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# Effects of temperature and salinity on egg development and larval settlement of an invasive ascidian species, *Herdmania momus* (Savigny, 1816)

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**Abstract:** The effects of temperature and salinity on egg development and settlement of the ascidian *Herdmania momus* were investigated. Adult specimens were collected from the Dodu Yacht facility in Jeju Island, Korea (33°30′30.54″N, 126°27′55.46″E) in August 2018. Egg development and larval settlement were observed and recorded at 8 h intervals using a stereomicroscope, under nine temperature (10, 13, 16, 19, 22, 25, 28, 31, and 34°C), and four salinity regimens (28, 30, 32, and 34 psu). The highest hatching rate (82.8±7%) was observed at 32 psu and 25°C and the lowest hatching rate (1.0±2%) was at 34 psu and 13°C. The developmental rate (0.222±0.0994) was highest at 28 psu and 28°C, and lowest (0.016±0.008) at 30 psu and 13°C. The highest settlement success rate (77.1±5%) was at 32 psu and 25°C and the lowest (0.1±1.0%) was at 30 psu, and 13°C. The rate of settlement (0.080±0.000) was highest at 28 psu and 28°C, and lowest (0.013±0.000) at 30 psu and 13°C. Both hatching and settlement success rates increased as temperature increased and tended to decrease beyond an optimal temperature range. *Herdmania momus* preferred 30–34 psu salinity and 22–25°C temperature. This study provides baseline information about the life history of *H. momus*, and important data to control the damage caused by the increase in number and distribution of this invasive ascidian.

**Keywords:** *Herdmania momus*, invasive species, hatching rate, development rate, settlement success rate, rate of settlement

## INTRODUCTION

Non-native marine species exert a global influence, threatening marine ecosystems (Gallardo *et al.* 2016), competing with native species and damaging biodiversity (Gurevitch and Padilla 2004). Globally, approximately 60 species belonging to the class Ascidiacea (phylum Chordata) have been reported as invasive species (Shenkar and Swalla 2011). In Korea, *Ascidiella aspersa*, *Ciona robusta*, *Clavelina lepadiformis*, *Molgula manhattensis*, *Styela plicata*, and *Herdmania momus* have been reported as invasive ascidian species (Shin *et al.* 2013). These invasive ascidians in Korea attach themselves to natural substrates such as shells, sea grass and rocks, and artificial structures in harbors such as boat hulls, pilings, buoys, and floating marinas (Bae 2018), which serve to spread the ascidians quickly and easily (Degnan 1990). In particular, the invasive species interfere with the growth of cultured marine species through competition for space and resources and severely damage culturing farms (Park *et al.* 2017).

*Herdmania momus*, a sessile marine benthic organism, is a solitary, red-throated ascidian belonging to the family Pyuridae, order Stolidobranchia, class Ascidiacea, subphylum Tunicata, and phylum Chordata (Degnan *et al.* 1996). This hermaphrodite species generally has an inflated, spherical body with a buccal siphon positioned near 1/3 of the spherical body and an atrial siphon nearly at the center of body, and the latter is slightly larger (Rho 1977). Its body length ranges from 4.5 cm to 9 cm (Nishikawa 2002; Kabalah-Amitai *et al.* 2013), and the pink outer skin is soft with slightly wrinkled surface (Rho and Lee 1991). The gonads are attached to the fascia of the gut muscle, and ovaries are distributed between the testes (Kott 2002). *H. momus*, like other ascidians, has larvae that are motile and attach to an appropriate substrate to undergo transformation into a juvenile (Goodbody 1963). After metamorphosis into young individuals, they grow in seawater by ingesting sediment particles, phytoplankton, and bacteria (Singh *et al.* 2009), and after approximately 4 months, they usually grow into a complete individual (Koplovitz *et al.* 2016). This species can be found attached to natural rocks and artificial substrates up to 30 m above sea level, and in a few cases, has been reported at 100 m to 150 m above sea level (Nishikawa 2002; Evans *et al.* 2013; Gewing *et al.* 2014; Afoncheva *et al.* 2016). These ecological characteristics contribute to marine biofouling, along with other sessile marine species, causing damage to oyster farms in particular (Lacoste *et al.* 2016), and they are expected to decrease the harvest of turban shells and abalones by competing for algal feed, and will ultimately reduce the sea food harvest in Korea. Therefore, basic development rate experiments were conducted to obtain the ecological data conducive to the spread and control of *H. momus* (Shenkar and Loya 2008; Koploviz *et al.* 2016). Other studies have also been conducted on its distribution and proliferation in Israel (Gewing *et al.* 2014). Although population dynamics experiments on *H. momus* have been conducted in Korea (Yi and Kim 2016), studies on its development and proliferation for efficient management and control are limited.

