ($2m^3$) according to Mugnier, Fostier, Guezou, Gaignon and Quemener (1998) who showed that turbots (*S. maximus*) acclimatized in the smallest volume are more tolerant than those conditioned in a large volume. Thanks to the good environmental conditions (especially the water temperature) maintained during our study in contrast with the conditions of natural medium, the spawns started in the first days of February, earlier than observed in the natural environment by Boulineau-Coatanea (1969), who observed them during March-April. Bromage (1995) observed the first spawn when females measured 35 cm and weighed1.5 kg, but the lack of spawn in some tanks of our study does not seem to be related to fish length, because certain fish used in our study spawned despite having dimensions lower than these limits. The variability observed in the qualitative and quantitative characteristics of spawns induces us to conclude on the effect of individual characteristics of the females that could conceal the possible effect of the volume. No volume in the range studied had a blocking effect on the spawns, but from the results, conditioning in the $8m^3$ tank seems to be a minimal condition for the well-being and reproduction of the sea bass.

This study will have to be supplemented by an analysis of the effect of the density, to seek for the best compromise between the maximal number of available breeders and the minimal

volume of stocking to use, in order to preserve the good performances of spawns and to improve the economic results of hatcheries.

References

Ali M., Nicieza A. & Wootton R. J. (2003) Compensatory growth in fishes: a response to growth depression. *Fish and Fisheries* **4** (2), 147–190.

Ambali A.J.D. & Little D.C. (1996) Studies on the effect of manipulating hapa size on broodstock conditioning of *Oreochromis niloticus* in fertilized earthen ponds. In: *3rd. Int. Symp. On Tilapia in Aquaculture, Abidjan (Côte d'Ivoire), 11-16 Nov 1991*. (ed. by R.S.V. Pullin, J. Lazard, M. Legendre, J.B. Amon Kottias & D. Pauly). ICLARM Conf. Proc., **41,** 223-228.

Arendt J. D. (1997) Adaptive intrinsic growth rates: an integration across taxa. *Quarterly Review of Biology* **72**, 149-177.

Asturiano J.F., Sorbera L.A., Ramos J., Kime D.E., Carrillo M. & Zanuy S. (2000) Hormonal regulation of the European sea bass reproductive cycle: an individualized female approach. *Journal of Fish Biology* **56**, 1155-1172.

Boulineau-Coatanea F. (1969) Contribution à l'étude biologique du bar *Dicentrarchus labrax*. Thèse de 3ème cycle, Faculté des Sciences, Univ. Paris. Océanographie et Biologie, 121p.

Bromage N.R. (1995) Broodstock management and seed quality-General considerations. In: *Broodstock management and egg and larval quality* (ed. by N.R. Bromage & R.J. Roberts), pp. 1-25, Blackwell Science, Oxford.

Bromage N., Porter M. & Randall C. (2001) The environmental regulation of maturation in farmed finfish with special reference to the role of photoperiod and melatonin. *Aquaculture* **197**, 63-98.

Campbell PM., Pottinger TG. & Sumpter JP. (1994) Preliminary evidence that chronic confinement stress reduces the quality of gametes produced by brown and rainbow trout. *Aquaculture* **120**, 151-169.

Carrillo M., Zanuy S., Prat F., Cerda J., Ramos J., Mananos E. & Bromage N. (1995) Sea bass (*Dicentrarchus labrax*). In *Broodstock management and egg and larval quality*. (ed. by N.R. Bromage & R.J. Roberts), pp. 138-168, Blackwell Science, Oxford.

Cleary J.J., Pankhurst N.W. & Battaglene S.C. (2000) The Effect of Capture and Handling Stress on Plasma Steroid Levels and Gonadal Condition in Wild and Farmed Snapper *Pagrus auratus* (Sparidae). *Journal of world aquaculture society* **31**, 558-562.

Fornies M.A., Mananos E., Carrillo M., Rocha A., Laureau S., Mylonas C.C., Zohar Y. & Zanuy S. (2001) Spawning induction of individual European sea bass females (*Dicentrarchus labrax*) using different GnRHa-delivery systems. *Aquaculture* **202**, 221-234.

Goolish E.M., Evans R., Okutake K. & Max R. (1998) Chamber volume requirements for reproduction of the zebrafish *Danio rerio*. *Progressive Fish Culturist* **60**, 127-132.

Mananos E.L., Zanuy S & Carrillo M. (1997) Photoperiodic manipulations of the reproductive cycle of sea bass (*Dicentrarchus labrax*) and their effects on gonadal development, and plasma 17beta-estradiol and vitellogenin levels. *Fish Physiology and Biochemistry* **16**, 211-222.

