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Research Article

Reproductive broodstock performance and egg quality of wild-caught and first-generation domesticated *Seriola rivoliana* reared under same culture conditions

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ABSTRACT. Almaco jack, *Seriola rivoliana* as well as some related species is of great interest in marine fish aquaculture. However, there are few studies about their reproduction in captivity. In this research work, reproductive performance and egg quality in two groups of adult *Seriola rivoliana*, caught in the wild and domesticated-F1 analyzed and compared, reared under optimal maturation conditions in a commercial private Laboratory. A total of 28 wild adult (>5 kg) were caught at La Paz Bay, Baja California Sur, Mexico, and 30 adult domesticated-F1 broodstock (>5 kg), were obtained from an original stock of 1,000 juveniles (3.5 g body weight) produced at Kona Blue (Hawaii, USA) sea farm. Fishes were transported to the Rancheros del Mar commercial private hatchery, where they were grown to adult size. Both groups were evaluated during eight months (May to December 2012) and compared in terms of reproduction performance (total number of spawning events, monthly spawning frequency, total number of eggs, total number of eggs per mL, and fertilization rate), egg biochemical composition (total proteins, total lipids, total carbohydrates, and triacylglycerides) and egg diameter. Results indicated that wild caught broostock showed a better reproductive performance in terms of fertilization rate, total number of spawning, monthly spawning frequency and total number of eggs produced. However, biochemical composition and egg diameter did not show statistical differences ($P < 0.05$) between two groups. The reproductive performance of broodstock and quality of eggs analyzed in this study are important traits to improve the aquaculture management of this species.

Keywords: *Seriola rivoliana*, reproductive performance, egg quality, wild-caught fish, domesticated fish, aquaculture.

Desempeño reproductivo y calidad de huevos en reproductores de origen silvestre y domesticado-F1 de jurel *Seriola rivoliana* bajo las mismas condiciones de cultivo

RESUMEN. El jurel *Seriola rivoliana* así como algunas especies relacionadas, son de gran interés en la acuicultura de peces marinos. Sin embargo, existen pocos estudios sobre su reproducción en cautiverio. En este trabajo se analizó y comparó el desempeño reproductivo y calidad del huevo en dos grupos de adultos de *Seriola rivoliana*, capturados en el medio silvestre y domesticados-F1 criados en óptimas condiciones de maduración en un laboratorio comercial. Un total de 28 adultos silvestres (>5 kg) se capturaron en la Bahía La Paz, Baja California Sur, México y 30 adultos de origen domesticado-F1 (>5 kg), se obtuvieron a partir de un lote de 1.000 juveniles (3,5 g de peso) producidos en la empresa Kona Blue (Hawái, EE.UU.) y transportados a la empresa Rancheros del Mar para su engorda y posterior maduración. Los reproductores de ambos orígenes, fueron evaluados durante echo meses (mayo a diciembre 2012) y comparados en términos de desempeño reproductivo (número de desoves totales, frecuencia mensual de desoves, número total de huevos, número total de huevos

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por mL, tasa de fertilización) y composición bioquímica del huevo (proteínas totales, lípidos totales, carbohidratos totales y triglicéridos), así como el diámetro del huevo. Los resultados obtenidos, indican que los reproductores de origen silvestre presentaron un mejor desempeño reproductivo en términos de porcentaje de fertilización, número total de desoves, frecuencia mensual de desoves y número total de huevos producidos. Sin embargo, la composición bioquímica y el diámetro del huevo no mostraron diferencias estadísticas (P < 0,05) entre los dos grupos. El desempeño reproductivo y la calidad de los huevos analizados en este estudio son aspectos importantes para mejorar el manejo en cautiverio de esta especie.

Palabras clave: *Seriola rivoliana*, desempeño reproductivo, calidad de huevos, peces silvestres, peces domesticados, acuicultura.

INTRODUCTION

World fishery production in marine waters was 82.6 million ton in 2011 and 79.7 million ton in 2012 (74.3 and 75.0 million ton excluding anchovy). Between 1980 and 2012, world aquaculture production volume increased at an average rate of 8.6 percent per year (FAO, 2014). World food fish aquaculture production more than doubled from 32.4 million ton in 2000 to 66.6 million ton in 2012. According to the latest information, FAO estimates that world food fish aquaculture production rose by 5.8% to 70.5 million ton in 2013 (FAO, 2014). Longfin yellowtail *Seriola rivoliana* as other S*eriola* species is considered as one of the most important emerging marine finfish species in Japan, Australia and the United States (Roo *et al.*, 2014). In the American Pacific, *Seriola rivoliana* is distributed from the United States to Peru (Eschmeyer *et al.*, 1983; Peterson *et al*., 1999) and in the Atlantic, from the US to Argentina (Cervigón, 1993).