Salinity and temperature are important factors influencing the distribution and proliferation of ascidians, including *H. momus* (Niermann-Kerkenberg and Hofmann 1989; Carver *et al.* 2006). Therefore, the egg development rate, hatching rate, settlement success rate, and rate of settlement of larvae after hatching were investigated at different water temperatures and salinity conditions in this study. The experimental results of the effect of temperature and salinity on various biological traits of *H. momus* can be used to provide basic data on their ecological characteristics, which will aid in devising strategies for the control of *H. momus*.

## MATERIALS AND METHODS

### 1. Collection and rearing of *Herdmania momus*

The specimens of *Herdmania momus* were collected from a dock of the Dodu Yacht facility of Jeju island in Korea (33°30′30.54″N, 126°27′55.46″E) in August 2018. This site is located in a temperate zone with four distinct seasons. The monthly mean water temperature ranged from 13.10 to 25.60°C, and the monthly mean salinity ranged from 32.20 to 34.30 psu in 2018 (KHOA 2020). *H. momus* collected from this sampling site were transferred to an insulated polystyrene container and quickly transported to the laboratory. They were acclimatized for approximately 30 minutes in a tank filled with sea water from the field, before being split into treatment groups in the experiment.

### 2. Artificial fertilization and egg development

For fertilization of *H. momus* eggs, the testes and ovaries of 30 adult individuals were placed in a plastic container (width 28 cm × length 29 cm × height 16 cm) containing filtered seawater and mixed for 50–60 minutes to induce fertilization. A stereomicroscope (SMZ1000; Nikon, Japan) was used to observe meridional cleavage (which forms about 40 mins after fertilization), and after cleavage was confirmed, excess sperm and unnecessary foreign substances were removed by using a 120 μm (pore size) Müller gauze.

Each egg was transferred into a well (diameter 15.5 mm × height 17.5 mm) in a 24-well plate (Cat.32024; SPL Life Science, Korea) with 5 mL of filtered seawater for each experimental treatment. The well plates were placed in a plastic sealed container which was placed in a glass water tank (diameter 140 cm × height 105 cm) set at a constant temperature to induce the development and settlement of eggs. For the low salinity treatments, salinity was adjusted by dilution of the seawater using purified water, and for the high salinities, by adding aquarium grade sea salt (Instant Ocean Reef Crystals salt; Aquarium systems, France). The temperature of the seawater bath was controlled using a heater (HE-300W; PERIHA, Korea) and a cooler (DA 500B; Daeil Chiller, Korea). The temperature and salinity of the seawater used in the experiment were measured using a multi-functional, water quality meter (Pro Plus; YSI, USA).

### 3. Egg hatching and larval settlement test

In order to identify optimal temperature and salinity conditions for egg development of *H. momus*, four salinity conditions (28, 30, 32, and 34 psu) and nine temperature conditions (10, 13, 16, 19, 22, 25, 28, 31, and 34°C) were employed in a total of 8 runs, with a 24-well plate for each temperature and salinity treatment, and a total of 192 fertilized eggs used for each treatment. Egg development and larval mortality were recorded every 8 h and recorded by images from the stereomicroscope. At the same time, the number of larvae that had attached on the walls of the plate (larvae that succeeded in settlement) and settlement time (which is the time from hatching to settlement) were recorded. "Settlement" is defined as metamorphosis with absorption of the tail of the larva, and attachment to the plate. These tests were conducted until all individuals had either settled or died.