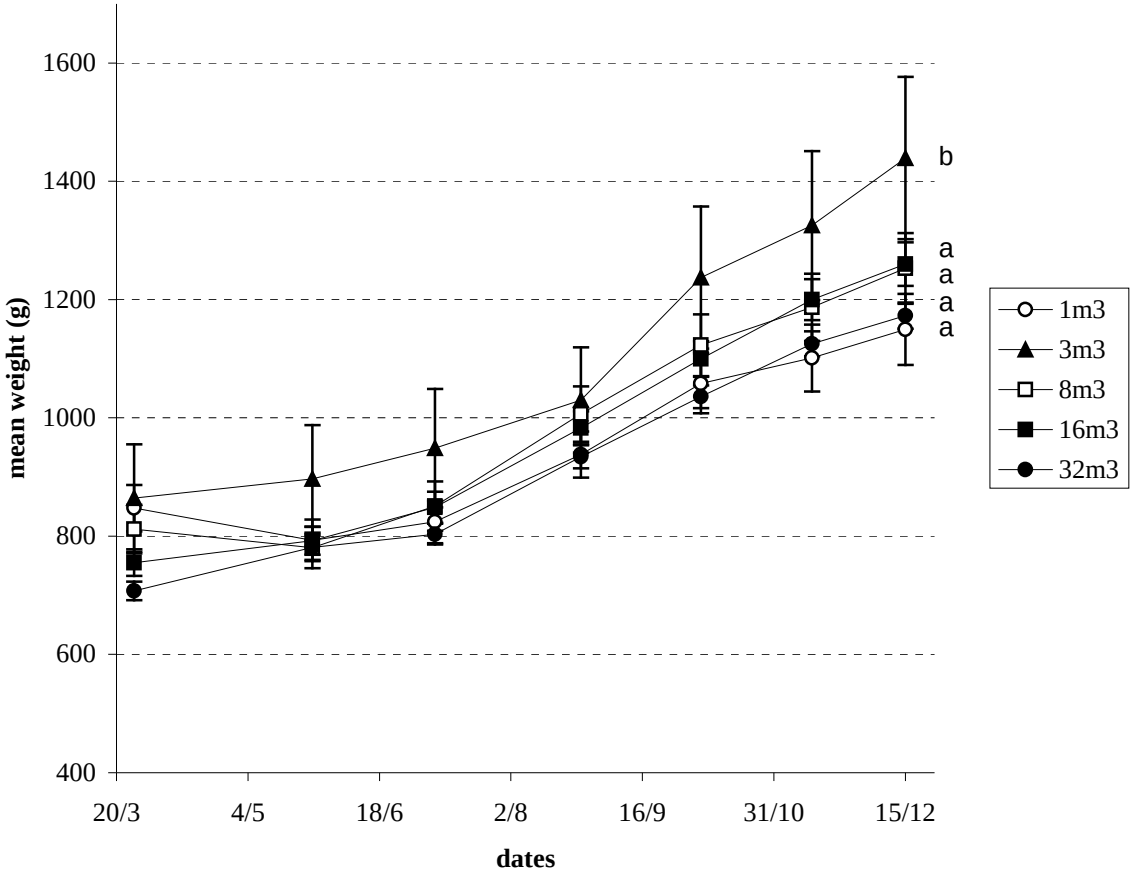
Mugnier C., Fostier A., Guezou S., Gaignon JL. & Quemener L. (1998) Effect of some repetitive factors on turbot stress response. *Aquaculture International* **6**, 33-45.

316 Nash J.P., Davail-Cuisset B., Bhattacharyya S., Suter H.C., Le Menn F. & Kime D.E. (2000) An
317 enzyme linked immunosorbant assay (ELISA) for testosterone, estradiol, and 17,20β-dihydroxy-
318 4-pregenen-3-one using acetylcholinesterase as tracer: application to measurement of diel
319 patterns in rainbow trout (Oncorhynchus mykiss). *Fish Physiology and Biochemistry* **20**, 355-
320 363.
321
322 Okumura S., Okamoto K., Oomori R. & Nakazono A. (2002) Spawning behavior and artificial
323 fertilization in captive reared red spotted grouper, *Epinephelus akaara*. *Aquaculture* **206**, 165-
324 173.
325
326 Prat F., Zanuy S., Carrillo M., De Mones A. & Fostier A. (1990) Seasonal changes in plasma
327 levels of gonadal steroids of sea bass, *Dicentrarchus labrax* L. *General and Comparative*
328 *Endocrinology* **78**, 361-373.
329
330 Prat F., Zanuy S., Bromage N. & Carrillo M. (1999) Effects of constant short and long
331 photoperiod regimes on the spawning performance and sex steroid levels of female and male
332 sea bass. *Journal of Fish Biology* **54**, 125-137.
333
334 Ridha M.T. & Cruz E.M. (1999) Effect of different broodstock densities on the reproductive
335 performance of Nile tilapia, *Oreochromis niloticus* (L.), in a recycling system. *Aquaculture*
336 *Research* **30**, 203-210.
337
338 Rodriguez L., Begtashi I., Zanuy S., Shaw M. & Carrillo M. (2001) Changes in plasma levels of
339 reproductive hormones during the first sexual maturation in European male sea bass
340 (*Dicentrarchus labrax* L.) under artificial day lengths. *Aquaculture* **202**, 235-248.
341
342 Schreck C.B., Contreras-Sanchez W. & Fitzpatrick, M.S. (2001) Effects of stress on fish
343 reproduction, gamete quality, and progeny. *Aquaculture* **197**, 3-24.
344

