การศึกษาชีวประวัติของไรน้ำสามชนิด (Cladocera : Moinidae) ในประเทศไทยในห้องปฏิบัติการ

Laboratory Study on Life History of Three Water Flea species (Cladocera : Moinidae) in Thailand

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การศึกษาครั้งนี้เพื่อเปรียบเทียบชีววิทยาของไรน้ำที่มีการเลี้ยงในเชิงพาณิชย์ คือ ไรแดง (*Moina macrocopa*) และไรแดงสยาม (*Moina siamensis*) กับไรน้ำที่พบในธรรมชาติ คือ ไรแดงเล็ก (*Moina micrura*) โดยแยกชนิดของไรน้ำและเลี้ยงในห้องปฏิบัติการ ผลการศึกษาพบว่า ไรน้ำทั้ง 3 ชนิดมีลูกครอกแรกเมื่ออายุ 2 วัน ไรแดงเล็กมีจำนวนครอกต่อแม่และจำนวนลูกต่อแม่น้อยกว่าไรแดงสยามอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) แต่ไม่แตกต่างทางสถิติกับไรแดง ($P > 0.05$) จำนวนลูกต่อครอกของไรแดงเล็ก (10.9 ± 2.08 ตัวต่อครอก, n = 10) และไรแดงสยาม (8.7 ± 2.45 ตัวต่อครอก, n = 10) ไม่แตกต่างกันทางสถิติ ($P > 0.05$) ไรแดงมีจำนวนลูกต่อครอก (16.5 ± 4.45 ตัวต่อครอก, n = 10) สูงกว่าไรน้ำชนิดอื่นอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) ไรแดงสยามมีอายุ (8.7 ± 1.70 วัน, n = 10) ยาวนานกว่าไรแดงเล็ก (5.4 ± 1.17 วัน, n = 10) และไรแดง (5.3 ± 1.16 วัน, n = 10) อย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) ไรแดงมีความยาวลำตัวสูงสุด (500 - 1,500 ไมโครเมตร) และไรแดงเล็กมีความยาวลำตัวต่ำสุด (200 - 850 ไมโครเมตร) ($P < 0.05$) อัตราการเจริญเติบโตจำเพาะของไรแดงสูงกว่าไรแดงสยามและไรแดงเล็กอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) การศึกษาครั้งนี้แสดงให้เห็นว่า ไรแดงเล็กมีลักษณะทางชีววิทยาไม่แตกต่างกับไรน้ำที่มีการเลี้ยงในเชิงพาณิชย์ และไรแดงเล็กมีขนาดเล็กกว่าไรน้ำชนิดอื่นจึงเหมาะในการใช้เป็นอาหารในการอนุบาลลูกสัตว์น้ำวัยอ่อน

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Abstract

Life histories of commercial water fleas, *Moina macrocopa* and *Moina siamensis*, and natural water flea *Moina micrura* were compared. Specimens were isolated, cultured separately in the laboratory and observed until the animals died. Life history parameters showed that all three species matured to adulthood within 2 days. *M. micrura* had the lowest number of broods and total number of offspring per female, significantly different from *M. siamensis* ($P < 0.05$) but not significantly different from *M. macrocopa* ($P > 0.05$). Number of offspring per brood was not significantly different ($P > 0.05$) between *M. micrura* at 10.9 ± 2.08, n = 10 and *M. siamensis* at 8.7 ± 2.45, n = 10, with greatest number of offspring per brood observed in *M. macrocopa* at 16.5 ± 4.45, n = 10 ($P < 0.05$). *M. siamensis* had a significantly longer lifespan (8.7 ± 1.70 days, n = 10) than *M. micrura* (5.4 ± 1.17 days, n = 10) and *M. macrocopa* (5.3 ± 1.16 days, n = 10) ($P < 0.05$). Largest body length was measured in *M. macrocopa* (500 - 1,500 µm) with the smallest specimen recorded in *M. micrura* (200 - 850 µm) ($P < 0.05$). *M. macrocopa* had higher specific growth rate than other species ($P < 0.05$). Results suggested that *M. micrura*, with smallest body length compared to the other two species, had similar characteristic traits to commercial water fleas as an appropriate feedstuff for new-born aquatic larvae.