Almaco jack has excellent aquaculture potential due to its adaptability to captivity, fast growth, and high market value, but information about rearing this species in captivity is limited (Kolkovski & Sakakura, 2004; Roo *et al.*, 2014). Sexual maturation under different culture conditions has been studied in different *Seriola* species, including *S. lalandi* (Poortenaar *et al.*, 2001), *S. rivoliana* (Blacio *et al.*, 2003, Roo *et al.*, 2014) and *S. dumerilli* (Roo *et al.*, 2009). A major constraint on the development of aquaculture for several *Seriola* species is their insufficient supply of eggs and the variable quality of larvae (Yamamoto *et al.*, 2008). Successful conditioning of broodstock remains a crucial step to produce a large quantity of eggs and good-quality larvae in this species. In fish as in other marine organisms, such as crustaceans and mollusks, several factors affect the quality of eggs and larvae. These factors may be endogenous (genotype origin, age, and size of broodstock) or exogenous (egg size, egg management, broodstock feeding, bacterial colonization of egg surface) (Ballestrazzi *et al.*, 2003; Kamler, 2005). Differences between egg batches often become apparent only well after their collection.

Many studies of marine organisms have used physical, biological, or biochemical parameters as indicators of broodstock reproductive performance and egg quality (Arcos *et al.*, 2003, 2009, 2011; Evans *et al.*, 1996; Kjørsvik *et al.*, 2003; Sangsawangchote *et al.*, 2010). Among teleost's, dietary components, such as proteins and lipids, have been implicated in various reproduction-related processes, such as gonadal maturation, gamete quality, and spawning performances (Izquierdo *et al.*, 2001; Coward *et al.*, 2002; Varghese *et al.*, 2009; Korwin-Kossakowski, 2011). Assessing the reproductive physiology of *Seriola* spp., broodstocks are important goals to improving the culturing of these fish.

First-generation domesticated "Hawaiian" (*Seriola rivoliana*) broodstock are already being reared for commercial production at the Rancheros del Mar hatchery in La Paz, Baja California, Mexico. This facility has achieved natural spawning of both wild-caught and domesticated broodstocks. However, maintaining actively spawning stocks of wild-collected *S. rivoliana* has proven difficult due to their susceptibility to a number of parasitic and bacterial pathogens. Domesticated (*S. rivoliana*) broodstocks appear to be substantially different from their wild counterparts (Rancheros del Mar, *pers. comm*.).

The present study analyzed the reproductive performance and egg quality of wild-caught and first-generation domesticated populations of *S. rivoliana*, under same maturation conditions in the Rancheros del Mar commercial hatchery. A multidisciplinary approach was used to evaluate possible differences in adult reproductive performance between populations. Egg biochemical composition was used as an indicator of broodstock nutritional and physiological condition.

MATERIALS AND METHODS

Broodstocks and rearing system

The study was carried out from May to December 2012. A total of 28 wild-caught adult *S. rivoliana* (>5 kg) were captured near the south coast of Bay La Paz, Baja California Sur, Mexico, and transported to the Rancheros del Mar commercial private hatchery (24°14'N, 110°18'W).

In addition, 30 *S. rivoliana* first-generation domesticated individuals (>5 kg) were obtained from an original stock of juveniles (average 3.5 g body weight) brought from Kona-Blue Water farms in Hawaii and transported to the Rancheros del Mar commercial private hatchery.