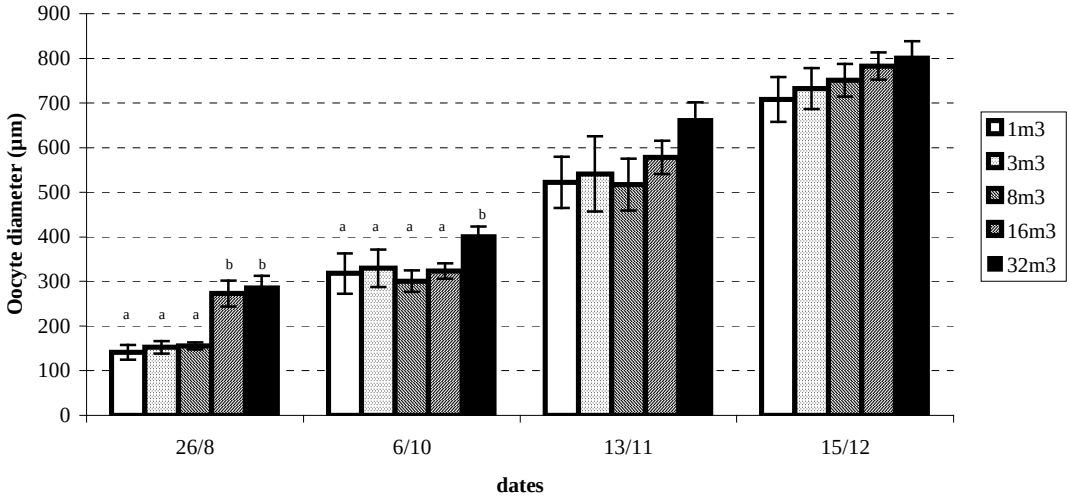
345 Sehgal H.S. & Toor H.S. (1995) Effect of stocking density on ovarian maturation, offspring
346 fitness and growth of common carp. *Aquaculture* **129**, 113-117.
347
348 Siddiqui A.Q., Al-Harbi A.H. & Hafedh Y.S. (1997) Effects of stocking density on patterns of
349 reproduction and growth of hybrid Tilapia in concrete tanks in Saudi Arabia. *Asian Fisheries*
350 *Science* **10**, 41-49.
351
352 Suquet M., Normant Y., Gaignon J.L., Quéméner L. & Fauvel C. (2005) Effect of water
353 temperature on individual reproductive activity of pollack (*Pollachius pollachius*). *Aquaculture*
354 **243**, 113-120.

Table I. Individual females characteristics at the end of vitellogenesis and individual females spawning characteristics. The values for oocyte diameter correspond at mean±SE. Two numbers for the same female and the same parameter, corresponds to the values of two spawns. In a column, same letter denotes homogeneous groups (P>0.05).