Keywords : life history, *Moina micrura*, *Moina macrocopa*, *Moina siamensis*, water flea

Introduction

Moina, a small aquatic microcrustacean, is commonly found around the world because their ephippial eggs could be easily transported overland to new habitats (Petrusek *et al*., 2004). The reproductive cycle of *Moina* has both a sexual and asexual phase (Rottmann *et al*., 2017). Under optimal conditions, population growth is mainly through parthenogenesis, a type of asexual reproduction whereby embryos develop without fertilization, producing only female offspring, resulting in rapid propagation and population growth (Azuraidi *et al*., 2013). Under adverse environmental conditions, sexual reproduction takes place which produces male offspring and resting eggs with an extra shell layer, also known as ephippia (Kleiven *et al*., 1992; Rottmann *et al*., 2017).

M. micrura is a commercially important zooplankton (Azuraidi *et al*., 2013; Vignatti *et al*., 2013) and a widely accepted live food starter suitable for nursing aquatic animal larvae (Azuraidi *et al*., 2013; Gogoi *et al*., 2016) such as freshwater prawn *Macrobrachium rosenbergii* (Alam *et al*., 1993a, b; Das *et al*., 2007), white shrimp *Litopenaeus schmitti* (Martin *et al*., 2006), loaches *Misgurnus anguillicaudatus* (Wang *et al*., 2008), African catfish *Heterobranchus longifilis* (Kerdchuen & Legendre, 1994), *Channa striatus* (War *et al*., 2011), *Clarias gariepinus* (Okunsebor & Ayuma, 2011; Adewumi, 2015) and *Leiopotherapon plumbeus* (Anano & Eguia, 2016).

In Thailand, *M. macrocopa* is the most popular aquacultural food source followed by *M. siamensis* and *M. micrura*. Intensive research and culture exist on *M. macrocopa* and *M. siamensis* but little information is available

regarding *M. micrura*, which most studies have been done in laboratories in temperate zone where is different in culture condition such as food concentration, food type, culture volume, nutrition conditions, and temperature (Benider *et al*., 2002; Sipauba-Tavares & Bachion, 2002; Martinez-Jeronimo *et al*., 2007; Chen *et al*., 2015). Advantages of *M. micrura* are smaller body size than both *M. macrocopa* and *M. siamensis*, and therefore suitable as live food for nursing fish larvae, it can survive in both fresh and brackish water (Saint-Jean & Bonou, 1994; Liu, 2008) and high protein content of 49.31 - 75.29 % (Saengphan *et al*., 2016), which similar to the protein content in *Artemia* of 53.7 - 60.5 % (Peykaran *et al*., 2014). As *Artemia* spp. has to be imported from abroad as feedstuff for nursing marine aquatic animals. Historically, Thailand has relied on importing at least 200 - 600 tons of *Artemia* cysts per year from other countries to feed shrimps, fish and other aquatic animals at a cost of more than 500 million baht (Department of Industry Promotion, 2008).

Thus, here, the biological characteristics of *M. macrocopa* and *M. siamensis* were defined and compared with *M. micrura* to better understand their life histories as useful knowledge for large-scale *M. micrura* culture to satisfy the fish feed requirements of the Thai aquacultural industry.

Methods

Experimental animals

M. micrura and *M. siamensis* were collected from fish ponds using a 60 µm size plankton net in Suphanburi Province, Thailand (14°49′38.7″ N, 99°41′47.7″ E). Specimens were kept in 1 L plastic bottles before sorting in the laboratory to identify and isolate *M. micrura* and *M. siamensis* under stereomicroscope (Nikon model SMZ 745) and light microscope (Carl Zeiss model Primo Star), respectively following the procedures of Goulden (1968) and Pascual *et al*. (2014). *M. macrocopa* was obtained from the Department of Fisheries, Suphanburi College of Agriculture and Technology. The three water flea species were taken to the laboratory at Mahasarakham University for life history studies. All experiments were conducted in 1 L glass beakers containing 500 mL of dechlorinated tap water as stocking culture and fed approximately 4×10^6 cells per mL of *Chlorella vulgaris* every 2 days (Azuraidi *et al*., 2013) in room constant temperatures between 27 - 30 °C and 12:12 (Light : Dark).

