

Feeding of scleractinian coral, *Galaxea fascicularis*, on *Artemia salina* nauplii in captivity

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Received: 16 December 2007 / Accepted: 6 August 2008 / Published online: 2 September 2008
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Abstract Satisfying nutrient requirement of corals is still a major constraint for maintaining corals in marine aquariums. Corals are polytrophic in nature. Heterotrophic feeding on zooplankton is one of the corals' strategies to overcome nutrient deficiency. *Artemia salina* nauplii are commonly used as biocarriers for many fish larvae in aquaculture and can also serve as a biocarrier for coral in aquariums, provided coral acceptability, optimal feeding rate, and digestibility of the nauplii are well understood. Feeding rate and digestibility of coral fed on *A. salina* nauplii at 100, 2,000, 4,000, 6,000, and 10,000 ind. l^{-1} under light and dark conditions was assessed in this study. The maximum feeding rates of *Galaxea fascicularis* under light and dark conditions was 113.6 ind. $polyp^{-1} h^{-1}$ and 76.9 ind. $polyp^{-1} h^{-1}$, respectively. The daily feeding rates of *G. fascicularis* varies and depends on nauplii density. Light plays an important role in coral feeding. Nevertheless, the quantity of *A. salina* nauplii consumed by the coral under light and dark conditions was not significantly different ($P > 0.05$). *A. salina* nauplii are well accepted by *G. fascicularis*. Complete nauplii digestion was observed after 180 min. Digestibility of *A. salina* nauplii by *G. fascicularis* was positively correlated with digestion time.

Keywords *Artemia salina* · Digestibility · Feeding rate · *Galaxea fascicularis* · Scleractinian coral

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Abbreviations

- ind. l^{-1} Individual of *Artemia salina* nauplii per liter
ind. polyp $^{-1}$ h $^{-1}$ Individual of *Artemia salina* nauplii per polyp per hour

Introduction

Marine ornamental industry is a multimillion dollar business (US \$200–330 million year $^{-1}$) (Wabnitz et al. 2003). Live coral is one of the most favorite marine organisms in the industry (Green 2003). Based on importers' data (1997–2001) from the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 99.7% of the total global trade in live corals is harvested from the wild, and only 0.3% is captive bred. Mortality rate of corals in the marine aquarium is high. Wabnitz et al. (2003) reported high mortality of *Plerogyra* spp. (54% mortality), *Catalaphyllia* spp. (60% mortality), *Heliofungia* spp. (100% mortality), *Goniopora* spp. (95% mortality), and *Tubastrea* spp. (100% mortality) in the aquarium. Harvesting coral from the wild is not a sustainable business because when corals are difficult to maintain in the aquarium, they must be replaced regularly (Arvedlund et al. 2003). Strong market demands imply a heavy harvesting pressure on coral reefs, and coral aquaculture is increasingly mentioned as a priority solution to reduce this pressure (Parks et al. 2003). Attempts to culture live coral in captivity have been carried out over the decades. However, reports of successful ex-situ cultivation of coral are sparse (Arvedlund et al. 2003). Satisfying the nutrient requirement of corals remains one of the major tasks in maintaining and reproducing the organisms under captivity.

Corals are notable for their symbiosis with the unicellular dinoflagellate algae zooxanthellae (Davies 1984). Corals protect zooxanthellae, which are enclosed in their endodermal cells. In return, zooxanthellae supply organic carbon to the host. Therefore, lighting is an essential component in marine aquariums. Corals are polytrophic in nature (Goreau et al. 1971). Heterotrophic feeding is essential for overcoming nutrient deficiency. Corals exhibit several modes of feeding and energy acquirement from multiple sources. Corals feed on plankton (Lewis 1992; Ferrier-Pages et al. 2003; Picciano and Ferrier-Pages 2007), bacteria (Ferrier-Pages et al. 1998), and particulate organic matter (Lasker 1981; Anthony 1999; Anthony and Fabricius 2000; Mills et al. 2004), and they even absorb dissolved nutrients from the water (Titlyanov et al. 2000; Ferrier 1991; Ferrier-Pages et al. 2003). Heterotrophic feeding of corals is one of the strategies to overcome nutrient deficiency. Heterotrophic feeding enhances coral growth, calcification rate, and photosynthesis rate and even affects the symbiotic zooxanthellae (Miller 1995; Titlyanov et al. 2001; Grottooli 2002; Ferrier-Pages et al. 2000, 2003; Houllbrequet et al. 2003, 2004; Davy et al. 2006).