At the beginning of the reproductive season, the wild caught group had an average body weight of 9.1 kg, whiles the domesticated-F1, had 5.5 kg. Each group was distributed into 55 m^3 circular fiberglass blue tanks with no more than 5 kg per metric ton of stocking density. Fish were kept under artificial photoperiod conditions (12 h light, 12 hours dark). Water was exchanged in each tank 18 times per day, using a closed recirculation system at 95%. Salinity was 36 g L^{-1} and temperature ranged from 26 to 26.5ºC year-round. After capture, fish were weighed, measured, and sexed by introducing a polyethylene cannula (1.6 mm e.d.) into the oviduct and oocyte samples were preserved in Davidson solution in seawater. Fish were fed daily with commercial pellets (13 mm, Vitalis Repro™: Skretting, Burgos, Spain) corresponding to 1% of body weight (BW), supplemented with frozen squid, sardine, and mackerel, adjusted to equal a total daily supply equivalent to 2% of their BW. The collector tanks of eggs with an 800 µm mesh size bags, were placed on the perimeter of the broodstock tanks (one per tank of each origin). Egg collectors were monitored early each morning, and the floating eggs were collected by overflow of a side opening of the broodstock tank due to the positive buoyancy of the eggs.

Reproductive performance of broodstocks

Reproductive performance of each broodstock type (wild-caught and domesticated) was evaluated in terms of total number of spawning events, spawning frequency per month, total number of eggs, volume of floating eggs (mL), and fertilization rate.

Total BW of each broodstock was recorded before they were returned to the maturation tank at the beginning of the spawning season. The survival rate of each group was measured until the end of the experimental evaluation (8 months).

Every day, the spawns were sampled and recorded. Eggs were separated into floating and non-floating in a measuring cylinder, and the volumes and number of eggs were counted. Floating eggs were removed by 500 µm mesh, washed thoroughly, and subsequently kept in seawater that had been UV treated. The eggs were observed under a stereo microscope to assess the morphology, fertilization success, and embryological stage.

Fertilization rate was assessed taking three 5 mL samples from each spawning, and eggs with normal cleavage were counted. Fertilization rate was calculated as follows:

$$\text{Fertilization rate} = \frac{\text{Number of fertilized eggs}}{\text{Total number of eggs}} * 100$$

Hatching rate was calculated by the counting of larvae (after 24 h of the spawn) versus fertilized eggs:

$$\text{Hatching rate} = \frac{\text{Total number of larvae}}{\text{Total number of fertilized eggs}} * 100$$

Egg diameter

Egg samples from each spawning of the two groups were collected every day during the 8-month experimental period and preserved in Davidson solution. From the fixed samples, eggs were observed and photos of each spawn event were taken using a fluorescence microscope Olympus BX41 (magnification 10x) connected to a video camera (CoolSNAP-ProColor). The recorded images were digitized using an image analysis program (Image Pro Plus, v.6.0).

Egg measurements were performed from digitized images and Image-Pro® analysis software. Fifty eggs were measured daily for each group (Fig. 1)

Egg biochemical analyses

In order to perform biochemical analysis, an approximately 200 mg egg mass from each of the two populations was concentrated using a 75-µm mesh filter and frozen at -80°C for later analysis.

Samples of eggs were weighed and individually homogenized in equal volumes of a buffer solution [0.05 M Tris, 0.5 M NaCl, 5 mM EDTA, pH 7 (3:1 v/v buffer: tissue)], and a protease inhibitor cocktail (0.003% ref. P2714, Sigma, St. Louis, MO, USA), using a FAST PREP-24 homogenizer for 1 min. The homogenate was centrifuged at 10,000 *g* for 15 min at 4ºC (Beckman ultracentrifuge, Pasadena, CA, USA), and the supernatant was stored at -80ºC for later quantification of total proteins (P), total lipids (L), total carbohydrates (C), and triacylglycerides (Tg). Enzymatic and colorimetric analyses adapted for small micro plates (Palacios *et al.*, 1998) were performed, and the quantification of P was realized (Bradford, 1976) after digestion in 0.1 N NaOH. Carbone was quantified by the Anthrone method, after precipitation of proteins with trichloroacetic acid **(**Roe, 1955). Lipids were measured according to the sulfophosphovanillin method (Barnes & Blackstock, 1973) and Tg was quantified using a kit (GOD-PAP, Merck).