### 4. Data analysis

Hatching rate (%) was calculated as the (number of hatched eggs/number of total eggs) × 100, and the developmental rate was 1/hatching time in hours. The settlement success rate (%) was the (number of attached larvae/total number of eggs) × 100, and the rate of settlement was 1/settlement time. The results of the hatching and settlement success rates were expressed as the mean ± S.D. of eight replicates, and the development rate and rate of settlement were expressed as the mean ± S.D. of the total number of eggs and larvae, respectively.

One-way analysis of variance (ANOVA) was conducted to analyze the differences between the means of hatching rate, egg development rate, settlement success rate, rate of settlement, as induced by temperature and salinity treatments. When a significant difference was found by ANOVA at the 0.05 level, Tukey's honest significant difference (HSD) *post hoc* comparisons were conducted to establish

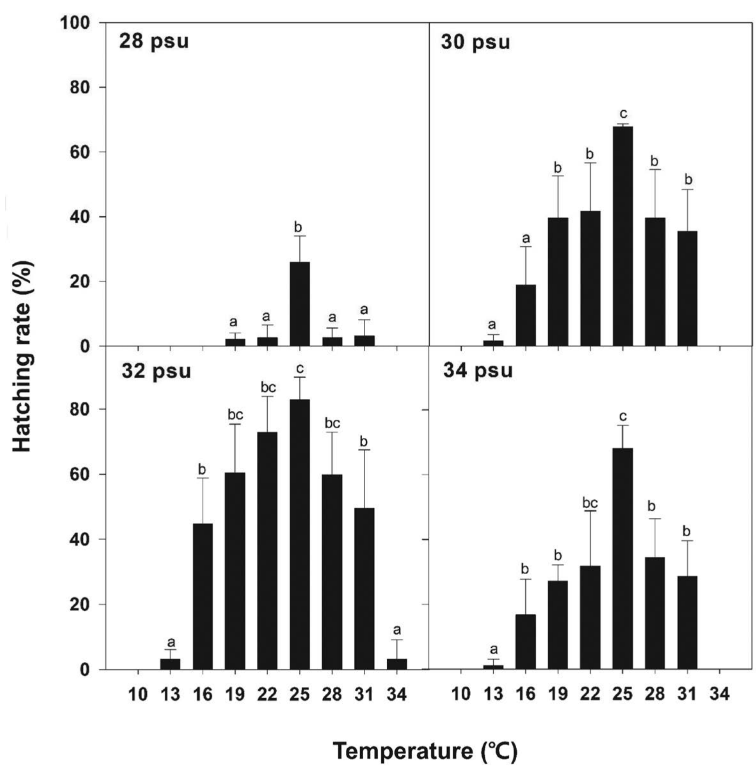


**Fig. 1.** Hatching rate of *Herdmania momus* at various combinations of temperature and salinity. Each bar is the mean obtained from 10°C to 34°C in experimental conditions, and vertical lines indicate the standard deviation. Means with different letters within each temperature point indicate significant differences at $p=0.05$ (Turkey's HSD *post hoc* comparisons).

what temperature/salinity treatments were different from one another. All statistical analyses were performed using SPSS software (Version 12.0) (SPSS Institute, Chicago, IL, USA), and the data were transformed before analyzing as needed.