Life history experiments

Parthenogenetic females of each species were cultured separately in 100 mL glass beakers containing 40 mL dechlorinated tap water. After maturation (when the first instar is present), new-born *Moina* (< 24 hour old) were cultured separately in 50 mL transparent plastic cups containing 30 mL dechlorinated tap water and fed approximately 4×10^6 cells per mL of *C. vulgaris* every 2 days. Each treatment was 10 replicates. Maturation time and lifespan were observed and recorded until the animals died. Once reproduction started, all neonates from each female were removed and counted under a stereomicroscope every day until the animals died to determine the number of offspring per brood and total number of offspring per female. Body length of females was determined

using a light microscope equipped with a micrometer eyepiece (Vignatti *et al*., 2013) every day throughout the experiment. A minimum number of 10 specimens were measured each day in all species. Specific growth rate was calculated according to the formula:

$$g = [\ln(l_t) - \ln(l_o)] \times 100 / t \quad (1)$$

where l_o and l_t are mean individual length initially and after t days.

Statistical analysis

Data variances were presented as standard deviation (SD) of the mean of 10 replicates and analyzed using one-way analysis of variance. Significant differences among treatments were determined by Duncan's multiple range tests at a 0.05 level of probability using SPSS version 14.0.

Results

Results showed that all three water flea species matured to adulthood within 2 days. Mean number of broods per female was significantly higher ($P < 0.05$) in *M. siamensis* than *M. micrura* and *M. macrocopa*. *M. macrocopa* had the lowest mean number of broods per female but highest ($P < 0.05$) number of offspring per brood at between 6 and 25. Highest ($P < 0.05$) total number of offspring per female for whole lifespan was observed in *M. siamensis* with lowest found in *M. micrura* but not significantly different ($P > 0.05$) from *M. macrocopa* (*Table 1*).

There was a significant difference in lifespan amongst treatments ($P < 0.05$). Longest lifespan was found in *M. siamensis* (8.7 ± 1.70 days) followed by *M. micrura* (5.4 ± 1.17 days) and *M. macrocopa* (5.3 ± 1.16 days) (*Table 1*).

Table 1 Life history parameters (mean ± SD, minimum and maximum values) of *M. micrura*, *M. macrocopa* and *M. siamensis*. Different letters in the same row indicate significant difference among treatments ($P < 0.05$).

Life history characteristics		*M. micrura*	*M. macrocopa*	*M. siamensis*
Maturation time (days)	Mean	2.0 ± 0.00 (n = 10)	2.0 ± 0.00 (n = 10)	2.0 ± 0.00 (n = 10)
Number of broods per female	Mean	3.9 ± 0.32^{b} (n = 10)	3.6 ± 0.52^{b} (n = 10)	7.2 ± 1.75^{a} (n = 10)
	Min.-max.	3 - 4	3 - 4	5 - 10
Number of offspring per brood	Mean	10.9 ± 2.08^{b} (n = 10)	16.5 ± 4.45^{a} (n = 10)	8.7 ± 2.45^{b} (n = 10)
	Min.-max.	5 - 15	6 - 25	5 - 12
Total number of offspring per female for whole life span	Mean	52.3 ± 13.36^{b} (n = 10)	62.1 ± 23.47^{b} (n = 10)	81.6 ± 21.97^{a} (n = 10)
	Min.-max.	26 - 70	24 - 98	48 - 110
Life span (days)	Mean	5.4 ± 1.17^{b} (n = 10)	5.3 ± 1.16^{b} (n = 10)	8.7 ± 1.70^{a} (n = 10)
	Min.-max.	4 - 7	4 - 7	6 - 11

Body length of the three water fleas showed significant differences ($P < 0.05$) between species. Largest body length was measured in *M. macrocopa* (500 - 1,500 µm), followed by *M. siamensis* (500 - 1,290 µm). The smallest specimen was recorded in *M. micrura* (200 - 850 µm) ($P < 0.05$). Body lengths of *M. micrura*, *M. macrocopa* and *M. siamensis* are presented in *Figure 1*. Growth data indicated that *M. macrocopa* grew faster than the other species, especially during day 2.

Growth curves of the three water fleas showed a parabolic shape with two successive phases: the first, from birth to 2 days presented fast increase in size at maximal growth rate, with the second, from the second day to death showing slow growth rate (*Figure 1*).