Corals in captivity should be fed with zooplankton to complete their nutrient requirements. However, harvesting zooplankton from the sea to feed corals in marine aquariums is neither sustainable nor economically viable. Brine shrimp, *Artemia salina* nauplii, may be the right candidate for feeding corals in captivity. *A. salina* is widely used as life food for culturing fish larvae in aquaculture (Lavens and Sorgeloos 2000). Dormant cysts of artemia can be stored for long periods, and it is commercially available. *A. salina* nauplii can also be enriched with different nutrients to meet the specific nutrient requirements of many organisms (Dhert et al. 1990; Olsen et al. 1999; Hanaee et al. 2005; Monroig et al. 2006; Olivotto et al. 2006). *A. salina* nauplii can be used as a biocarrier and life food for corals in captivity provided that acceptability, optimal feeding rate, and digestibility are well understood.

Materials and methods

Coral specimens and *A. salina* nauplii

About 30 colonies of the scleractinian zooxanthellate coral *Galaxea fascicularis* were collected from Pulau Bidong, Malaysia. The corals were maintained in a 150-l aquarium supplied with running seawater and illuminated with white fluorescent light at 870.0 ± 82.8 lux on a 12-h light/12-h dark cycle. The experiment was conducted under a constant environment at parameters 28°C, salinity 30 ppt, and pH 8, with dissolved oxygen maintained at 5–7 mg l⁻¹. Coral colonies were then broken into similar-sized coral pieces using a hammer and screw driver. Each coral piece had about 30 polyps. The pieces were allowed to acclimatization for 5 days before the experiment. Pieces from the coral colonies were mixed and pooled and randomly selected from the pool for the experiments. *A. salina* nauplii (Royal Artemia, 99% hatching) were prepared 24 h prior to the experiments. Preparation of *A. salina* nauplii was based on the procedure described by Dhont and Stappen (2003).

Determination of optimal feeding rate

Feeding experiments were conducted based on the method described by Leverage (1976) and Dai and Lin (1993). The coral pieces were fed different densities of *A. salina* nauplii at 100, 2,000, 4,000, 6,000, and 10,000 ind. l⁻¹. Three pieces used in each treatment were randomly selected from the pool. Each piece was transferred from the aquarium into a 2-l clear glass beaker 1 h before the experiment. The experiment was conducted in three replicates and started when most of the polyps were fully extended. The feeding experiments were conducted in the morning and repeated every 24 h up to 6 days. *A. salina* nauplii at the mentioned densities were added to the beaker, and the volume of seawater in the beaker was made up to 1 l to yield the desired nauplii density in each treatment. The coral colonies were allowed to feed for 1 h before they were carefully transferred back into the aquarium. Densities of the remaining *A. salina* nauplii were determined by counting 10-ml samples (five replicates) from each beaker. This gives the average number of nauplii in each beaker. The total number of *A. salina* nauplii consumed by the corals was determined by the difference of initial and final density of the nauplii. *G. fascicularis* feeding rate was determined as the number of *A. salina* nauplii ingested per coral polyp per hour:

$$\text{Feeding rate} = \frac{\text{Density}_i - \text{Density}_r}{\text{Number of polyps} \times \text{Time}}$$

where, density_i = initial number of *A. salina* nauplii, density_r = remaining *A. salina* nauplii after 1 h.

Effects of light on *G. fascicularis* feeding

To determine the effect of light provision on *G. fascicularis* feeding, the feeding rate of *G. fascicularis* was determined under light and dark conditions. Under light conditions, coral colonies were illuminated with white fluorescent light at 870 ± 82.8 lux, and under dark conditions, the colonies were fed in the dark. *G. fascicularis* feeding rates with and without light were determined, as described previously.