## RESULTS

### 1. Hatching rate of eggs

*H. momus* eggs hatched at 34 psu at all experimental temperatures (13, 16, 19, 22, 25, 28, and 31°C) except 10°C and 34°C, and hatching rate varied from 1.0% to 68.2%. At 30 psu, eggs successfully hatched as at 34 psu (1.6–67.7%). Eggs hatched at 32 psu, except at 10°C, and hatching rate ranged from 3.1% to 82.8%. At 28 psu, hatching occurred except at 10, 13, 16 and 34°C, and hatching rate ranged from 2.1 to 26.0%. The lowest hatching rate was 1.0±2.0% at 13°C and 34 psu, whereas the highest hatching rate was 82.8±7.0% at 32 psu and 25°C (Fig. 1). Under all salinity treatments, the hatching rate increased with increasing temperature, and it tended to decline rapidly at temperatures above 25°C (Fig. 1). At 34 psu, hatching rate was low (1.0% to 16.7%) at 13°C and 16°C, but significantly higher (27.1% to 68.2%) at 19, 22, 25, 28 and 31°C ($F_{8,1719}=27.466$, $p<0.05$). At 32 psu, a relatively low hatching rate of 3.1% was obtained at 13°C and 34°C, whereas a high hatching rate of 44.8% to 82.8% was observed at temperatures of 16, 19, 22, 25, 28, and 31°C ($F_{8,1719}=74.895$, $p<0.05$) (Fig. 1). At 30 psu, the hatching rate was similar to that of 34 psu, which was relatively low (1.6%–18.8%) at 13°C and 16°C, but was higher (35.4%–67.7%) at 19, 22, 25, 28 and 31°C ($F_{8,1719}=33.732$, $p<0.05$). At 28 psu, the hatching rate was higher (26%) at 25°C and lower (2.1%–3.1%) at 19, 22, 28, and 31°C ($F_{8,1719}=35.473$, $p<0.05$). At 13°C, the hatching rate was relatively low (0.0–3.1%) compared to other temperatures, but not significantly so ($F_{3,764}=2.036$, $p=0.107$) (Fig. 1). At 25°C, the hatching rate was highest (26.0%–82.8%) ($F_{3,764}=9.334$, $p<0.05$). The hatching rate at each temperature and the four salinity levels showed significant differences at 16, 19, 22, 28, and 34°C ($F_{3,764}=25.652$; $p<0.05$ for 16°C, $F_{3,764}=56.031$; $p<0.05$ for 19°C, $F_{3,764}=57.666$; $p<0.05$ for 22°C, $F_{3,764}=48.560$; $p<0.05$

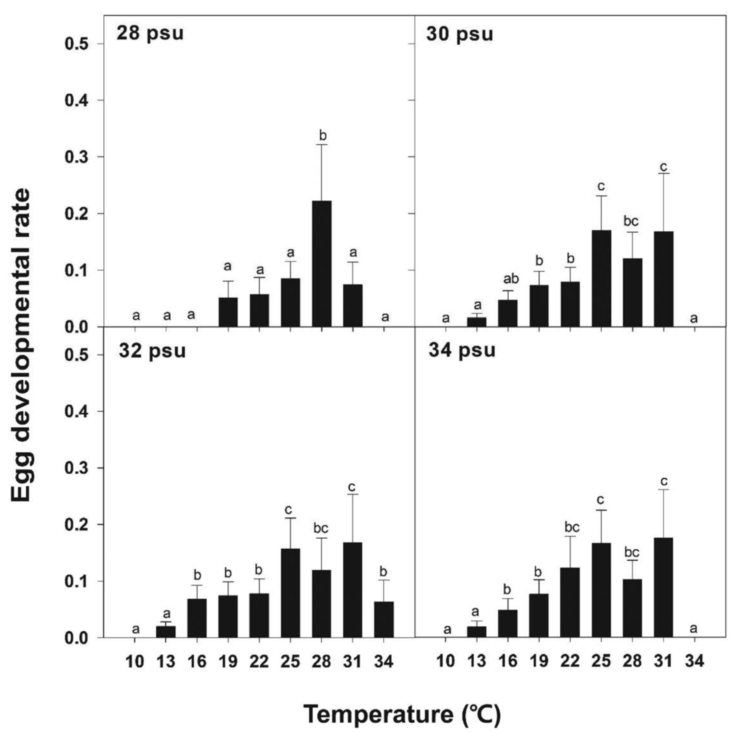


Fig. 2. Egg development rate of *Herdmania momus* at various combinations of temperature and salinity. Each bar is the mean obtained from 10°C to 34°C in experimental conditions, and vertical lines indicate the standard deviation. Means with different letters within each temperature indicate significant differences at $p=0.05$ (Turkey's HSD *post hoc* comparisons).

