The spawning, embryonic and early larval development of the green wrasse *Labrus viridis* (Linnaeus, 1758) (Labridae) in controlled conditions

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**A B S T R A C T**

Green wrasse, *Labrus viridis* (Linnaeus, 1758), is an endangered species in the southern Adriatic Sea, but it is also of interest for potential rearing in polyculture with other commercial species for the repopulation of areas where it is endangered or as a new aquaculture species. A parental stock of the green wrasse was kept in aquaria for six years. The spawning, embryonic and early larval development maintained under controlled laboratory conditions are described and illustrated. The average diameter of newly spawned eggs was 1.01 ± 0.03 mm. Mature and fertilized eggs were attached to the tank bottom by mucus. Hatching started after 127 h at a mean temperature of 14.4 ± 0.8 °C. The average total length of newly hatched larvae was 4.80 ± 0.22 mm. Absorption of the yolk-sac was completed after the 5th day when larvae reached 5.87 ± 0.28 mm.

Larvae were fed with the rotifers *Brachionus plicatilis*. The pigmentation of *L. viridis* larvae is similar to that of *Labrus merula* and *Labrus bergylta*, but the main differences between these species are in the size of larvae and the development time of the melanophores on the anal fin-fold (five days later than with *L. merula*) and on top of the head (nine days earlier than with *L. merula*).

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1. Introduction

Green wrasse, *Labrus viridis* (Linnaeus, 1758), is an endangered species in the southern Adriatic Sea, but it is also of interest for potential rearing in polyculture with other commercial species for the repopulation of areas where it is endangered or as a new aquaculture species. Green wrasse is distributed throughout the Mediterranean, in the western region of the Black Sea and in the eastern Atlantic from Portugal to Morocco (Quignard and Pras, 1986). Quignard (1966) noted more than 40 years ago that the wrasse was a very rare species in the northern Adriatic, scarcer in the central Adriatic and that larger specimens could still only be caught in the southern Adriatic. The same data (Onofri, 1975) concerning the endangermant of wrasse was noted ten years later, while researching various species of labrids along the eastern shores of the Adriatic. It is the only species in Croatian coastal waters whose fishing and trading is permanently banned due to population reductions since 2002 (Directive on the Protection of Fish and Other Marine Organisms, National Gazette, 101/02, 2002). In the time prior to the ban, wrasse was caught at a rate of about 2 tons of per year along the eastern shores of the Adriatic (Jardas, 1996). There are no available data on the annual catch of wrasse since the introduction of the Directive and up to the present time. During the 1970s, the largest recorded length of green wrasse was 60 cm (Onofri, 1975), while it decreased to 55 cm in the nineties (Jardas, 1996). The average catch length 10 years ago was 20–35 cm, with a weight of up to 1.7 kg (Jardas, 1996). In the south-
ern Adriatic, the wrasse inhabits rocky seabeds with many crevices, and it is always one individual. These habitats are located on the outer side of islands facing the open sea and along vertical rocky sea beds (Onofri, 1975) at depths of 2–50 m (Jardas, 1996). The reasons for the reduction of green wrasse populations are due to intense commercial and sport fishing.

The green wrasse is an obligate carnivore, preying on mollusks, worms, crabs and urchins (Quignard and Pras, 1986; Onofri, 1975; Jardas, 1996). The species is a protogynous hermaphrodite, and sex changes at a length of 27 cm (Quignard and Pras, 1986; Jardas, 1996). Spawning takes place at the end of winter and at the beginning of spring in natural conditions (Onofri, 1975; Jardas, 1996). Onofri (1975) states that this species attaches eggs to algae, but the author did not give any data on this phase of development for eggs transported to the laboratory. Onofri (1970, 1975) presented the morphological and meristic data of adult stages of green wrasse and other species of labrids in the southeastern Adriatic, but there is insufficient information on the early developmental stages of green wrasse. Information on the spawning and early developmental stages of another LABRID species Labrus merula on the eastern shores of the Adriatic is given by Dulčić et al. (1999). Globally, much research has been carried out due to problems with parasites, such as sea lice. Due to damages in the rearing of salmonid caused by sea lice, in the last few years, the possibility of biological control by using cleaner wrasse has become very interesting for aquaculture (Bjordal, 1990; Darwall et al., 1992; Kvenseth, 1993; Treasurer, 1993, 1994, 1996, 2002; Deady et al., 1995; Young, 1996; Tully et al., 1996).

