論文

東海大学紀要海洋学部「海―自然と文化」第14巻第2号　1-6頁（2016）
Journal of The School of Marine Science and Technology, Tokai University, Vol.14, No.2, pp.1-6, 2016

タツノオトシゴ属サンゴタツの親の体サイズが子に与える影響

大谷明範＊1・大塚　悠＊2・鈴木宏易＊3・赤川　泉＊4

The effects of parent body size on young of the Japanese seahorse *Hippocampus mohnikei*

Akinori OTANI, Yu OTSUKA, Hiroyasu SUZUKI, and Izumi AKAGAWA

Abstract

The effects of parent size on the number and size of young, and the relationships between reproductive intervals and water temperature, and between number and size of young, were investigated in the pair rearing Japanese seahorse *Hippocampus mohnikei*. Significant sex-related size differences and sex ratio bias were not found in collected fish, reproduction occurring in any size combination with a 5 mm difference in standard length (mate choice not permitted). Brood young numbers (18-128) were significantly correlated to female SL, but not to male SL or water temperature. Young SL was not significantly related to male SL but tended to be related to female SL. Reproductive intervals (11-20 days) were negatively correlated to water temperature. The relationship between SL and number of young was not significant even among broods of the same pair. Consequently, not only do female *H. mohnikei* not manipulate batch egg number according to male body size, but also males do not appear to raise larger young from lower initial egg batch sizes.

Introduction

Syngnathid males, including those of *Hippocampus*, are known to guard eggs in a brood pouch or on the abdominal region until birth, an act exclusive to males. In some species, males also provide oxygen and nutrition, in addition to aiding osmoregulation for eggs in the brood pouch (Berglund *et al*. 1986, Carcupino *et al*. 2002, Ripley and Foran 2006, 2009; Stolting and Wilson 2007), the male metabolic rate increasing significantly during this time (Berglund et al. 1986). In *H. zosterae*, male metabolic rates increase from 10 to 52% over pregravid levels (Masonjones 2001). The question remains, however, which of syngnathid incubating males or egg-producing females has the greater reproductive cost and exercises the greater mate choice? Males usually cannot acquire more eggs than their capacity to accommodate and females normally would not spawn with males having a reduced brooding capacity compared to female egg production capacity, or may control the egg number according to male capacity if only smaller males are available. However, small *H. abdominalis* males have been shown to carry exceptionally large broods (Mattel and Wilson, 2009), which raises a further question: is the growth of young impaired or not when larger numbers of eggs are carried by small males?

H. mohnikei is a small seahorse inhabiting seagrass beds in Japan. Although difficult to observe in the field, its reproductive behavior can be readily observed in aquaria. Yoshino *et al*. (2009) noted that courtship of aquarium-held

2016年6月24日受付　2017年2月10日受理
＊1　マリンピア松島水族館（現，仙台うみの杜水族館）（Marinepia Matsushima Aquarium（Present: Sendai Umino-Mori Aquarium））
＊2　東海大学海洋学部（現，株式会社ビーボックスアクアリウム）（Graduate School of Marine Science and Technology, Tokai University（Present: B-Box aquarium））
＊3　東海大学海洋科学博物館（Marine Science Museum, Social Educator Center, Tokai University）
＊4　東海大学海洋学部海洋生物学科（Department of Marine Biology, School of Marine Science and Technology, Tokai University）

H. mohnikei was initiated by either sex. Although males courted females actively, regardless of the body size of the latter, females did not court males smaller than themselves. They also suggested that female mate choice was more definitive than that of males because the probability of spawning was greater when the females actively courted males, rather than the converse.

Masonjones (1997) demonstrated a positive correlation between male size and brood size in *H. zosterae* males collected from the field, while Vincent and Giles (2003) showed that female size was the key determinant of the number of young released by male *H. whitei*. Essentially, if the number of young is positively correlated with female body size in various size combinations of male and female pair rearing, female control of egg number based on male body size or male condition is less likely to take place. On the other hand, if the number of young is related to male body size, either the female might spawn only the number of eggs appropriate to the male capacity, or the male might incubate only the number of eggs according to his capacity among the eggs received (Vincent 1990; Ahnesjö 1992a, 1992b).