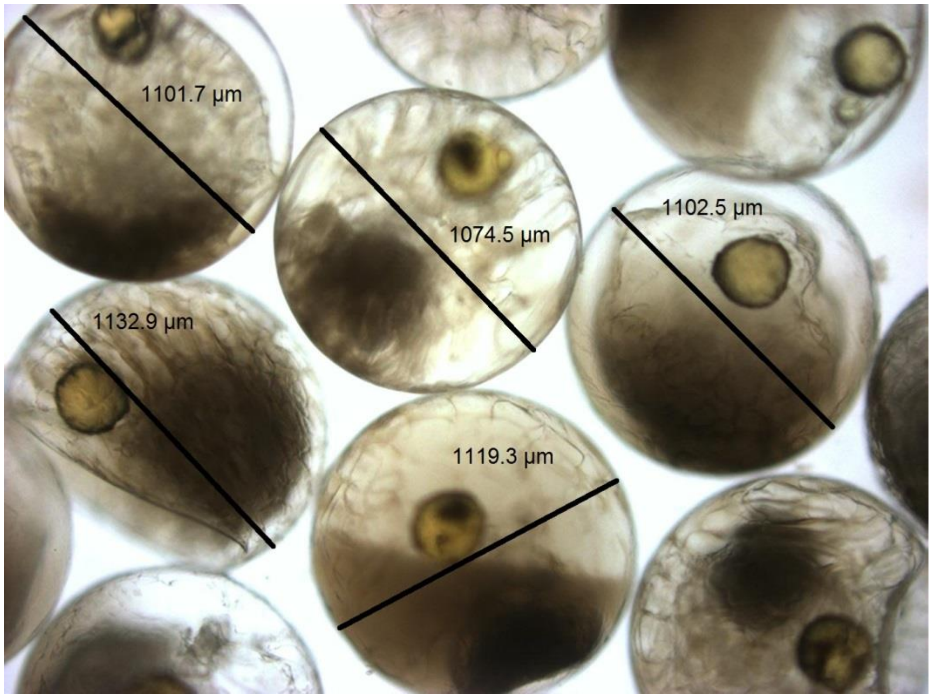

Figure 1. Measurement and recording of the oocytes diameter from digitized images (4x).

Statistical analyses

Broodstock reproductive performance

First, single-factor fixed ANOVA analysis was used to assess differences in broodstock reproductive performance variables (total number of spawning events, spawning frequency per month, total number of eggs, total number of eggs per mL, fertilization rate, and average egg diameter) between the two population groups. The factor "broodstock type" was considered with two levels, wild-caught and domesticated populations. A *post-hoc* Tukey's test for multiple comparisons of means was used in cases in which the results of ANOVA were significant.

Next, ANCOVA analysis was used to assess differences in the reproductive performance between the two population groups. The factor "broodstock type" was considered with two levels, wild-caught and domesticated populations, but female total weight was introduced as a covariate. Mean comparisons were performed by specific contrast of least square means, and adjusted means.

Egg diameter

Two different ANOVA models were used for morphometric and biochemical egg variables. First, single-factor fixed ANOVA was used for morphometric variables, including egg diameter. For the independent variable "broodstock type", there were two levels, wild-caught and domesticated populations. A *post-hoc* Turkey's test for multiple comparisons of means was realized in cases in which the results of ANOVA were significant.

In addition, ANCOVA analysis was conducted for biochemical composition of eggs. The same factor "broodstock type" was considered with the two levels, but female body weight and egg diameter were introduced as covariates. Mean comparisons were performed using a specific contrast of least square means, and adjusted means are presented.

Pearson's correlation was applied to establish the relationship between the broodstock reproductive performance variables and egg variables (morphometric and biochemical composition).

For all ANOVA analyses, biochemical data was transformed to logarithm base 10 to fit a normal distribution, and the percentage fertilization data was transformed to arcsine (Zar, 2010), before analyses. Means and back-transformed means are presented and the standard errors are those obtained from untransformed variables.

Statistical significance was preset at $P < 0.05$, although P values obtained are indicated. Statistical analyses were performed with the General Linear Model module in Statistica version 10 (StatSoft Inc., Tulsa, OK, USA).

RESULTS

Broodstock reproductive performance

There were significant differences between wild-caught and domesticated broodstocks in all measured reproductive variables (Table 1). The total weight of wild-caught broodstocks was significantly higher than that of the domesticated broodstocks. Wild-caught broodstocks showed a greater spawning frequency and produced more eggs, but the eggs of both populations were the same size. No differences in broodstock survival at the end of the 8-month experimental evaluation were observed.

Egg diameter

Although no significant differences were found in the egg diameter average between eggs from the different broodstocks, the wild caught group showed average values slightly higher over time, and more spawning's during the same period (Table 1).