 

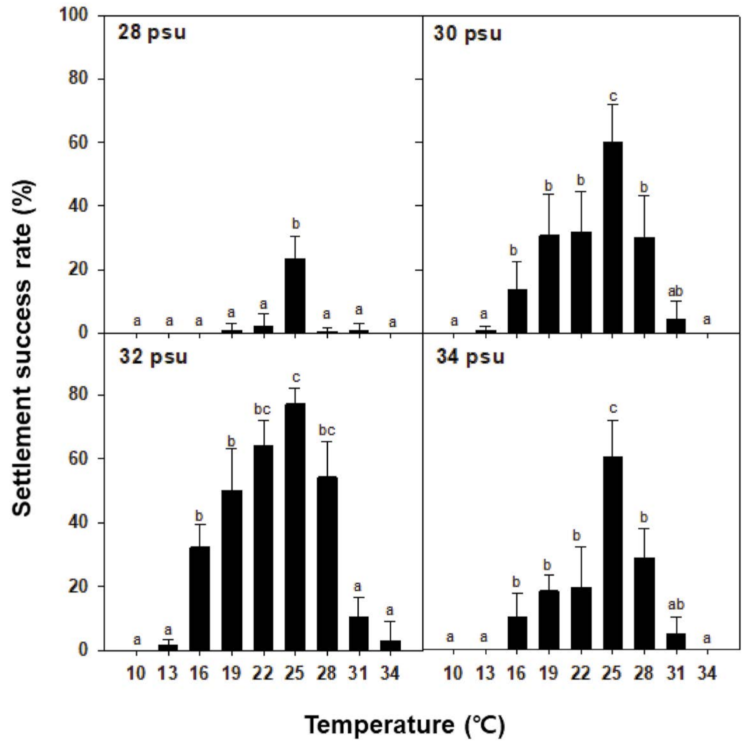


**Fig. 3.** Settlement success rate of *Herdmania momus* at various combinations of temperature and salinity. Each bar is the mean obtained from 10°C to 34°C in experimental conditions, and vertical lines indicate the standard deviation. Means with different letters within each temperature indicate significant differences at $p=0.05$ (Turkey's HSD *post hoc* comparisons).

for 28°C, $F_{3,764}=5.888$; $p<0.05$ for 34°C). However, no significant difference was observed at 31°C ($F_{3,764}=2.951$, $p=0.32$).

## 2. Egg development to larval stage

The rate of egg development of *H. momus* was lowest at 13°C at 30, 32, and 34 psu (0.016±0.008) for 30 psu, 0.020±0.009 for 32 psu, 0.018±0.011 for 34 psu) (Fig. 2). The highest rate was observed at 31°C (0.168±0.103 for 30 psu, 0.168±0.086 for 32 psu, 0.175±0.086 for 34 psu). At 28 psu, it was lowest at 19°C (0.051±0.030) and highest at 28°C (0.222±0.099). The development rate was low (0.018±0.0105) at 34 psu and at 13°C, but higher (0.076 to 0.175) at 19, 22, 25, 28 and 31°C ($F_{8,1719}=107.70$, $p<0.05$). At 32 psu, the development rate was low (0.020±0.009) at 13°C, but higher (0.068 to 0.168) at 16, 19, 22, 25, 28, 31 and 34°C ($F_{8,1719}=143.240$, $p<0.05$). Although development at 30 psu showed a similar trend to development at 34 psu, the rate was lower (0.016±0.008) at 13°C, but higher (0.073 to 0.168) at 19, 22, 25, 28 and 31°C ($F_{8,1719}=119.55$, $p<0.05$). At 28 psu, development rate was 0.222±0.099 at 28°C, but lower (0.051–0.085) at 19, 22, 25 and 31°C ($F_{8,1719}=42.284$, $p<0.05$) (Fig. 2). The development rate under the four salinity conditions was not significantly different at 13°C, but at other temperatures it was significantly different ($F_{3,764}=2.570$; $p=0.53$ for 13°C, $F_{3,764}=66.329$; $p<0.05$ for 16°C, $F_{3,764}=4.459$; $p<0.05$ for 19°C, $F_{3,764}=47.994$; $p<0.05$ for 22°C, $F_{3,764}=65.117$; $p<0.05$ for 25°C, $F_{3,764}=34.994$; $p<0.05$ for 28°C, $F_{3,764}=6.754$; $p<0.05$ for 31°C, $F_{3,764}=5.887$; $p<0.05$ for 34°C).