Due to the vulnerability and declining population numbers of this species on the east coast of the southern Adriatic, our investigations of controlled breeding are useful for repopulation or as potential mariculture in polyculture production for the fish market. This paper presents the first data on egg, embryonic and larval development of wrasse under controlled laboratory conditions. The objectives are to describe the early life history and to assist in the identification of the planktonic stages of this species, and also to provide first information on possible breeding.

2. Materials and methods

2.1. Brood stock

Parental fishes were collected from southeastern Adriatic waters, around the island of Lokrum near Dubrovnik. Fish were caught on hooks or in fish traps and, after being quarantined, they were placed with other specimens in the brood stock tank. A parental stock (two males and six females) was kept in aquaria at the Institute for Marine and Coastal Research in Dubrovnik. The dimensions of the aquarium tank were 120 × 80 × 80 cm (0.8 m³). Sex was determined based on body colors, size and behavior of individuals during spawning. Fish were held under ambient salinity (37.1–39.2 psu, mean 38.5 psu), temperature (from 12.3 in February to 25.8 °C in August), oxygen (7.2–8.2 mg/l, mean 7.8 mg/l), pH (7.8–8.2, mean 7.9) and photoperiod conditions. During captivity, fish were usually fed with small pelagic fish, mollusks and sea urchins. When male interest for females increased, fish were removed to the laboratory tank (300 l). These specimens, one male (420 g, TL 34.0 cm, 4+ age) and one female (480 g, TL 33.0 cm, 4+ age) spawned spontaneously. During the spawning period, temperature was 14.2 °C, salinity 38.1 psu, oxygen 7.2 mg/l, and pH 7.9. After spawning, the fish were returned to the aquarium pool. The same male also spawned with another female (458 g, TL 31.0 cm, 4+ age) ten days after the first spawning.

2.2. Egg incubation and embryonic development

The first release of eggs occurred in the aquarium tank, and immediately afterwards, the male and the female were transferred to the laboratory tank, where the spawning continued. We gathered the first eggs released from the aquarium’s gravelly bottom, together with the gravel to which they were attached, which served as a control for embryonic development in further research. Prior to stocking in the experimental tank for incubation, these egg samples were disinfected for 15 min using a low-concentration solution of formaldehyde (1 part 37% formalin to 600 parts of water) (Ferguson, 1978; Cross and Needham, 1978). This egg sample was placed inside the laboratory tank in a dish the size of the bottom 80 cm², with a permeable bottom made of plankton netting of 500 µm mesh for better aeration. Other eggs that were released during spawning in the laboratory tank were attached to the tank bottom and could not be retrieved for sampling. The eggs had a constant daily exchange of 50–70% seawater through a 50-µm mesh net. The experiment was carried out under an artificial photoperiod (12L:12D h, 2000 lux). The water was gently aerated from the bottom of the tank.

Eggs and larvae were incubated from 13.8 to 15.5 °C (mean 14.4 °C). Dead larvae were removed daily. After fertilization, a sample of 10–15 eggs was taken every 5–7 min to determine the exact time of first cleavage. Random samples of 10–15 eggs were taken every hour during the first 10 h after fertilization, and subsequently every 6 h. The egg diameter was measured and the stages of the embryonic development were recorded using a binocular microscope. Photos of individual stages were taken. The number of eggs and larvae were significantly lower during the second spawning with the same male and the other female. Due to the low number of spawned eggs during the second spawning, egg measurements and the monitoring of embryonal development in this group was not carried out.