Egg biochemical analyses

There was no difference between the two groups in the total content of proteins, lipids, carbohydrates, or triacylglycerides (Table 2). The proportion of carbohydrates was very low in eggs of both broodstock types, compared with the amounts of proteins and lipids.

Correlations among reproductive performance variables

Correlations among the reproductive performance variables evaluated in both populations are shown in Table 3. There were significant positive correlations between total female weight of wild-caught individuals and fertilization rate (0.518), total number of spawning events (0.732), total number of eggs (0.963), and diameter of eggs (0.950). The total number of eggs was significantly correlated with the fertilization rate (0.936) and the total number of spawning events (0.857). Positive correlations among the same reproductive performance variables were also observed in domesticated broodstock.

Correlations among reproductive performance variables and egg variables

Correlations among all egg quality variables and between all reproductive performance variables and egg variables for the two broodstocks populations are shown in Table 4. The highest values and the most consistent correlations were found between wild-caught female total weight and protein in comparison with domesticated broodstock respectively (0.982), (0.965); lipid (0.917), (0.891); and triacylglycerides (0.794), (0.738), respectively. Significant positive correlations were observed between the two factors egg diameter and fertilization rate with the three biochemical variables proteins, lipids, and triacylglycerides. The total number of eggs was significantly correlated with proteins and lipids for both broodstock populations. There were also correlations between the total number of spawning events and proteins, lipids, and triacylglycerides.

DISCUSSION

The costs of feeding and maintaining *Seriola* spp. broodstock are high; thus, it is desirable to develop a methodology to compare different broodstock types in order to select broodstock with high reproductive performance and high egg quality. In this study, a multidisciplinary approach was used to evaluate possible differences in reproductive performance and egg quality between wild-caught and domesticated broodstock populations.

Significant differences in total BW, fertilization rate, total number of spawning events, monthly spawning frequency, total number of eggs, and total number of egg per mL were observed between wild-caught and domesticated broodstocks. Some morphometric variables regarding females or eggs could be used as non-invasive predictive criteria to select females with higher reproductive performance. For example, in our study, females with a greater total weight had a higher spawning capacity. However, this evaluation should be applied only to homogeneous populations (of the same age and reared under the same culture conditions) and should be further evaluated. Such a selection procedure could be combined with other criteria, such as biochemical levels in eggs. It is known that lipids, followed by proteins, are the major sources of energy available in vitellus for embryogenesis (Evans *et al.*, 1996; Kjørsvik *et al.*, 2003; Kamler, 2005). More studies are needed to evaluate the value of total protein levels as predictive criteria in *Seriola* spp.

Several studies of fish have used biochemical components of eggs as indices of quality, particularly lipids, which perform energetic and structural functions during embryonic development (Kamler, 2005). In this study, no differences were observed between two different broodstocks in the amount of proteins, lipids, carbohydrates, or triacylglycerides in eggs, indicating not only that females transfer biochemical reserves to eggs, but also that wild-caught and domesticated females produce good quality eggs. This finding is reinforced by the observation of good egg quality in terms of the L and Tg content of eggs obtained from these females. Previous studies have reported the rela-

Table 1. Reproductive performance of *Seriola rivoliana* wild-caught and first-generation domesticated broodstocks evaluated for 8 months. Mean values (± standard error) of the variables are presented. Different superscripts indicate significant differences according to Tukey's test or specific contrast of least squares for multiple comparisons of means ($P < 0.05$). ANCOVA significance for the covariate (female body weight) is presented in the second column

	Broodstock types		ANOVA	ANCOVA
	Wild-caught	Domesticated		
Total body weight (kg)	9.1 ± 2.3[a]	5.5 ± 1.1[b]	$P < 0.01$	
Survival during 8 months (%)	92.8 ± 1.4	90.0 ± 2.0	$P < 0.05$	$P < 0.05$
Fertilization rate (%)	94.5 ± 1.9[a]	75.3 ± 2.8[b]	$P < 0.01$	$P < 0.01$
Total number of spawning	57.0 ± 2.0[a]	28.0 ± 1.0[b]	$P < 0.01$	$P < 0.01$
Monthly spawning frequency (%)	9.2 ± 2.0[a]	5.5 ± 1.0[b]	$P < 0.01$	$P < 0.01$
Total number of eggs (× 103)	610.44 ± 2.5[a]	163.79 ± 6.6[b]	$P < 0.01$	$P < 0.01$
Total number of eggs (mL)	612.28 ± 2.1[a]	164.44 ± 6.4[b]	$P < 0.01$	$P < 0.01$
Egg diameter (µm)	1044.87 ± 22.8[a]	1035.83 ± 20.8[b]	$P > 0.05$	$P > 0.05$

Table 2. Overall comparisons of the total content (mean ± standard error) of proteins (P), lipids (L), carbohydrates (C), and triacylglycerides (Tg) in the eggs of wild-caught and first-generation, domesticated, *Seriola rivoliana* females. N = 28 wild-caught females and 30 domesticated females. ANCOVA significance for the covariate (egg diameter) is presented.