In the present study, pair-rearing of different size combinations of male and female pairs of *H. mohnikei*, was carried out to investigate the relationship between parent size and the numbers or size of offspring, and to explore the possibility of female control of egg number or male control of young number or growth.

Materials and methods

Fish were collected from a boat utilizing a long hand net or by a traditional fishery technique (Boda-ryo - a trap fishery for shrimps and small fishes utilizing a bunch of tree branches or bundle of nets sunk in shallow, calm inlet water), monthly from April to July, 2007 in Matsushima Bay, Miyagi Prefecture, Japan. A total of 64 adult specimens (30 females and 34 males) were collected, there being no significant sexual ratio bias. Standard lengths were measured in the laboratory to the nearest 1 mm, following Lourie (1999). No significant size difference was apparent between females (mean ± SD = 61.4 ± 6.5 mmSL) and males (62.4 ± 9.1 mmSL) (*t*-test, $p > 0.05$), pairs being established for the rearing experiments on the basis of female and male SL.

Pair-rearing experiments, involving various size combinations of female and male fish, were conducted from July to November 2007, reproductive frequencies, birth dates and intervals between births from the male, and offspring numbers and body sizes being recorded after fixation in 5% seawater formalin on the birth day. The experiment was performed in the laboratory at Marinepia Matsushima Aquarium, Miyagi Prefecture, Japan, using nine female (45-65mmSL) and male (45-78mmSL) pairs, housed in nine glass aquaria (45 × 30 × 30 cm in height) with airlifted filtered water systems. Water temperatures were allowed to fluctuate under natural conditions, varying from 18.7 to 28.1 ℃ during the experiment. Water temperature was recorded at 11 am daily. Seawater was controlled at 30 ± 1 psu and the laboratory maintained in a 12L12D light/dark cycle. Equal weights of Artemia larvae were supplied twice daily to each aquarium.

Table 1 Female and male *Hippocampus mohnikei* standard length (SL) and reproduction frequency in each pair of three size classes.

	SL (mm)		Reproduction (n = 13)
	Female	Male	
Small			
F = M	45	45	0
F > M	50	45	1
F < M	45	50	1
Medium			
F = M	55	55	0
F > M	60	55	2
F < M	55	60	2
Large			
F = M	65	65	5
F > M	70	65	1
F < M	65	78	1

Small, medium and large size class pairs of seahorse were established (Table 1), with three replicates of each size class: same size female and male (F = M), female SL 5 mm larger than male (F > M) and male SL 5 mm larger than female (F < M) (maximum male size 78 mm SL.)

Pearson's correlation coefficient r was calculated between the number of young and female or male SL, mean temperature and male birth interval, mean temperature and number of young, and the relationship between the number and size of young. $p < 0.05$ was defined as significant and $p < 0.1$ as showing tendency.

Results

Reproduction occurred 13 times, involving seven of the nine pairs (Table 1), the exceptions being the small and medium size pairs of equal-sized fish (Ssize, F = M ; Msize, F = M). The most frequent occurrence (5 times) was in the

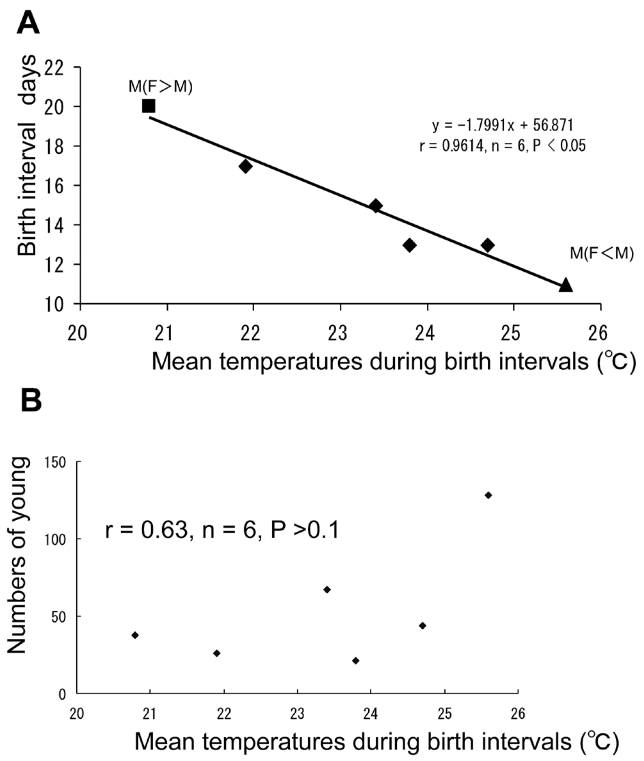

Fig. 1 Relationship between mean temperatures during birth intervals and birth interval length (A), and brood size of *Hippocampus mohnikei* (B). Different symbols indicate different pairs.