Digestion rate of *A. salina* nauplii by *G. fascicularis*

To determine the digestion rate of *A. salina* nauplii by *G. fascicularis*, coral specimens were fed with *A. salina* nauplii at 10,000 ind. l⁻¹. After feeding *A. salina* nauplii to the coral, the gastrovascular cavity contents of five polyps were withdrawn using a 1-ml syringe (0.36 mm Ø; Micro-Fine[®]) at intervals of 10, 30, 60, 90, 120, 180, and 420 min. The gastrovascular cavity contents were then examined using a compound microscope (Motic) under 40× magnification. The experiment was conducted in three replicates. Gastrovascular content of starved coral were used as controls. A few drops of 10% formalin were added to the gastrovascular cavity contents for preservation. A scale from one to five [0–20% digested scale (1), 20–40% digested scale (2), 40–60% digested scale (3), 60–80% digested scale (4), and 80–100% digested scale (5)] was assigned to indicate digestibility of the specimen.

Statistical analysis

G. fascicularis feeding rate at different densities of *A. salina* nauplii were evaluated using nonlinear least squares regression (Michaelis–Menten models), as described by Anthony (1999). The curvilinear Michaelis–Menten model is:

$$F_D = \frac{(F_{\max} D)}{(K + D)}$$

where, F_D is the feeding rate as a function of nauplii density (D), F_{\max} is the maximum feeding rate, and K is the nauplii density at which half-saturation occurs. The effect of feeding condition (with and without light provision) and rate of *G. fascicularis* was tested using a split plot design analysis of variance (ANOVA). Spearman's rank order correlation was conducted to test the correlation between digestibility of *A. salina* nauplii and coral digestion time. All null hypotheses were rejected at $P \leq 0.05$.

Results

G. fascicularis feeding rate

G. fascicularis feeding rate increased with increasing nauplii densities (Fig. 1). *G. fascicularis* feeding with and without light provision was significantly correlated with the curvilinear model (P values <0.0001 and 0.0015, respectively, Table 1). With light provision, the maximum feeding rate was 113.6 ind. polyp⁻¹ h⁻¹, whereas the maximum feeding rate under dark conditions was 76.9 ind. polyp⁻¹ h⁻¹ (Table 2). When *G. fascicularis* was fed at high nauplii density, it achieved its feeding saturation in a shorter time. The half-saturation constant (K) values of *G. fascicularis* with and without light provision were 1.25×10^4 ind. l⁻¹ and 5.32×10^3 ind. l⁻¹, respectively (Table 2). Corals pieces fed with *A. salina* nauplii retained a 100% survival rate for more than 10 months.

Figure 2 shows that coral feeding has a rhythmic trend. Under light conditions, the daily feeding rate declined on day 2 but increased on day 4. However, the feeding rhythm extended up to day 3 under dark conditions. The daily feeding rate varied from day to day, and there was a significant interaction between light provision and feeding time ($P < 0.05$, Table 3). Nevertheless, the average feeding rate was not significantly different under light and dark conditions ($P > 0.05$, Table 3).

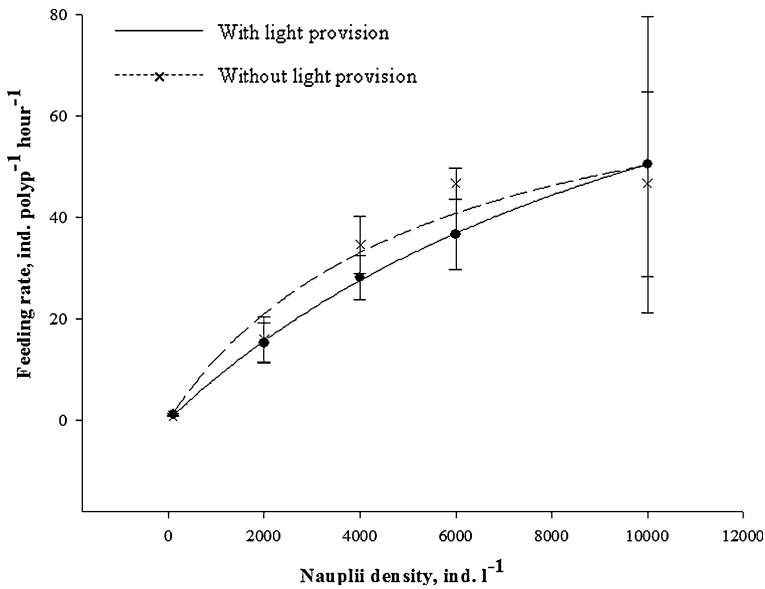


Fig. 1 Feeding rates as a function of *Artemia salina* nauplii densities for *Galaxea fascicularis* under light and dark conditions. Markers ● and × are the means of $n = 3$ (with and without light provision, respectively). The solid line (with light provision) and dash line (without light provision) show the best-fit curve