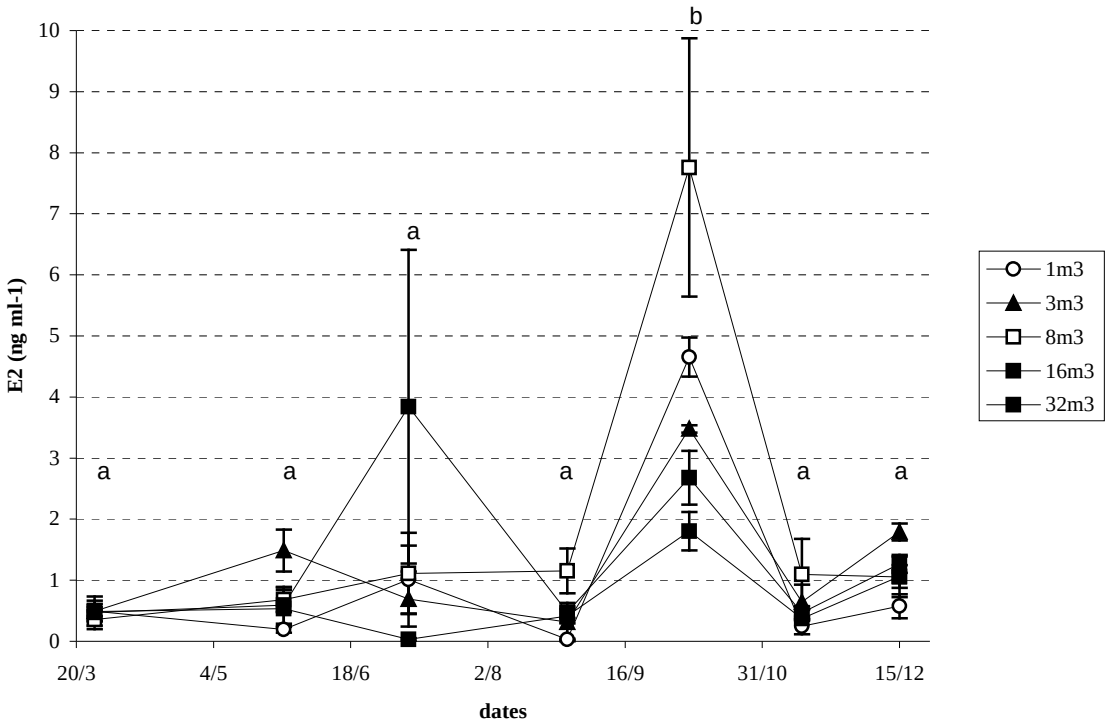
♀	Conditioning volume (m^3)	Data at the beginning of the spawning period (dec-15)				Day of spawn	Fecundity (eggs.spawn^{-1})	Relative fecundity (eggs.kg^{-1})	Viability rate (%)	Hatching rate (%)	Larval deformity rate (%)
		Weight (g)	SGR (% day^{-1})	Estradiol (ng ml^{-1})	Oocyte diameter (µm)						
1	8	1177	0.191	0.433	795.3±12.3	-	-	-	-	-	-
2	1	1256	0.108	0.958	770.7±12.6	-	-	-	-	-	-
3	16	1562	0.234	0.847	790.0±11.7	03/03	173 450	309 456	52.0	38.3	13.5**a**
						03/23	309 920		88.7	75.8	17.6**a**
4	3	1291	0.209	2.057	816.0±10.1	-	-	-	-	-	-
5	1	936	0.033	0.315	693.3±18.0	-	-	-	-	-	-
6	32	940	0.173	1.484	797.3±6.3	03/03	95 640	101 745	98.2	92.3	29.6**a**
7	16	1583	0.213	1.687	830.0±11.9	02/12	288 980	215 351	83.5	89.8	11.6**a**
						03/09	51 920		83.5	45.0	16.3**a**
8	16	1656	0.178	1.123	788.0±10.3	04/06	133 930	80 876	0.0	-	-
9	3	1674	0.158	1.599	714.7±9.3	-	-	-	-	-	-
10	32	919	0.315	0.477	825.3±9.7	-	-	-	-	-	-
11	8	1680	0.187	0.928	835.3±12.1	02/07	414 690	469 946	77.6	76.8	13.6**a**
						03/05	374 820		72.9	78.3	5.3**a**
12	32	1465	0.238	0.696	828.0±8.9	-	-	-	-	-	-
13	8	1400	0.223	0.467	848.0±12.4	03/23	207 610	276 257	64.7	31.3	62.0**b**
						04/09	179 150		80.1	51.6	19.7**a**
14	3	2237	0.182	1.715	666.0±8. 1	03/03	387 260	379 865	88.9	68.3	8.3**a**
						03/30	462 500		94.5	70.7	19.7**a**
15	1	1469	0.140	0.450	660.0±9.3	03/07	35 240	23 989	63.6	21.9	18.2**a**



359 Figure 1: Change of mean weight over time in relation to the five conditioning volumes. Data are
360 given with SE (same letter denotes homogeneous groups (P>0.05)). (n= 9 for 1 and 3m^3, n= 24,
361 48, 96 for respectively 8, 16 and 32 m^3)
362



362 Figure 2: Changes of mean oocytes diameters over time in relation to the conditioning volume.
363 Data are given with SE (same letter denotes homogeneous groups (P>0.05)). (n= 3 for 1 and
364 3m^3, n= 8 for 8, 16 and 32 m^3)
365



365 Figure 3: Evolution of plasma E2 concentrations over time in relation to conditioning volume.
366 Values are given with SE (measurement days not sharing a common letter have an average
367 plasmatic oestradiol concentration, for the whole of observed females, significantly different
368 (P>0.05)). (n= 3 for 1 and 3m^3, n= 8 for 8, 16 and 32 m^3)