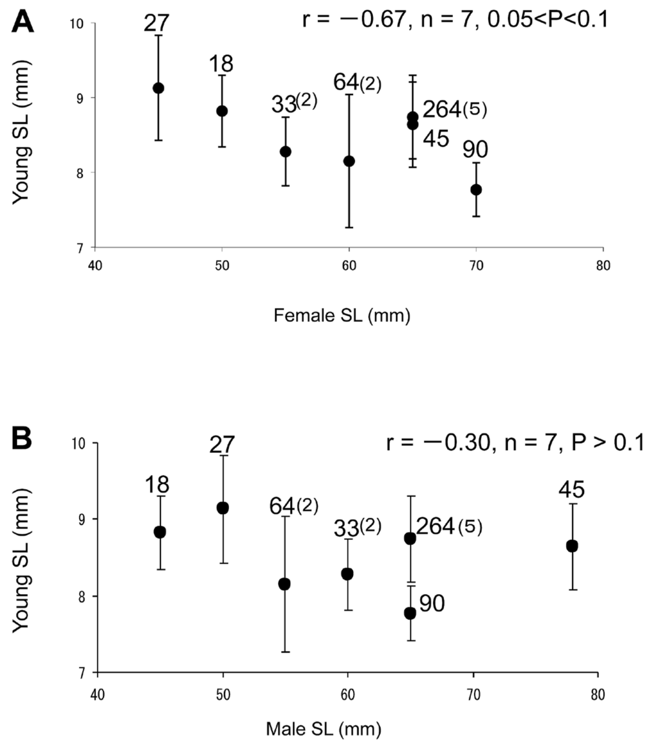

Fig. 2 Relationship between standard lengths (SL) of young and female (A), and male (B) *Hippocampus mohnikei*. Numerals on bars indicate number of total young of the female or the male and numerals in parentheses indicate the brood number and without parentheses indicate only one brood.

largest same sized pair (Lsize, F = M), although reproduction took place in all of the female-male size relationship groups, F = M (one of three pairs, five times in total), F＞M (three of three pairs, four times in total) and F＜M (three of three pairs, four times in total).

Male birth intervals varied between 11-20 days (Fig. 1), being about 16 days in a mean water temperature of ca. 23 ℃. The mean water temperature during male birth intervals had a significant negative correlation with birth interval days ($y = -1.799\times + 56.87$, $r = 0.96$, $n = 6$, $p < 0.01$) (Fig. 1-A), but showed no correlation between male birth intervals and number of young ($n = 6$, $p > 0.05$) (Fig 1-B).

The mean SL of all young on the birth day was 8.9 ± 0.6 mmSL (n = 13 broods), the largest mean SL of the 13 broods being 9.5 mmSL (n = 26 young; parent, Lsize, F = M) and the smallest, 7.8 mmSL (n = 90 young; parent, Lsize, F＞M). The mean SL of young was significantly related to neither female nor male SL, but as female SL increased, the SL of young showed a tendency to decrease ($r = -0.67$, $n = 7$, $p < 0.1$) (Fig. 2).

Numbers of young per brood varied between 18 (Ssize, F＞M) and 128 (Lsize, F = M, one of five broods), the mean number of young being significantly correlated with female SL ($y = 2.147\times - 82.37$, $r = 0.82$, $n = 7$, $p < 0.05$) (Fig. 3-A), but not with male SL ($r = 0.58$, $n = 7$, $p > 0.05$) (Fig. 3-B).

The mean size of young per brood bore no correlation with brood size in any pair, even for that (Lsize, F = M) which reproduced five times (Fig. 4). In fact, the smallest young of this pair were produced in the second lowest brood size.