2.3. Larval development

After hatching commenced, various measurements were made on live larvae, sampled randomly at least three times a day, 8:00 am, 14:00 pm and 20:00 pm. All changes in the larvae were recorded. In each sample, 15–20 larvae were examined and measured.

Larvae were anaesthetized in a solution of benzocaine (0.05 mg/l) and carefully measured using an ocular micrometer attached to a binocular microscope (±0.001 mm).
These measurements included: standard length (the distance along the midline of the body, from the tip of the snout to the end of the urostyle); total length (the distance along the midline of the body, from the tip of the snout to the end of caudal fin rays) pre-anal length (the distance along the midline the body, from the tip of the snout to the anus); body depth (the perpendicular depth of the trunk at the anus) head length (the distance between the tip of the upper jaw and the cleithrum) eye diameter; longer diameter length of yolk sac.

The time period until full yolk-sac absorption, as well as the mouth opening, was also recorded. The mouth width of larvae was measured with the larvae in dorsal position, at the point where both lips meet (Shirota, 1970).

2.4. Larval feeding

Larvae were fed exclusively on the rotifers Brachionus plicatilis, as a first food after yolk-sac absorption and the mouth opening. The rotifers were cultured in a thermostatic chamber at 26 °C and at 25–28 psu. Rotifers fed on the green alga, Chlorella sp. and were added to tanks with larvae, to a density of 7–10 ind./ml. At the initiation of feeding, 60 rotifers were measured and a size range of 90–280 μm was established. The number of larvae in the tank was measured daily in order to monitor the survival rate, taking one litre of medium five times, in which the larvae were counted.

3. Results

3.1. Spawning

The start of spawning was observed in the aquarium on March 26th at approximately 13:00 h. Before spawning, the dominant male chased away other fish from the part of the aquarium tank chosen as a spawning place, and changed into a dark-green color. A dominant male would choose one of the mature females and spawning occurred after a few days of courtship. The female also changed color to a dark-green. Spawning continued after fish were removed into the laboratory tank with an area of 15 cm × 15 cm (≈225 cm²) and at 3–5 cm above the bottom with tiny gravel. The male followed the female swiftly (40–50 cm/s) in different directions above the spawning place. As the female emitted eggs, the male started to fertilize these eggs with short and fast body contractions on the left and right side. These contractions continued for 2–3 s. Spawning in the laboratory tank was noted usually 1–3 times, from the early morning hours to noon, over a period of three days. The adhesive eggs were placed at the bottom of the laboratory tank.

3.2. Embryonic development

The developmental stages of the embryos are shown in Table 1 and Fig. 1. The average diameter of newly spawned eggs was 1.01 ± 0.03 mm, with the size varying from 0.86 to 1.04 mm. Mature and fertilized eggs were attached to the bottom of the tank by mucus. The yolk was homogeneous and non-segmented. There were no
visible oil globules in the eggs, which we also did not record in the larvae. The first and second cleavages are shown in Fig. 1A and B. The eggs showed a typical discoidal cleavage and the formation of equally sized blastomeres. In the gastrulation stage, the blastoderm showed expansion and spread towards the vegetal pole (Fig. 1F). The embryo form was detectable after 35 h (Fig. 1G), and after 42 h (Fig. 1H), it was completely visible. During embryonic development, first dendritic melanophores appeared on the yolk sac (n = 22–32) and on the dorsal and ventral surface (n = 33–41) 55 h after fertilization. The number and the position of melanophores were the same during the entire embryonic stage. Heart beating was observed after 67 h, and 1–2 movements of the complete body were noted during 1 min. The embryo was folded, with the tip of the tail reaching the posterior end of the head 72 h after fertilization, and optic capsules were observed (Fig. 1I). Just before hatching, movements were noted every 3–5 s.