Table 1 Summary of analysis of variance (ANOVA) for nonlinear regression analysis for feeding responses of *Galaxea fascicularis* with and without light provision

| Feeding condition | Sources of variation | df | MS | F | P |
|-------------------------|----------------------|----|-----------|-----------|-------------------|
| With light provision | Regression | 1 | 1446.7551 | 6957.5310 | <0.0001 |
| | Error | 3 | 0.2079 | | |
| Without light provision | Regression | 1 | 1542.7563 | 60.2210 | 0.0015 |
| | Error | 3 | 25.6128 | | |

df—degree of freedom, MS—mean squares, F—Fisher F ratio, P—probability
Significant values ($P < 0.05$) are indicated in bold

Table 2 Summary of regressions for feeding responses of *Galaxea fascicularis* with and without light provision

| Feeding condition | Curvilinear Michaelis–Menten model | | Parameter estimates ^a | |
|-------------------------|------------------------------------|--------|--|-------------------------|
| | $F_D = \frac{(F_{max} D)}{(K+D)}$ | R^2 | F_{max} , ind. polyp ⁻¹ h ⁻¹ | K, ind. l ⁻¹ |
| | N | | | |
| With light provision | 15 | 0.9998 | 113.6 | 12,494 |
| Without light provision | 15 | 0.9779 | 76.9 | 5,341 |

^a Parameters for the Michaelis–Menten model (F_{max} maximum rate of ingestion; K half-saturation constant) were calculated using iterative least-squares regression

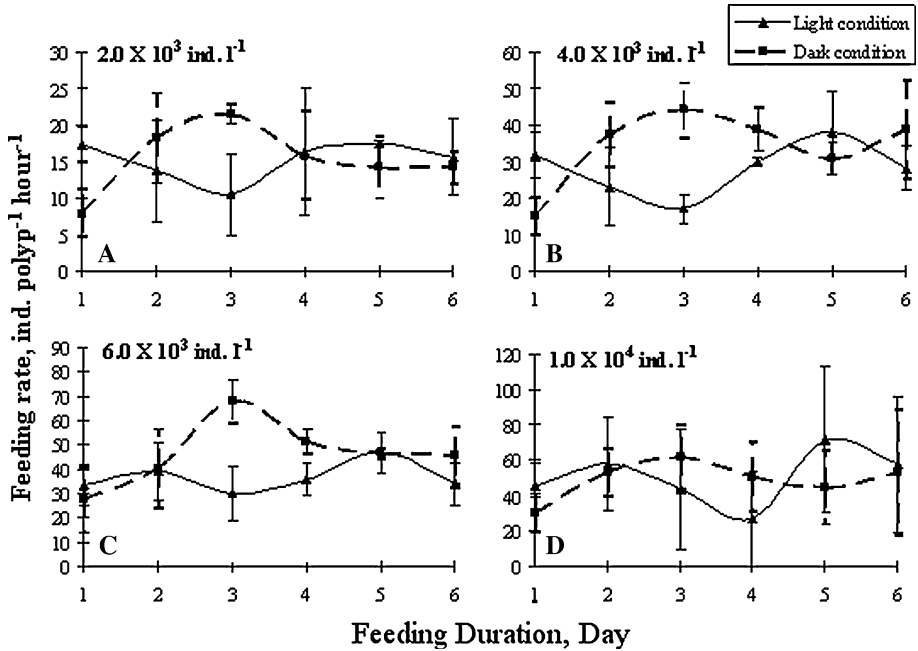


Fig. 2 *Galaxea fascicularis* feeding rates with and without light provision at different nauplii densities. Markers are the mean, and vertical bars show standard deviation with $n = 3$. (a) 2×10^3 ind. l⁻¹; (b) 4×10^3 ind. l⁻¹; (c) 6×10^3 ind. l⁻¹; (d) 10×10^3 ind. l⁻¹