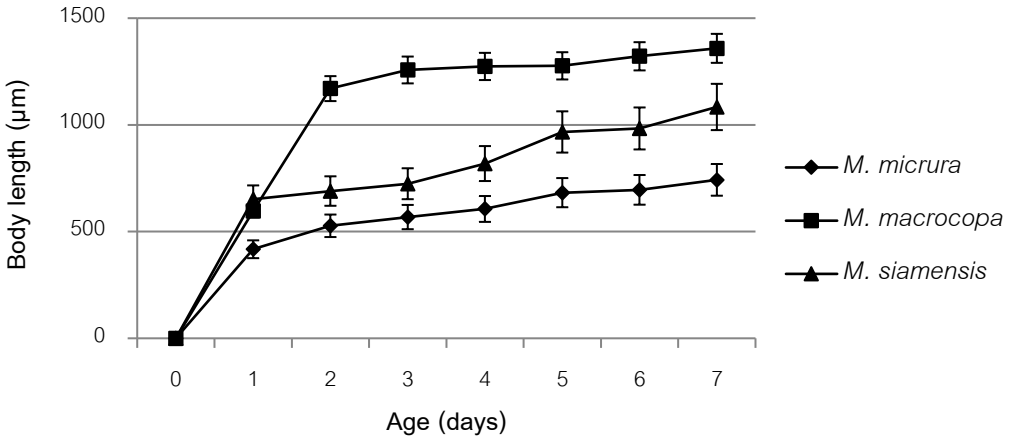

Figure 1 Mean body length (µm) of *M. micrura*, *M. macrocopa* and *M. siamensis* based on laboratory cultures for 7 days.

Specific growth rates of *M. micrura*, *M. macrocopa* and *M. siamensis* were 9.6 ± 1.05% per day (n = 10), 13.7 ± 1.05% per day (n = 10) and 8.5 ± 0.77% per day (n = 10), respectively. Comparative specific growth rate showed that *M. macrocopa* had higher specific growth rate than other species ($P < 0.05$) (*Figure 2*).

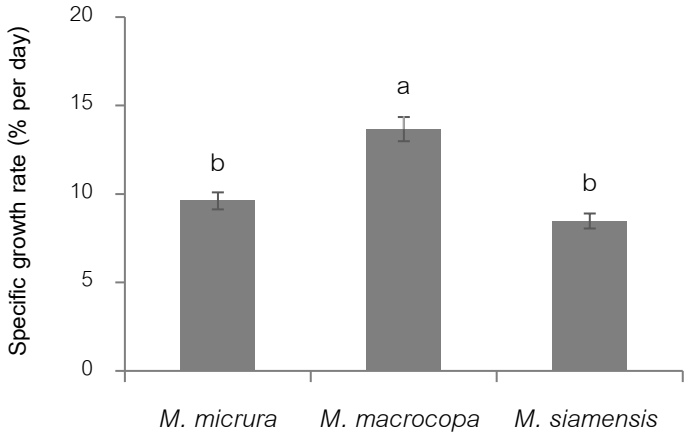

Figure 2 Mean specific growth rate (% per day) of *M. micrura*, *M. macrocopa* and *M. siamensis* based on laboratory cultures for 7 days. Different letters indicate significant difference among treatments ($P < 0.05$).

Discussion

Life history of the three Moinidae species from Thailand shows rapid maturation time (2 days), which is faster than *M. mongolica* from China, which takes 3.4 days at 30 °C (He *et al*., 2001). The age of first reproduction is very important to the population of the ecosystem (Roff, 2001). It may vary for up to 10 days (Dumont & Negrea, 2002) which the environment affects the development period of the reproductive age. When limited natural resources, the slow reproduction occurs to limit the population and the population will increase again when the environment comes back properly (Sarma *et al*., 2005). Chen *et al*. (2015) reported that *M. micrura* grow faster when temperature rise. In addition, they will reproduce faster when in an environment is more predators (Pietrzak *et al*., 2015).

Offspring number of Thai Moinidae were higher than shown in previous studies. Total number of offspring per female of *M. micrura*, *M. macrocopa* and *M. siamensis* were 26 - 70, 24 - 98 and 48 - 110, respectively covering the entire lifespan. Martinez-Jeronimo *et al*. (2007) reported that *M. micrura* produced 23 - 43 offspring per female when fed with 3.6×10^4 cells per mL of *Chlorella* sp. at culture volumes 30 - 120 mL (1 individual per 20 mL), while 11 - 26 offspring per female in *M. macrocopa* fed with 0.5×10^6 - 4.5×10^6 cells per mL of *C. vulgaris* (Nandini & Sarma, 2000). These results indicated that *Moina* from Thailand were suitable for commercial production because they produced a high number of progenies, resulting in rapid population growth. Offspring number of Thai Moinidae in this study is different from previous studies, maybe due to differentiation in culture condition like food density, food type, culture volume and temperature, that may affect number of offspring per female (Nandini & Sarma, 2000; Sipauba-Tavares & Bachion, 2002; Martinez-Jeronimo *et al*., 2007; Chen *et al*., 2015), while increase in food level resulted in increased offspring production (Rose *et al*., 2000).