## 3. Settlement success rate of larvae

The highest settlement success rate of larvae was 77.1%±5% at 32 psu at 25°C, and the lowest was 0.1±1.0% at 30 psu at 13°C (Table 1). At 34 psu, settlement was successful at 16, 19, 22, 25, 28, and 31°C, and sharply increased at 25°C and decreased from 31°C. At temperatures of 16, 19, 22, and 31°C, the settlement success rate was relatively low (4.7%–18.8%), but it was 27.6%–57.8% ($F_{8,1719}=35.785$, $p<0.05$) at 25°C and 28°C. At 32 psu, settlement occurred at 13, 16, 19, 22, 25, 28, 31, and 34°C (Fig. 4). In addition,

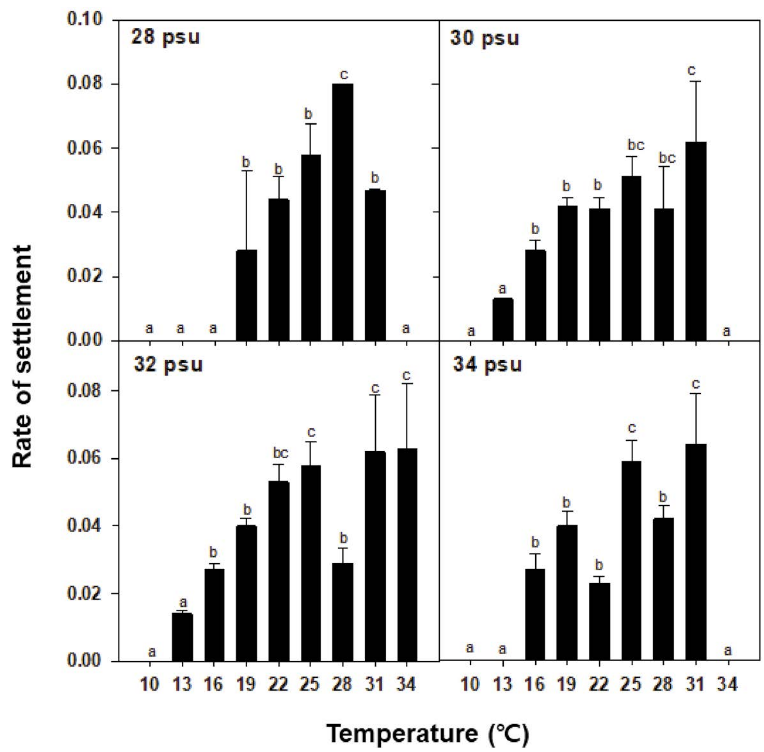


**Fig. 4.** Rate of settlement of *Herdmania momus* at various combinations of temperature and salinity. Each bar is the mean obtained from 10°C to 34°C in experimental conditions, and vertical lines indicate the standard deviation. Means with different letters within each temperature indicate significant differences at $p = 0.05$ (Turkey's HSD *post hoc* comparisons).

the settlement success rate was relatively low (1.6%–32.3%) at 13, 16, 31, and 34°C, and was higher (50.0%–77.1%) at 19, 22, 25, and 28°C ($F_{8,1719} = 75.053$; $p < 0.05$) (Table 1). In the case of 30 psu, settlement occurred at 13, 16, 19, 22, 25, 28, and 31°C, and increased rapidly at 19°C, and decreased rapidly at 31°C (Fig. 4). It was relatively low (0.5%–13.5%) at 13, 16, and 31°C, but higher (30.2%–59.9%) at 9, 22, 25, and 28°C ($F_{8,1719} = 44.830$; $p < 0.05$) (Table 1). At 28 psu, settlement only occurred only 19, 22, 25, 28, and 31°C. At 25°C, settlement success rate increased sharply and decreased rapidly after 28°C (Fig. 4). It was lower (0.5%–2.1%) at 19, 22, 28, and 31°C, and settlement was higher (23.4%) at 28°C ($F_{8,1719} = 35.903$; $p < 0.05$) (Fig. 4). Significant differences in settlement success rate were observed at all temperatures (except 13°C) between the four salinity treatments.