### 3.3. Hatching and larval development

Hatching started approximately 127 h after fertilization (31st March, around 20:00 h), and within 3 h, all yolk-sac larvae hatched. During hatching, the temperature was 14.5 °C, salinity 38.0 psu, oxygen 7.1 mg/l, and pH 7.8. Changes in larval length during the first seven days of life are shown in Table 2.

The body of newly hatched larvae was elongated immediately after the release of larvae from eggs (Fig. 2A). The average total length of newly hatched larvae was 4.80 ± 0.22 mm and was characterized by an elongated yolk sac under the anterior part of the body and without an oil drop. The body was segmented into 39–41 myomeres, 15–18 pre-anal and 22–25 post-anal myomeres. The mouth was undeveloped upon hatching, the eyes were not pigmented, and a simple tubular gut was observed. There were black and yellow-green chromatophores covering the head and the trunk, except for the caudal region. The distance from the snout to the posterior end of the pigmented area was 4.12 ± 0.03 mm. After hatching, the head length was 12% of the total length. In newly hatched larvae, the body depth ranged from 0.71 mm to 0.95 mm. The anus opened slightly and was located more than halfway to the caudal part of the body. The locations with a higher number of melanophores were on the surface of the yolk sac and around the anus. On the yolk sac, 60–64 dendritic melanophores were noted, and 7–8 around the anus. There were no melanophores on the dorsal and ventral fin-folds. After hatching, the larvae were distributed in the upper layers of the tank. Only occasional tail contractions were noted on the first day.

At the beginning of the second day after hatching, granular pigmentation of the eyes was apparent and the melanophores were bigger around the anus and in the dorsal region of the notochord. The development of a caudal fin started with changes in the tissue of the ventral region of the notochord. The changes were noticed as a thickening of tissue, the beginnings of formation of rays. One-third of the yolk sac had been adsorbed (Fig. 2B). The second day after hatching, larvae were dispersed throughout the

### Table 1

Embryonic development of Labrus viridis at a mean temperature 14.4 °C.

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Fertilization</td>
<td>Meridional first cleavage</td>
</tr>
<tr>
<td>2</td>
<td>2 cells</td>
<td>Cleavage parallel to the second</td>
</tr>
<tr>
<td>2</td>
<td>4 cells</td>
<td>Cleavage parallel to the first</td>
</tr>
<tr>
<td>3</td>
<td>8 cells</td>
<td>The blastoderm consisted of many blastomeres</td>
</tr>
<tr>
<td>4</td>
<td>16 cells</td>
<td>The blastodisc begones multilayered, visible</td>
</tr>
<tr>
<td>5</td>
<td>32 cells</td>
<td>Gastrulation starts</td>
</tr>
<tr>
<td>16</td>
<td>Morula</td>
<td>Invagination of blastomeres ends</td>
</tr>
<tr>
<td>26</td>
<td>Blastula</td>
<td>Formation of nerular groove starts</td>
</tr>
<tr>
<td>29</td>
<td>Gastrula</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Gastrula</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Nerula</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>37</td>
<td>12-h embryo stage</td>
</tr>
<tr>
<td>52</td>
<td>16</td>
<td>Somatic segmentation begins, formation of optic vesicles</td>
</tr>
<tr>
<td>55</td>
<td>30</td>
<td>Formation of miomeres begins</td>
</tr>
<tr>
<td>67</td>
<td>20</td>
<td>Movements of complete body were noted</td>
</tr>
<tr>
<td>72</td>
<td>05</td>
<td>Rhythmic movements every 15–17 s of 50% blastomeres appear on the head, the tip of the tail reaching posterior end of the head</td>
</tr>
<tr>
<td>78</td>
<td>30</td>
<td>Melanophores appear on the yolk sac and faster rhythmic movements every 3–5 s</td>
</tr>
<tr>
<td>91</td>
<td>10</td>
<td>Melanophores appear on the tail</td>
</tr>
<tr>
<td>102</td>
<td>40</td>
<td>30–32 melanophores on the yolk sac, 4 melanophores on the head</td>
</tr>
<tr>
<td>127</td>
<td>40</td>
<td>Hatching begins</td>
</tr>
<tr>
<td>130</td>
<td>10</td>
<td>All yolk sac larvae hatched</td>
</tr>
</tbody>
</table>
Table 2. Changes in length and shape of Labrus viridis yolk-sac larvae during the first 7 days post hatch (values in table were measured every day at 20:00 h, from 31st March to 6th April).