Variable	Wild-caught	Domesticated	ANOVA	ANCOVA
P (mg g^{-1})	120.41 ± 2.5	113.44 ± 2.5	$P > 0.05$	$P > 0.05$
L (mg g^{-1})	151.07 ± 4.9	167.38 ± 4.8	$P > 0.05$	$P > 0.05$
C (mg g^{-1})	5.51 ± 1.5	5.94 ± 1.5	$P > 0.05$	$P > 0.05$
Tg (µg g^{-1})	57.7 ± 1.3	53.35 ± 1.06	$P > 0.05$	$P > 0.05$

tionship between egg biochemical composition and the performance of the resulting larvae (Evans *et al.*, 1996; Kjørsvik *et al.*, 2003); therefore, it is expected that both broodstock types would produce high-quality larvae when egg biochemical components are high.

The proportion of carbohydrates was very low in both types of eggs, compared with the amounts of proteins and lipids. Apparently, this component is not an important source of energy during embryonic development; it may play a greater role in later structural growth (Salze *et al.*, 2005).

No differences were observed in egg biochemical composition between the broodstock types; however, it has been reported that egg quality decreases over time in production. Therefore, the 8 months that elapsed during this study could have affected egg quality measurements. We do not know whether a longer period of evaluation in which more first spawning events occurred would produce a different result.

To compare reproductive performance and egg quality between wild-caught and domesticated broodstocks, female total weight, and egg diameter were used as covariates. The choice of these covariates was justified by the positive correlations found between female total weight and all reproductive performance variables and biochemical components analyzed, and between egg diameter and the biochemical components. Our ANCOVA analysis used female total weight and/or egg diameter as covariates to analyze reproductive performance and egg quality variables between different broodstock types, independently of female weight or egg size.

The use of covariates to correct data is common among animal breeders when estimating differences in parameters (Anang *et al.*, 2001). This improvement in the estimation of the parameters by the use of covariates has been observed in other marine species studies (Perez-Rostro & Ibarra, 2003a, 2003b). In shrimp and fish, some of the common effects on reproduction variables indicate that correction or an adjustment of data by the use of covariates is needed (Ojanguren *et al.*, 1996; Arcos *et al.*, 2003).

Positive correlations between broodstock weight or length and egg traits have also been reported for various other fish species, as rainbow trout, bighead carp, Nile tilapia, and channel catfish (Huang & Gall, 1990; Bolivar *et al.*, 1993; Walser & Phelps, 1993; Estay *et al.*, 1994). A surprisingly large positive correlation was obtained between female weight and the amounts of proteins, lipids, carbohydrates, and triacylglycerides in their eggs, suggesting that female weight plays an important role in egg quality.

Table 3. Pearson's correlation coefficient (*r*) between reproductive performance variables assessed for wild-caught and first-generation broodstocks, domesticated females and the reproductive performance parameters of each group of females. *Significant correlation ($P < 0.05$).

Wild-caught broodstocks	Female total weight (kg)	Fertilization rate (%)	Total number of spawning events	Total number of eggs	Egg diameter (μm)
Female total weight (kg)	-				
Fertilization rate (%)	0.518*	-			
Total number of spawning events	0.732*	0.207	-		
Total number of eggs	0.963*	0.936*	0.857*	-	
Egg diameter (μm)	0.950*	0.545	0.250	0.478	-
Domesticated Broodstocks					
Total female weight	-				
Fertilization rate (%)	0.439*	-			
Total number of spawning events	0.718*	0.339	-		
Total number of eggs	0.889*	0.871*	0.894*	-	
Egg diameter (μm)	0.918*	0.414	0.301	0.369	-

Table 4. Pearson's correlation coefficient (*r*) between biochemical variables assessed in the eggs of wild and domesticated-F1, females and the reproductive performance parameters of each group of females. *Significant correlation ($P < 0.05$). Proteins (P), lipids (P), carbohydrates (C), and triacylglycerides (Tg).