Lifespan of *M. micrura*, *M. macrocopa* and *M. siamensis* were 4 - 7, 4 - 7 and 6 - 11 days, respectively. *M. macrocopa* in our study had a shorter lifespan than the maximal 17.4 days reported by Benider *et al*. (2002), which found when fed with *Chlorella sorokiniana* at 6.25×10^6 cells per mL, but concurred with Nandini & Sarma (2000) at 5 ± 1 days, fed with 4.5×10^6 cells per mL of *C. vulgaris*. Lifespan of *M. micrura* was close to the study of Sipauba-Tavares & Bachion (2002) at 5 - 6 days, fed 4×10^6 cells per mL of *Ankistrodesmus gracillis*. Differentiation in lifespan between these studies probably due to environmental condition difference such as food concentration, population density, temperature and water quality. Short lifespans result from environmental risks of predation (Pietrzak *et al*., 2015) and increasing temperature (Benider *et al*., 2002). Conversely, longevity was recorded with low food concentration and decrease in temperature (Nandini & Sarma, 2000; Benider *et al*., 2002). Nutrition conditions, population density and crowding influenced both longevity and survival (Benider *et al*., 2002).

Differentiation in life history strategies between species might be due to the diversity of natural habitats (Vanschoenwinkel *et al*., 2010; Dararat *et al*., 2011). In Thailand, *M. macrocopa* was found only in rearing ponds or ponds flooded by water drained from rearing ponds of *M. macrocopa* (Saengphan *et al*., 2013) but in other countries

like Slovakia, the Czech Republic, India and Argentina, *M. macrocopa* are commonly found in permanent water bodies as small village ponds or sewage ponds, temporary pools (such as rain pools or ditches) and fishponds (Petrusek, 2002; Vignatti *et al*., 2013). Generally, rapid maturation and short life span are found in temporary pools (Vanschoenwinkel *et al*., 2010; Dararat *et al*., 2011). Conversely, late reproduction and long lifespan are observed in permanent water bodies or long-lasting pond (Vanschoenwinkel *et al*., 2010; Dararat *et al*., 2011). However, a short lifespan and rapid maturation of *M. micrura* in Thailand is recorded in temporary pools, permanent water and fishponds (Saengphan *et al*., 2013). They are also considered to be a cosmopolitan species with extensive morphological and ecological plasticity, occurring in a wide range of different habitats (Petrusek, 2002). *M. siamensis*, which recorded a long lifespan, inhabits ephemeral pools in contrast to the general trend. Populations in temporary ponds are expected to show rapid growth, early start of reproduction and have shorter lifespans (Vanschoenwinkel *et al*., 2010; Dararat *et al*., 2011).

Growth curves of specimens studied here were similar to Benider *et al*. (2002) who mentioned that growth curves of *Moina* included two phases. The first phase, before the first egg, is characterized by fast growth and the second phase, after sexual maturity of the females, corresponded to a slow growth phase.

Our results showed significant size differences ($P < 0.05$) between the three water flea species. Largest body length was recorded in *M. macrocopa* (500 - 1,550 µm). Our largest species was smaller than *M. macrocopa* from Argentina (600 and 1,800 µm) (Vignatti *et al*., 2013) but larger than *M. macrocopa* from South America (1,190 µm) (Paggi, 1997) and Rio de Janeiro (1,080 µm) (Elmoor-Loureiro *et al*., 2010). The body size of *M. macrocopa* and *M. siamensis* (500 - 1,290 µm) is suitable for nursing *Katsuwonus pelamis*, *Girella punctata*, *Clupea pallasi* and *Cyprinus capio* which have mouth sizes between 570 - 930 µm (Shirota, 1970).