<table>
<thead>
<tr>
<th>Hours after hatching (h)</th>
<th>Total length (mm)</th>
<th>Prectal length (mm)</th>
<th>Head length (mm)</th>
<th>Body depth (mm)</th>
<th>Longest yolk-sac diameter (mm)</th>
<th>Daily temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4.80 ± 0.22</td>
<td>4.76 ± 0.21</td>
<td>2.56 ± 0.11</td>
<td>0.83 ± 0.05</td>
<td>1.28 ± 0.09</td>
<td>14.3</td>
</tr>
<tr>
<td>+12</td>
<td>4.93 ± 0.20</td>
<td>4.83 ± 0.19</td>
<td>2.59 ± 0.11</td>
<td>0.84 ± 0.08</td>
<td>1.30 ± 0.09</td>
<td>14.4</td>
</tr>
<tr>
<td>+48</td>
<td>5.15 ± 0.25</td>
<td>4.91 ± 0.15</td>
<td>2.61 ± 0.12</td>
<td>0.85 ± 0.09</td>
<td>1.31 ± 0.10</td>
<td>14.5</td>
</tr>
<tr>
<td>+72</td>
<td>5.33 ± 0.27</td>
<td>5.11 ± 0.15</td>
<td>2.56 ± 0.17</td>
<td>0.87 ± 0.08</td>
<td>1.32 ± 0.12</td>
<td>14.8</td>
</tr>
<tr>
<td>+120</td>
<td>5.57 ± 0.28</td>
<td>5.65 ± 0.28</td>
<td>2.72 ± 0.17</td>
<td>0.91 ± 0.14</td>
<td>1.33 ± 0.13</td>
<td>14.8</td>
</tr>
<tr>
<td>+240</td>
<td>6.04 ± 0.20</td>
<td>5.79 ± 0.26</td>
<td>2.93 ± 0.26</td>
<td>0.97 ± 0.12</td>
<td>1.34 ± 0.14</td>
<td>14.1</td>
</tr>
</tbody>
</table>

Fig. 2. Early larval development of Labrus viridis: (A) newly hatched yolk-sac larvae (4.76 ± 0.21 mm SL) 33 somites, (B) 24-h old yolk-sac larvae (4.94 ± 0.15 mm SL), (C) 4-day old yolk-sac larvae (5.65 ± 0.28 mm SL) the mouth is invaginated but not open, (D) 7-day old larvae (6.81 ± 0.29 mm SL), (E) 20-day old larvae (7.11 ± 0.39 mm SL).

By day 3, the development and growth of melanophores continued. Changes on the head were noted, such as the development of the mouth. The jaws, maxilla and mandible formed without significant difference. The body and notochord were straight. Half of the yolk sac had been adsorbed.

At the beginning of the 4th day, 90% of the yolk sac was absorbed (Table 2), the foregut and hindgut were visible, and the anus was open. The eye was completely pigmented and the mouth started opening. The number and size of melanophores increased. The differentiation of pectoral fins had started (Fig. 2C).

During the 5th day, the mouth opened and was functional with an opening of 0.33–0.51 mm. Melanophores were now present on the anal fin-fold. The melanophores (5–7) were located in a line on the fin fold just under the notochord. The fifth day after hatching, the number of larvae was 1.66 ind./l.

By day 6, the melanophores on the anal fin-fold were bigger and had spread on the entire fin-fold around the entire tank column. The larvae density in the tank was 2.16 ind./l.
In 80% of the larvae, the yolk sac had been completely absorbed. An increase in pigmentation was also noted after the absorption of the yolk-sac and at the beginning of active feeding.