## 4. Rate of settlement of larvae

The time elapsed from hatching to settlement of *H. momus* larvae for all salinity conditions (except 28 psu) was fastest at 31°C at 17–18 h. At a salinity of 28 psu, the fastest settlement time was recorded as 12 h at 28°C. The longest settlement time was observed at 13°C, at 30 psu and 32 psu, as 71–76 h. At 34 psu, the longest settlement time was observed at 22°C as 43 h, and at 28 psu and 19°C, the shortest settlement time was 24 h. The rate of settlement of *H. momus* were relatively low at 0.027–0.034 at 16°C and 22°C at a salinity of 34 psu. At 19, 25, 28, and 31°C water temperatures, rates of settlement were 0.040–0.064 ($F_{8,1719} = 99.007$, $p < 0.05$) (Fig. 4). At a salinity of 32 psu, rate of settlement at 13, 16, and 19°C was low, at 0.014 to 0.029. On the other hand, the rate of settlement was significantly higher (0.040–0.062) at 19, 22, 25, 31, and 34°C ($F_{8,1719} = 127.233$, $p < 0.05$) (Fig. 4). At 28 psu, rate of settlement was relatively high (0.080 ± 0.000) at 28°C and low (0.044 to 0.058) at 19, 22, 25, and 31°C ($F_{8,1719} = 42.284$, $p < 0.05$) (Fig. 4). The four salinity treatments showed significant differences at all water temperatures except at 13°C ($F_{3,764} = 2.105$; $p = 0.098$ for 13°C, $F_{3,764} = 28.987$; $p < 0.05$ for 16°C, $F_{3,764} = 48.402$; $p < 0.05$ for 19°C, $F_{3,764} = 116.479$; $p < 0.05$ for 22°C, $F_{3,764} = 35.900$; $p < 0.05$ for 25°C, $F_{3,764} = 26.865$; $p < 0.05$ for 28°C, $F_{3,764} = 6.333$; $p < 0.05$ for 31°C, $F_{3,764} = 5.887$; $p < 0.05$ for 34°C) (Fig. 4).

 

**Table 1.** The optimal temperature, optimal salinity, end point, and location of the ascidians revealed as invasive species in Korea.

| Invasive ascidian species in Korea | Optimal temperature (°C) | Optimal salinity (psu) | End point | Location | Reference |
|---|---|---|---|---|---|
| *Ascidiella aspersa* | 20–22 | 30–34 | Hatching rate, development rate | Korea | Kim *et al.* 2018a |
| *Ciona robusta* | 16–20 | 32–34 | Egg development rate, larval settlement rate | Korea | Kim *et al.* 2018b |
| | 14–23.4 | – | Abundance, maximum animal size, the percentage of successful fertilization events | Italy | Caputi *et al.* 2015 |
| *Styela plicata* | 22–26 | 30–34 | Embryonic development, larval metamorphosis, post larval growth rate | Hongkong | Thiyagarajan and Qian 2003 |
| *Herdmania momus* | 22–25 | – | Abundance, size, reproduction | Israel | Shenkar and Loya 2008 |
| | 22–26 | – | Abundance, size | Israel | Koplovitz *et al.* 2016 |
| | 22–25 | 30–34 | Hatching rate, egg development rate, settlement rate, settlement time | Korea | Present study |

## DISCUSSION

Water temperature and salinity are considered as the most influential environmental factors in other invasive ascidian species in Korea such as *Ascidiella aspersa*, *Ciona robusta*, and *Styela plicata* (Table 1). Of the list of six invasive ascidian species (Shin *et al.* 2013), only *A. aspersa* and *C. robusta* have been investigated for their biological traits (hatching rate, developmental rate, and settlement rate) in Korea (Table 1). *H. momus* has been identified as an invasive species that migrated from the Red Sea to the Mediterranean Sea when the Suez Canal was opened (Shenkar and Loya 2008), and has the potential to damage the aquaculture industry in the South Sea, including Jeju Island in Korea (Yi and Kim 2016; Park *et al.* 2020). In the previous study, the distribution and spreading of *H. momus* has also been reported to be affected by water temperature and salinity in model predictions using Maximum entropy model (MaxEnt) (Park *et al.* 2020). The experimental results of the present study provide important data for predicting the distribution of *H. momus*, and controlling its density. To the best of our knowledge, this study is the first to report the effect of both temperature and salinity on the various biological traits of *H. momus*, using the largest number of replications.