Discussion

Sexual size dimorphism has not been observed in *Hippocampus mohnikei* from Matsushima Bay at any time (unpublished data), suggesting similar evolutionary pressure for body size in both males and females. In the present study, females reproduced four times with larger males, four times with smaller males, and five times with a similarly sized male (same pair- no alternative mate choice). The probability of reproductive success did not differ significantly between larger female pairs and larger male pairs, in cases of pair size differences of ca. 5 mm SL and no mate choice, although Yoshino *et al.* (2009) reported that male larger pairs reproduced more than female larger pairs

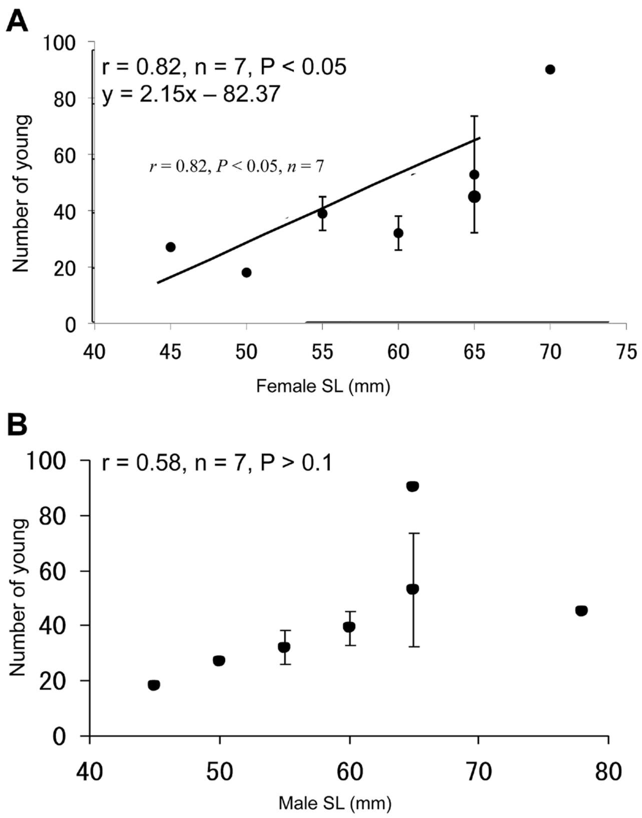

Fig. 3 Relationship between number of young and SL of females (A) and males (B). Numbers of young or means with SE are shown for individuals.

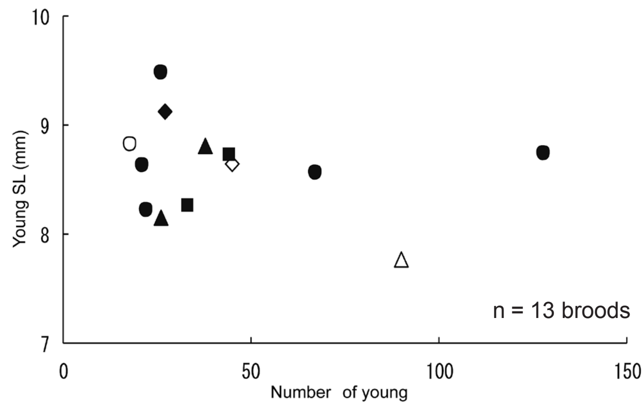

Fig. 4 Number and SL of young for seven pairs of *Hippocampus mohnikei*. Different symbols indicate different pairs.

when mate choice was permitted in this species.

Higher water temperature shortens male birth intervals in *Syngnathus typhle* and other Syngnathids (Vincent *et al.* 1994) as well as other fishes like damselfishes (e.g. Tanaka 1998) , although the number of young in one brood does not increase with temperature (Fig. 1-A, B). Actually subsequent matings occur earlier and successful reproduction more frequently in higher water temperatures.