The smallest species from our study was *M. micrura* (200 - 920 µm), smaller than *M. micrura* from Lake Kasumigaura in Japan (450 - 1,200 µm) (Hanazato & Yasuno, 1985) and Australia (1,200 µm) (Goulden, 1968) but larger than *M. micrura* from Lake Kivu in Africa (499 µm) (Descy *et al*., 2012). *M. micrura* is suitable for nursing *Gadus macrocephalus*, *Carassius auratus*, *Konosirus punctata* and *Engraulis japonica* which have small mouths ranging from 250 to 424 µm (Shirota, 1970).

Size of water fleas differed between regions (Vignatti *et al*., 2013). Body size depends on food concentration (Goulden, 1968; Lampert & Trubetskova, 1996; Sipauba-Tavares & Bachion, 2002; Azuraidi *et al*., 2013) diet content (Lampert & Trubetskova, 1996; Sipauba-Tavares & Bachion, 2002), population density (Jana & Pal, 1985) and temperature (Lampert & Trubetskova, 1996; Sipauba-Tavares & Bachion, 2002).

The results from this study showed the number of broods and total number of offspring per female of *M. micrura* was not significantly different from *M. macrocopa* ($P > 0.05$) and number of offspring per brood not significantly different ($P > 0.05$) from *M. siamensis*. In addition, they were short lifespan similar to *M. macrocopa* and same rapid maturation as *M. macrocopa* and *M. siamensis*. Thus, they have similar characteristic traits to

commercial water fleas, which possible for large-scale aquaculture production. Moreover, they can survive in both fresh and brackish water (Saint-Jean & Bonou, 1994; Liu, 2008) and contain 49.31 - 75.29 % protein (Saengphan *et al*., 2016), which close to 53.7 - 60.5 % protein of *Artemia* (Peykaran *et al*., 2014), making them suitable as live food for nursing marine aquatic animals and can replace *Artemia*, that need to be imported from abroad.

Conclusions

Our results indicated that *M. micrura* had similar characteristic traits to commercial water fleas. They have a short lifespan, small size and show rapid maturation, making them suitable for large-scale aquaculture production. Moreover, they recorded the smallest body length and are, therefore, appropriate as new-born aquatic larval feed.

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References

Adewumi, A.A. (2015). Growth performance and survival of *Clarias gariepinus* hatchlings fed different starter diets. *European Journal of Experimental Biology*, *5*(3), 1 - 5.

Alam, M.J., Ang, K.J., & Cheah, S.H. (1993a). Use of *Moina micrura* (Kurz) as an *Artemia* substitute in the production of *Macrobrachium rosenbergii* (de Man) post-larvae. *Aquaculture*, *109*(3), 337 - 349.

Alam, M.J., Ang, K.J., & Cheah, S.H. (1993b). Weaning of *Macrobrachium rosenbergii* (de Man) larvae from *Artemia* to *Moina micrura* (Kurz). *Aquaculture*, *112*(2), 187 - 194.

Anano, J.A.P., & Eguia, M.R.R. (2016). Morphological development and survival of Philippine silver therapon larvae, *Leiopotherapon plumbeus* (Kner, 1864) reared under different feeding schemes. In *Proceedings of the DLSU Research Congress 2016*. (pp. 1 - 7). Manila: De La Salle University.

Azuraidi, O.M., Yusoff, F.M., Shamsudin, M.N., Raha, R.A., Alekseev, V.R., & Matias-Peralta, H.M. (2013). Effect of food density on male appearance and ephippia production in a tropical cladoceran, *Moina micrura* Kurz, 1874. *Aquaculture*, *412 - 413*, 131 - 135.

Benider, A.,Tifnouti, A., & Pourriot, R. (2002). Growth of *Moina macrocopa* (Straus, 1820) (Crustacea, Cladocera): influence of trophic conditions, population density and temperature. *Hydrobiologia*, *468*, 1 - 11.

Chen, R., Xu, N., Zhao, F., Wu, Y., Huang, Y., & Yang, Z. (2015). Temperature-dependent effect of food size on the reproductive performances of the small-sized cladoceran *Moina micrura*. *Biochemical Systematics and Ecology*, *59*, 297 - 301.

Dararat, W., Starkweather, P.L., & Sanoamuang, L. (2011). Life History of Three Fairy Shrimps (Branchiopoda: Anostraca) from Thailand. *Journal of Crustacean Biology*, *31*(4), 623 - 629.

Das, S.K., Tiwari, V.K., Venkateshwarlu, G., Reddy, A.K., Parhi, J. Sharma, P., & Chettri, J.K. (2007). Growth, survival and fatty acid composition of *Macrobrachium rosenbergii* (de Man, 1879) post larvae fed HUFA-enriched *Moina micrura*. *Aquaculture*, *269*(1), 464 - 475.