*H. momus* development and reproduction has been known to occur at temperatures above 13°C (Yi and Kim 2016) in the present study, the hatching, development, and settlement success rates were found to increase from 13°C up to an optimal temperature, and then decreased again after passing the optimum temperature. Moreover, all biological traits of *H. momus* were significantly affected by the salinity. Hatching and development rates were highest at 32 psu, and hatching occurred at 13–34°C. At salinities of 30 and 34 psu, similar hatching rates were found at 32 psu (1.0–68.2% for 30 and 34 psu; 1.0–68.2% for 32 psu) between water temperatures of 13°C and 31°C. Hatching occurred at a salinity of 28 psu and temperatures of 19–31°C, but the hatching rate was low (2.1–26.1%). Under all salinity conditions, the hatching rate was the highest at 25°C water temperature. In Korea, similar results were observed for the development of *H. momus* between 22–25°C in temperature, with no hatching at 10°C and very low hatching at 13°C (Yi and Kim 2016). Likewise, the development rate was higher at 22–28°C, and the highest and lowest developmental rates were shown at 25°C and 13°C, respectively. Shenkar and Loya (2008) reported the maturity and development of *H. momus* occurred from

17°C to 31°C, with the optimum temperature range of 22–25°C (Table 1). In addition, Koplovitz *et al.* (2016) also reported an optimum temperature range for *H. momus* of 22°C to 26°C (Table 1). Hatching and development of *H. momus* occur consistently in the literature at an optimal temperature and salinity of 22–25°C and 30–34 psu, respectively.

The optimum temperature of *H. momus* was higher than that of *A. aspersa* and *C. robusta* (Table 1). *A. aspersa* and *C. robusta* are usually found at Tongyeung (34°49′42.2″N, 128°26′06.9″E) and Pohang (35°59′24.8″N, 129°33′20.6″E), respectively (Kim *et al.* 2018a; Kim *et al.* 2018b). These locations are located north of Jeju Island where *H. momus* is usually found, and have a lower water temperature than Jeju Island (annual average temperature: 15.99°C for Tongyoung, 15.60°C for Pohang, 18.19°C for Jeju; minimum monthly temperature: 5.3°C for Tongyoung, 4.3°C for Pohang, 12.4°C for Jeju) (KHOA 2020). The salinity of these locations was similar at 30–33 psu (KHOA 2020) which was the optimum salinity for *H. momus*. Considering the lowest temperature of *H. momus* at which development begins (13°C) and the differences in optimum temperature between *H. momus* and other invasive species (*A. aspersa* and *C. robusta*), an increase in water temperature can be the most important factor for the incursion of *H. momus* northward in Korea. Therefore, it is necessary to predict and prepare for this event, considering the increasing of water temperatures induced by climate change.

Although the hatching and development rates were higher at 31°C, the larvae were abnormal, either lacking a tail or having shorter tail than normal. The survival and settlement of all ascidians, including *H. momus*, has been known to be affected by the length of the larva's tail after hatching, and they die if they fail to attach to the proper habitat of hard substrate such as rock, buoys and seawalls (Lee *et al.* 2008). *H. momus* showed a significant decrease in settlement success rate at 31°C (Fig. 3), as a result of having no tail or a short tail. Lee *et al.* (2008) also showed that survival of the larvae depends on the length of their tail.

The increase and decrease in hatching, settlement, and development of *H. momus* outside of their optimum range were similar to the results of invasive alien species such as *C. robusta* and *A. aspersa* (Kim *et al.* 2018a; Kim *et al.* 2018b). However, the optimum temperature of *H. momus* was higher than that of *A. aspersa* and *C. robusta* (Table 1). If climate change causes water temperature increments in the Korean Peninsula, *H. momus* can spread from its main habitat, Jeju Island, to the north, including Tongyoung and Pohang. This is expected to lead to increased competition for space and resources with native species, which may be a threat to native species out and disrupt marine ecosystems, with concomitant economic damage to the marine industry. This study was carried out to obtain basic biological data to devise and implement control strategies to mitigate damage caused by the rapid hatching and development of *H. momus*. These results can be used as benchmark data to predict the occurrence and spread of *H. momus* in Korea.

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