A. salina nauplii digestion by *G. fascicularis*

Table 4 shows the digestibility of *A. salina* nauplii by *G. fascicularis*. Complete *A. salina* nauplii digestion (scale 5) was observed after 180 min. Most gastrovascular cavity contents of the specimen showed minor digestion (scale 1) 10 min after feeding (Fig. 3). All major body parts were intact, but there was some minor degradation in the nauplii appendices. The modes of nauplii digestibility after 30 and 60 min were recorded at scales 2 and 3, respectively. Nauplii were partially digested at the time. After 90 and 120 min, most *A. salina* nauplii were further digested and recorded at scale 4. *A. salina* nauplii body shape could hardly be recognized at this time. After 180 and 420 min after feeding, only mucus was left in the contents. As for controls, only mucus was found in the gastrovascular cavity contents withdrawn from the coral polyps. Analysis of Spearman's rank order correlation indicates that there was a significant correlation between *A. salina* nauplii digestibility and digestion time ($r = 0.920$, $P = 0.014$).

Discussion

G. fascicularis is one of the favorite organisms in the marine ornamental industry (Wabnitz et al. 2003). The scarcity of data in coral feeding and nutritional requirement renders it difficult to maintain corals in captivity. *A. salina* nauplii acting as a biocarrier may be useful to study nutrient requirements of corals. Our results revealed that *G. fascicularis* was able to feed on *A. salina* nauplii. Coral feeding capacity was positively

Table 3 Summary of split-plot design analysis of variance (ANOVA) of the effect of feeding condition (with and without light provision) and feeding time on feeding rate of *Galaxea fascicularis* at different loads of *Artemia salina* nauplii

| Split-plot design ANOVA | | | | | | |
|---|---|--------|---------|-------|--------------|--|
| Nauplii density (ind. l ⁻¹) | Source of variation | df | MS | F | P | |
| 2.0 × 10 ³ | Feeding condition | 1 | 0.078 | 0.001 | 0.976 | |
| | Feeding time | 5 | 11.185 | 0.724 | 0.613 | |
| | Interaction of feeding condition and feeding time | 5 | 72.437 | 4.690 | 0.005 | |
| | Error | 20 | 15.445 | | | |
| 4.0 × 10 ³ | Feeding condition | 1 | 344.288 | 2.272 | 0.206 | |
| | Feeding time | 5 | 104.379 | 2.426 | 0.071 | |
| | Interaction of feeding condition and feeding time | 5 | 367.994 | 8.552 | 0.000 | |
| | Error | 20 | 43.029 | | | |
| 6.0 × 10 ³ | Feeding condition | 1 | 896.104 | 5.237 | 0.084 | |
| | Feeding time | 5 | 256.041 | 2.917 | 0.039 | |
| | Interaction of feeding condition and feeding time | 5 | 370.475 | 4.220 | 0.009 | |
| | Error | 20 | 87.785 | | | |
| 1.0 × 10 ⁴ | Feeding condition | 1 | 20.763 | 0.006 | 0.944 | |
| | Feeding time | 3.146 | 792.182 | 3.936 | 0.033 | |
| | Interaction of feeding condition and feeding time | 3.146 | 904.185 | 4.493 | 0.022 | |
| | Error | 12.584 | 201.258 | | | |

df—degree of freedom, MS—mean squares, F—Fisher F ratio, P—probability
 Significant values (P < 0.05) are indicated in bold