Department of Industry Promotion. (2008). *Production of Fairy Shrimp for Aquaculture Industry*. Bangkok: Advanced Research Group. (in Thai)

Descy, J.P., Darchambeau, F., & Schmid, M. (2012). *Lake Kivu: Limnology and biogeochemistry of a tropical great lake*. New York: Springer Dordrecht Heidelberg.

Dumont, H., & Negrea, S. (2002). *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World.* Leiden: Backhuys Publishers.

Elmoor–Loureiro, L.M.A., Santangelo, J.M., Lopes, P.M., & Bozelli, R.L. (2010). A new report of *Moina macrocopa* (Straus, 1820) (Cladocera Anomopoda) in South America. *Journal of Biology*, *70*(1), 225 - 266.

Gogoi, B., Safi, V., & Das, D.N. (2016). The Cladoceran as live feed in fish culture: A brief review. *Research Journal of Animal, Veterinary and Fishery Sciences*, *4*(3), 7 - 12.

Goulden, C.E. (1968). The systematics and evolution of the Moinidae. *Transaction American Philosophical Society*, *58*, 1 - 101.

Hanazato, T., & Yasuno, M. (1985). Effect of temperature in the laboratory studies on the growth, egg development and first parturition of five species of Cladocera. *Japanese Journal of Limnology*, *46*(3), 185 - 191.

He, Z.H., Qin, I.G., Wang, Y., Jiang, H., & Wen, Z. (2001). Biology of *Moina mongolica* (Moinidae, Cladocera) and perspective as live food for marine fish larvae: A review. *Hydrobiologia*, *457*, 25 - 37.

Jana, B.B., & Pal, G.P. (1985). Effects of inoculum density on growth, reproductive potential and population size in *Moina micrura* (Kurz). *Limnologica*, *16*, 315 - 324.

Kerdchuen, N., & Legendre, M. (1994). Larval rearing of an African catfish, *Heterobranchus longifilis*, (Teleostei, Clariidae): a comparison between natural and artificial diet. *Aquatic Living Resources*, *7*, 247 - 253.

Kleiven, O.T., Larsson, P., & Hobæk, A. (1992). Sexual reproduction in *Daphnia magna* requires three stimuli. *Oikos*, *65*, 197 - 206.

Lampert, W., & Trubetskova, I. (1996). Juvenile growth rate as a measure of fitness in Daphnia. *Functional Ecology*, *10*, 631 - 635.

Liu, R. (2008). *Checklist of marine biota of China Seas*. Beijing: Science Press.

Martín, L., Arenal, A., Fajardo, J., Pimentel, E., Hidalgo, L., Pacheco, M., García, C., & and Santiesteban, D. (2006). Complete and partial replacement of *Artemia* nauplii by *Moina micrura* during early postlarval culture of white shrimp (*Litopenaeus schmitti*). *Aquaculture Nutrition*, *12*, 89 - 96.

Martinez-Jeronimo, F., Rodriguez-Estrada, J., & Villasenor-Cordova, R. (2007). Effect of culture density and volume on *Moina micrura* (Kurz, 1874) reproduction, and sex ratio in the progeny. *Hydrobiologia*, *594*, 69 - 73.

Nandini, S., & Sarma, S.S.S. (2000). Lifetable demography of four cladoceran species in relation to algal food (*Chlorella vulgaris*) density. *Hydrobiologia*, *435*, 117 - 126.

Okunsebor, S.A., & Ayuma, V. (2011). Growth, survival rate and condition factor of *Heteroclarias* hatchlings fed cultured *Moina micrura*, shell free artemia and combination of both as starter feed. *Livestock Research for Rural Development*, *23*, 3.

Paggi, J.C. (1997). *Moina macrocopa* (Straus 1820) Branquiopoda, Anomopoda in South America : another case of species introduction. *Crustaceana*, *70*(8), 886 - 893.

Pascual, J.A.F., Rizo, E.Z.C., Han, B., Dumont, H.J., & Papa, R.D.S. (2014). Taxonomy and distribution of four Cladoceran families (Branchiopoda: Cladocera: Moinidae, Bosminidae, Chydoridae and Sididae) in Philippine inland waters. *Raffles Bulletin of Zoology*, *62*, 771 - 794.