During the 7th day, 4–5 melanophores appeared on the frontal part of the fin-fold around the anus (Fig. 2D). The head length after the 7th day increased to 20.1% of the total length. Larvae were mobile and started feeding actively. The passage of food was clearly visible along the open digestive tract. The number of larvae in the tank was 0.73 ind./l.

Three weeks after hatching, the total length ranged from 6.91 to 7.25 mm, and the pre-anal length ranged from 3.62 to 3.97 mm. The head length was 21.3% of the total length.

The period between the 7th and the 20th day after hatching was characterized by a more intensive body pigmentation of the larvae (Fig. 2E). Pigmentation occurred in the same places as on the yolk-sac larvae. Some body parts were without pigmentation, such as the head, ventral and caudal fin-fold and caudal part of the notochord. A small number of larvae survived up until the 20th day after hatching (0.1 ind./l).

3.4. Larval feeding

The fifth day after hatching, we recorded the beginning of active feeding with 35% of the larvae. The maximum gape of the open mouth averaged 0.44 mm. After 24 h, 72% of the larvae started to feed on rotifers. We noted that larvae showed interest in prey only when it appeared in front of them at 2–3 mm and the first day after being given rotifers, the larvae hunted 4–5 times per hour.

Larval survival up to the mouth opening (66 h after hatching) was 76.6%; 10 days after hatching, 15.2% larvae survived; after 20 days 4.6% larvae survived and 24 days after hatching, all larvae died.

4. Discussion

Spawning of green wrasse in the aquarium started in the second half of March, which is in accordance with Grubišić (1962, 1988), Onofri (1975), and Jardas (1996). Green wrasse is a serial spawner and spawning occurred between a dominant male and one of the mature females.

The time of maturation and partial spawning corresponded to the behavior of other Labridae, *L. merula*, but the release of ripe eggs in this species lasted for 20 days (Duščić et al., 1999).

The behavior of males during the spawning period was similar to *L. merula* males. The way of courtship and the movements during spawning above the chosen area on the sea bed were the same for these species. The only difference was in the color of the body during spawning, as *L. viridis* only intensifies its color, while *L. merula* completely changes the color of its body, which is particularly pronounced in the male (Duščić et al., 1999). For the female, body colorations are less intense than with males and together with thicker abdomens, it represents a visual way of determining sex.

The eggs of *L. viridis* are demersal, glued down in nests or shallow depressions (Onofri, 1970). Most labrids spawn small (0.5–1.1 mm) pelagic eggs, but three northeast Atlantic genera have adhesive, demersal eggs with parental care (Richards and Leis, 1984). In the Mediterranean, only two of the labrid species, *Ctenolabrus rupestris* and *Coris julis*, spawn pelagic eggs (Russell, 1976). In comparison with *L. merula* and other labrids, *L. viridis* have larger eggs and newly hatched yolk-sac larvae (Table 3). The main characteristic of *L. viridis* eggs is the sticky mucous layer that glues eggs to the bottom. A few hours before hatching, the mucous layer loses its stickiness and separates from the eggs.

Temperature has an important role in the duration of embryonic and larval stages (Quignard, 1967; Lasker, 1981). In the present study, embryonic development at a mean temperature of 14.4 °C lasted 127 h, which is longer than the embryonic development of *L. merula* (106 h 45 min) with a mean temperature of 14.3 °C. It may be concluded that *L. viridis* have longer embryonic development than *L. merula* at the same incubation temperatures.

In addition to egg sizes, newly hatched larvae, the duration of embryonic and larval stages, pigmentation in the early stages is one factor that can help in the identification of labrid species. Ford (1922) described larval pigment patterns of different labrids and grouped larvae according to their pigmentation. According to this division, *L. viridis* larvae are similar to *L. merula* and *Labrus bergylta*. The main differences between these species are in the size (Table 3).