The body size of young *Hippocampus mohnikei* was not significantly related to either male or female body size (Fig. 2), although a negative tendency ($p<0.1$) was found regarding female SL, larger females having smaller young. On the other hand, the number of young being significantly related to female SL (Fig. 3) is consistent with the findings of several other syngnathid studies (Berglund *et al.* 1986, 1988, 1989; Vincent 1990, Ahnesjo 1996; Teixeira and Musick 2001, Vincent and Giles 2003). However, in *H. abdominalis* the number of young from pregnant males collected in the field (without information on maternal fish) had a significant positive relationship with male SL (Woods 2005). Furthermore, Woods (2005) showed that the SL of young was related to neither male SL nor young number. Also considering that species, a subsequent rearing experiment demonstrated that the egg size, egg number and young size are positively related to female body size (Mattle and Wilson 2009). If *H. mohnikei* undergoes size assortative mating in the field, the number of young may be indirectly related to paternal SL due to competition and/or mate choice. As survivorship of larger young is generally expected to be better, the reason for the negative relationship found here between female SL and young SL in *H. mohnikei* requires further clarification. The larger females might take precedence of the number before the size of young because smaller young here can have more chance to survive. The investigation of embryo survivorship in *Syngnathus typhle* (Mobley *et al.* 2011) demonstrated that the eggs of larger females in larger numbers are more viable than those of smaller females in larger numbers, whereas the eggs of smaller females in smaller numbers are more viable than those of larger females in smaller numbers, a more complex situation than previously thought.

The present study found no evidence of females actively controlling egg number according to coexisted male body size. Similarly, there was no indication that males reduce the number of eggs according to their own body size. Hatchlings were not always larger in smaller broods, even from the same parents (Fig. 4), although in *S. typhle*, Ahnesjo (1992a, b) found a negative correlation between the body weight and number of young, with fewer hatchlings resulting in superior body weights. Furthermore, Dzyuba *et al.* (2006) suggested that in *H. kuda*, when relatively few embryos are present, they may attach to functionally advantageous sites. However, the present findings suggest the possibility that not only male body size and brood number but also other factors, including male condition, may affect hatchling size.

Acknowledgements

We greatly appreciate the supports of Mr. T. Kawamura and Mr. K. Sawaki (Marinepia Matsushima Aquarium), and Mr. Tsunoda (Master of Boda-ryo in Matsushima) for their help in sampling and encouragement for our research. Our sincere thanks go to Dr. G. Hardy (Ngunguru, New Zealand) for his comments on the manuscript and help with English.

References

Ahnesjö, I. (1992a): Consequences of male brood care: weight and number of newborn in a sex-role reversed pipefish. Functional Ecol. **6**, 274-281.

Ahnesjö, I. (1992b): Fewer newborn result in superior juveniles in the paternally brooding pipefish *Syngnathus typhle* L. J. Fish Biol. **41**, 53-63.

Ahnesjö, I. (1996): Apparent resource competition among embryos in the brood puch of a male pipefish. Behav. Ecol. Sciobiol. **38**, 167-172.

Berglund, A., G. Rosenqvist and I. Svensson (1986): Reversed sex roles and parental energy investment in zygotes of two pipefish (Syngnathidae). Mar. Ecol. Prog. Ser. **29**, 209-215.

Berglund, A., G. Rosenquvist and I. Svensson (1988): Multiple matings and paternal brood care in the pipefish, *Syngnathus typhle*. Oikos **51**, 184-188.

Berglund, A., G. Rosenqvist and I. Svensson (1989): Reproductive success of females limited by males in two pipefish species. Am. Nat. **133**, 506-516.

Carcupino, M., A. Baldacci, M. Mazzini and P. Franzoi (2002): Functional significance of the male brood pouch in the reproductive strategies of pipefishes and seahorses: a morphological and ultrastructural comparative study on three anatomically different pouches. J. Fish Biol. **61**, 1465-1480.

Dzyuba, B., K.J.W. Van Look, A. Cliffe, H.J. Koldewey and W.V. Holt (2006): Effect opf parental age and associated size on fecundity, growth and survival in the yellow seahorse *Hippocampus kuda*. J. Experim. Biol. **209**, 3055-3061.

Lourie, S.A. (1999): Seahorse measurement protocol. 158-161. *In*, Lourie, S.A., A.C.J .Vincent and H.J. Hall eds., Seahorses: an identification guide to the world's species and their conservation. Project Seahorse, London.

Masonjones, H.D. (1997): Sexual selection in the dwarf seahorse, *Hippocampus zosterae* (Syngnathidae): an investigation into the mechanisms determining the degree of male vs. female intrasexual competition and intersexual choice. PhD Thesis. Tufts University, Massachusetts.