Petrusek, A. (2002). *Moina* (Crustacea: Anomopoda, Moinidae) in the Czech Republic: A review. *Acta Societas Zoologicae Bohemicae*, *66*, 213 - 220.

Petrusek, A., Cerny, M., & Audenaert, E. (2004). Large intercontinental differentiation of *Moina micrura* (Crustacea: Anomopoda): one less cosmopolitan cladoceran. *Hydrobiologia*, *526*, 73 - 81.

Peykaran, M.N., Vahabzadeh, H., Seidgar, M., Hafezieh, M., & Pourali, H.R. (2014). Proximate composition and fatty acids profiles of *Artemia* cysts, and nauplii from different geographical regions of Iran. *Iranian Journal of Fisheries Sciences, 13*(3), 761 - 775.

Pietrzak, B., Dawidowicz, P., Predki, P., & Danko, M.J. (2015). How perceived predation risk shapes patterns of aging in water fleas. *Experimental Gerontology*, *69*, 1 - 8.

Roff, D.A. (2001). Age and size at maturity. In C.W. Fox, D.A. Roff, & D.J. Fairbairn. (Eds.). *Evolutionary Ecology. Concepts and Case Studies*. (pp. 99 - 127). New York: Oxford University Press.

Rose, R.M., Warne, M.St.J., & Lim, R.P. (2000). Life history responses of the cladoceran *Ceriodaphnia* cf. *dubia* to variation in food concentration. *Hydrobiologia*, *427*, 59 - 64.

Rottmann, R.W., Graves, J.S., Watson, C., & Yanong, R.P.E. (2017). *Culture techniques of Moina: The ideal Daphnia for feeding freshwater fish fry*. Florida: Fisheries and Aquatic Sciences Department, UF/IFAS Extension, University of Florida.

Saengphan, N., Suksomnit, A., & Chaloiesak, P. (2016). *Modern water flea ephippia culture: Culture for 4 water flea ephippia production*. Pathum Thani: National Science and Technology Development Agency. (in Thai)

Saengphan, N., Teeramaethee, J., & Chaloiesak, P. (2013). *Species diversity and biology of the Cladocera in family Moinidae in Thailand*. Bangkok: Office of the Vocational Education Commission. (in Thai)

Saint-Jean, L., & Bonou, C.A. (1994). Growth, production and demography of *Moina micrura* in brackish tropical fishponds (Layo, Ivory Coast). *Hydrobiologia*, *272*, 125 - 146.

Sarma, S.S.S., Nandini, S., & Gulati, R.D. (2005). Life history strategies of cladocerans: comparisons of tropical and temperate taxa. *Hydrobiologia*, *542*, 315 - 333.

Shirota, A. (1970). Studies on the mouth size of fish larvae. *Bulletin of Japanese Society for the Science of Fish*, *36*, 353 - 368.

Sipauba-Tavares, L.H., & Bachion, M.A. (2002). Population growth and development of two species of Cladocera, *Moina micrura* and *Diaphanosoma birgei*, in laboratory. *Brazilian Journal of Biology*, *62*(4), 701 - 711.

Vanschoenwinkel, B., Seaman, M., & Brendonck, L. (2010). Hatching phenology, life history and egg bank size of fairy shrimp *Branchipodopsis* spp. (Branchiopoda, Crustacea) in relation to the ephemerality of their rock pool habitat. *Aquatic Ecology*, *44*, 771 - 780.

Vignatti, A.M., Cabrera, G.C., & Echaniz, S.A. (2013). Distribution and biological aspects of the introduced species *Moina macrocopa* (Straus, 1820) (Crustacea, Cladocera) in the semi–arid central region of Argentina. *Biota Neotropica*, *13*(3), 86 - 92.

Wang, Y., Hu, M., Cao, L., Yang, Y., & Wang, W. (2008). Effects of daphnia (*Moina micrura*) plus chlorella (*Chlorella pyrenoidosa*) or microparticle diets on growth and survival of larval loach (*Misgurnus anguillicaudatus*). *Aquaculture International*, *16*(4), 361 - 368.

War, M., Altaff, K., & Haniffa, M.A. (2011). Growth and survival of larval snakehead *Channa striatus* (Bloch, 1793) fed different live feed organisms. *Turkish Journal of Fisheries and Aquatic Sciences*, *11*, 523 - 528.