<table>
<thead>
<tr>
<th>Species</th>
<th>Source</th>
<th>Egg diameter (mm)</th>
<th>Hatched yolk-sac larvae</th>
<th>Larvae-start of Preanal length</th>
<th>The Eye diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ctenolabrus rupestris</em></td>
<td>Ehrenbaum (1905–1909)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heincke and Ehrenbaum (1900)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Holt (1899)</td>
<td>0.72–1.01</td>
<td>1.95–2.19</td>
<td>3.14</td>
<td></td>
</tr>
<tr>
<td><em>Labrus bergylta</em></td>
<td>Matthews (1887)</td>
<td>1.00</td>
<td>3.80</td>
<td>2.10</td>
<td>0.27</td>
</tr>
<tr>
<td><em>Symphodus cinereus</em></td>
<td>Danois (1913)</td>
<td>0.70–0.80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Crenilabrus ocellatus</em></td>
<td>Sparta (1931)</td>
<td>0.68</td>
<td>3.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Symphodus</em> (Crenilabrus) melops</td>
<td>Quignard (1967)</td>
<td>0.80–0.85</td>
<td>2.50–3.00</td>
<td>2.90–3.10</td>
<td></td>
</tr>
<tr>
<td><em>Ctenolabrus rupestris</em></td>
<td>Stone (1996)</td>
<td>0.85</td>
<td>2.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Symphodus melops</em></td>
<td>Stone (1996)</td>
<td>0.90</td>
<td>2.60–2.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Labrus merula</em></td>
<td>Dulčić et al. (1999)</td>
<td>0.83–1.05</td>
<td>3.76</td>
<td>4.45</td>
<td>2.00</td>
</tr>
<tr>
<td><em>Labrus viridis</em></td>
<td>Present study</td>
<td>0.86–1.04</td>
<td>4.80</td>
<td>5.37</td>
<td>2.56</td>
</tr>
</tbody>
</table>
and development time of melanophores on the anal fin-fold and on top of the head. Melanophores on the anal fin-fold of *L. viridis* were noted at the beginning of the 6th day, which is five days later than with *L. merula*, but melanophores on top of the head were noted on the 7th day, which is nine days earlier than with *L. merula*.

The length of newly hatched green wrasse yolk-sac larva is larger than the larvae of *L. merula* and *L. bergylta*, whose larvae have 3.7–3.8 mm lengths (Matthews, 1887; Dulčić et al., 1999). The growth speed of newly hatched larvae is higher in the first 24 h (7.2%), and after the 7th day, larvae are 20.6% longer than at hatching. In comparison to *L. merula* larvae (Dulčić et al., 1999), the newly hatched larval of *L. viridis* grew faster in the first hours, but after the 7th day, growth was similar.

The spawning period and geographical distribution could also assist in distinguishing labrids species (Dulčić et al., 1999), but knowledge of embryonic and larval development of each labrid species is the main determining factor, especially in areas with many labrid species.

After the mouth opened, we noted the start of active feeding by larvae that accepted brachionus as first food. Considering that the functional opening of the mouth is based on the prey/gape ratio by only 25–50% (Shirata, 1970; Busch, 1996; Fernández-Díaz et al., 1994; Munk, 1997; Cunha and Planas, 1999; Ostergaard et al., 2005), the functional size of the mouth opening for wrasse larvae according to this ratio would be 0.11–0.22 mm. Based on the observed mouth opening, about 70% of added rotifers had a lorica width suitable as first prey.

5. Conclusion

This study suggests that it is possible to maintain brood stock and obtain mature individuals that spontaneously spawn in controlled conditions. The results showed that after yolk sac resorption, the larvae were large enough to be fed with rotifers. Existing technology in the mariculture of commercial species can meet the requirements for the rearing and preservation of this species. Future research, alongside the protection and repopulation of this species, can also be directed towards polyculture rearing in terms of market positioning. The use of wrasse as cleaner fish can perhaps also alleviate problems relating to ectoparasites.

References