Masonjones, H.D. (2001): The effect of social context and reproductive status on the metabolic rates of dwarf seahorses (*Hippocampus zosterae*). Comparative Biochemistry and physiology – Part A: Molecular and Integrative physiology, **129**, 541-555.

Mattel, B., A.B. Wilson (2009): Body size preferences in the pot-bellied seahorse *Hippocampus abdominalis*: choosy males and indiscriminate females. Behav. Ecol. Sociobiol. **63**, 1403-1410.

Mobley, K.B., C. Kvarnemo, I .Ahnesjo, C. Partridge, A. Berglund and A.G. Jones (2011): The effect of maternal body size on embryo survivorship in the broods of pregnant male pipefish. Behav. Ecol. Sociobiol. **65**, 1169-1177.

Ripley, J.L. and C.M. Foran (2006): Differential parental nutrient allocation in two congeneric pipefish species (Syngnathidae: *Syngnathus spp*.). J. Exp. Biol. **209**, 1112-1121.

Ripley, J.L. and C.M. Foran (2009): Direct evidence for embryonic uptake of paternally-derived nutrients in two pipefishes (Syngnathidae: Syngnathus spp.). J. Comp. Physiol. **B179**, 325-333.

Stolting, K.N. and A.B. Wilson (2007): Male pregnancy in seahorses and pipefish: beyond the mammalian model. BioEssays **29**, 884-896.

Tanaka, Y. (1998): Reproductive behavior and morphology of eggs and larvae of damselfish. J. School Mar. Sci. & Tech. Tokai Univ. **45**, 167-179. (in Japanese and with English abstract and figure captions).

Teixeira, R.L. and A. Musick (2001): Reproduction and food habits of the lined seahorse, *Hippocampus erectus* (Teleostei: Syngnathidae) of Chesapeake Bay, Virginia. Brazilian J. Biol. **61**, 79-90.

Vincent, A.C.J. (1990): Reproductive ecology of seahorses. PhD Thesis, Cambridge University, U.K.

Vincent, A.C.J., I. Ahnesjo and A. Berglund (1994): Operational sex ratio and behavioural sex differences in a pipefish population. Behav. Socio. Biol. **34**(6), 435-442.

Vincent, A.C.J. and B.G.Giles (2003): Correlates of reproductive success in a wild population of *Hippocampus whitei*. J. Fish Biol. **63**(2), 344-355.

Vincent, A.C.J. and L.M. Sadler (1995): Faithful pair bonds in wild seahorses, *Hippocampus whitei*. Anim. Behav. **50**, 1557-1569.

Woods, C.M.C. (2005): Reproductive output in the male seahorses, *Hippocampus abdominalis*, from Wellington harbour, New Zealand: Implications for conservation. New Zealand J. Mar. Fresh. R. **39**, 881-888.

Yoshino, M., K. Araki, H. Suzuki and I. Akagawa (2009): Courtship behavior, mate choice and potential mating system variations in *Hippocamps mohnikei*. Bull. Inst. Res. & Develop. Tokai Univ. **30**, 21-29 (in Japanese and with English abstract and figure captions).

大谷明範・大塚　悠・鈴木宏易・赤川　泉

要　旨

ペア飼育下のタツノオトシゴ属サンゴタツにおいて，親の体サイズが子の数と体サイズに与える影響，水温と繁殖間隔の関係，および子の数とその体サイズの関係を調査した．採集したサンゴタツには，性的なサイズの相違や性比の偏りは見られなかった．配偶者選択のできないペア飼育下では，雌雄のどちらが標準体長で5 mm 大きくても，同じ体長でも繁殖が行われた．繁殖間隔（11-20日）は水温と負の相関を呈したが，子の数とは相関しなかった．子の体長はオスの体長には相関しなかったが，メスの体長には相関する傾向がみられた（P＜0.1）．一回の産仔数（18-128）はメスの体長に有意に相関したが，オスの体長や水温には相関しなかった．子の数と子の体サイズの関係は，同じペアからの場合ですら有意ではなかった．以上の結果からすると，メスのサンゴタツは配偶相手のオスの体サイズによって産卵数を調整しているわけではなく，いっぽうオスは受け取った卵数が少ないほど大きく育てて産出するということもなさそうであった．