Eggs from wild-caught females	Total female weight (kg)	Fertilization rate (%)	Total number of spawning events	Total number of eggs	Egg diameter (μm)
P (mg g^{-1})	0.982*	0.639*	0.513	0.852*	0.998*
L (mg g^{-1})	0.917*	0.701*	0.593	0.845*	0.661*
C (mg g^{-1})	0.237	0.120	0.101	0.180	0.207
Tg (mg g^{-1})	0.794*	0.731*	0.492	0.774	0.701*
Eggs from domesticated females					
P (mg g^{-1})	0.965*	0.714*	0.422	0.731*	0.997*
L (mg g^{-1})	0.891*	0.695*	0.534	0.701*	0.647*
C (mg g^{-1})	0.149	0.222	129	0.151	0.260
Tg (mg g^{-1})	0.738*	0.593*	0.492	0.695	0.685*

Furthermore, a positive correlation between body weight or body length and number of eggs has also been reported in fish (Huang & Gall, 1990), and was observed in the present study. Some studies have shown that female size and spawning time affect egg size, fecundity, and egg viability (Kamler, 2005; Sangsawangchote *et al.*, 2010).

Typically, teleosts show a trade-off between egg number and size, but during a spawning season, the sizes of eggs in successive batches may differ (Evans *et al.*, 1996; Kamler, 2005), although Kamler (2005) also reported no effect of egg batch sequence. In the present study, egg number and size were not significantly correlated.

In some fish, such as Atlantic halibut (*Hippoglossus hippoglossus*), egg biochemical composition was size dependent (Evans *et al.*, 1996), although in other fish species, such as *Pseudopleuronectes americanus*, the amounts of protein and lipids in the eggs were independent of egg size (Buckley *et al.*, 1991). In this study, however, the biochemical composition of eggs from both populations was highly correlated with egg size.

Our preliminary estimate of the correlation between reproductive performance and egg quality variables from different broodstock types indicated an association between these variables. Therefore, some females spawn more and faster, or produce eggs with higher quality. By selecting the females that display those traits for use in aquaculture, hatchery managers can increase egg production and egg quality.

Egg diameter is easily measured and is one of the most frequently reported quality criteria in studies of marine reproductive biology (Kamler, 2005). The biochemical composition of eggs, particularly the composition of yolk components, which support the energetic and structural needs of developing embryos, is also a useful indicator of egg quality (Fraser, 1989; Racotta *et al.*, 2003). The Tg concentration is an indicator of nutritional status and therefore a predictor of survival among fish larvae. Hilton *et al.* (2008) reported greater Tg reserves in eggs and larvae of fish that developed faster. Tg levels in eggs also can be used to infer the nutritional status of broodstocks (Hilton *et al.*, 2008; Saito, 2012).

The proper development of eggs depends on the biochemical reserves that are transferred to the eggs from the female. As the levels of these reserves could determine larval quality at a later stage, the quantities of those reserves may be considered indicators of future larval quality (Racotta *et al.*, 2003). The biochemical composition of the egg itself could indicate the quantities of nutrients transferred to that egg.

Arcos *et al.* (2003) found higher fecundity and fertilization rates and higher levels of triacylglycerides and vitellin in the eggs, of the first spawning of females that later had multiple spawns. They proposed that those traits could be used as non-invasive predictive criteria to select females with high reproductive quality. Further studies on predictive criteria are needed in *Seriola* culture species. A capacity for multiple spawning events within a reproductive season has been demonstrated in several *Seriola* species and is a promising trait for aquaculture (Poortenaar *et al*., 2001).

CONCLUSIONS

This study indicates that broodstock from a wild-caught population of *S. rivoliana* was in better physiological condition than that of a domesticated population in terms of morphometric production variables (body weight, fertilization rate, total number of spawning events, spawning frequency per month, and total number of eggs produced). However, biochemical composition of eggs was the same for both populations. Our results confirm that the physiological condition and egg quality of fish were not affected by Rancheros del Mar hatchery conditions, and the reproductive performance and egg quality could even be improved with the use of a specific diet. The egg and female quality variables analyzed in this study are important reproductive traits that are applicable to programs to improve the culturing of this species.

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