correlated with nauplii availability. When nauplii are present at low density (1.0 × 10² ind. l⁻¹), *G. fascicularis* feeding rate under light and dark conditions was 1.2 ind. polyp⁻¹ h⁻¹ and 0.8 ind. polyp⁻¹ h⁻¹, respectively. When nauplii were present at high density (1.0 × 10⁴ ind. l⁻¹), *G. fascicularis* feeding rate under light and dark conditions was 50.5 ind. polyp⁻¹ h⁻¹ and 46.6 ind. polyp⁻¹ h⁻¹, respectively. When the corals were fed with high nauplii density, their feeding capacity was about 50 times higher than those fed with low nauplii density. Similar results were documented by Lasker et al. (1982); Clayton and Lasker (1982); Ferrier-Pages et al. (2003); and Picciano and Ferrier-Pages (2007). Ferrier-Pages et al. (1998) reported that *Stylophora pistillata*, a zooxanthellate coral, increased its feeding rate by 2,000 times when the ciliates density increased from 200 to 800 ciliates ml⁻¹. In another study, the feeding rate of a Mediterranean red coral, *Corrallium rubrum*, doubled, for a sixfold increase in prey concentration (Picciano and Ferrier-Pages 2007).

Feeding satiation and nauplii density was a typical curvilinear response. *G. fascicularis* feeding rate and nauplii density was well fitted into a saturation curve (Fig. 1). Feeding by coral polyps was analogous to the active sites as in the enzymatic kinetics. *G. fascicularis* feeding rate can be estimated using the Michaelis–Menten equation. The maximum *G. fascicularis* feeding rate with light provision was 113.6 ind. polyp⁻¹ h⁻¹, whereas the maximum *G. fascicularis* feeding rate without light provision was 76.9 ind. polyp⁻¹ h⁻¹.

Table 4 Degree of *Artemia salina* nauplii digestion by *Galaxea fascicularis* at different sampling times

| Replicate | Degree of digestion | | | | | | | |
|-----------|---------------------|----|----|----|-----|-----|-----|----------------------|
| | Time (min) | | | | | | | |
| | 10 | 30 | 60 | 90 | 120 | 180 | 420 | Control ^a |
| R1 | 1 | 2 | 3 | 3 | 5 | 5 | 5 | 5 |
| R2 | 1 | 2 | 3 | 4 | 4 | 4 | 5 | 5 |
| R3 | 2 | 2 | 3 | 4 | 4 | 5 | 5 | 5 |
| R4 | 1 | 3 | 3 | 4 | 4 | 5 | 5 | 5 |
| R5 | 1 | 4 | 2 | 4 | 4 | 4 | 5 | 5 |
| R6 | 1 | 3 | 2 | 4 | 3 | 4 | 5 | 5 |
| R7 | 1 | 3 | 2 | 4 | 4 | 4 | 5 | 5 |
| R8 | 2 | 4 | 3 | 4 | 4 | 5 | 5 | 5 |
| R9 | 1 | 2 | ND | 4 | ND | 5 | 5 | 5 |
| R10 | 1 | ND | ND | 4 | ND | 5 | 5 | 5 |
| R11 | 2 | ND | ND | ND | ND | 5 | 5 | 5 |
| R12 | 1 | ND | ND | ND | ND | 5 | 5 | 5 |
| R13 | 1 | ND | ND | ND | ND | 5 | 5 | 5 |
| R14 | 1 | ND | ND | ND | ND | 5 | 5 | 5 |
| R15 | 1 | ND | ND | ND | ND | 5 | 5 | 5 |
| R16 | 3 | ND | ND | ND | ND | 5 | 5 | 5 |
| R17 | 1 | ND | ND | ND | ND | 5 | 5 | 5 |
| Mode | 1 | 2 | 3 | 4 | 4 | 5 | 5 | 5 |

ND—no nauplii was observed in gastrovascular content of the specimen

^a Control: Corals starved for 1 week

The half-saturation constant (K) of the coral's feeding with and without light provision was 1.25×10^4 ind. l^{-1} and 5.32×10^3 ind. l^{-1} , respectively. When the corals were fed with higher nauplii density than the half-saturation constant, there was no further increment in the coral feeding rate.

A plateau was observed in *G. fascicularis* when it was fed with high nauplii density. Ferrier-Pages et al. (1998) reported a feeding plateau in *S. pistillata* feeding after the coral ingested 4×10^4 ciliates. However, Clayton and Lasker (1982) and Picciano and Ferrier-Pages (2007) did not observe any feeding plateau over the range of prey densities fed to corals. Anthony (1999) reported the feeding rate of four coral species, *Pocillopora damicornis*, *Montipora digitata*, *Acropora millepora*, and *Porites cylindrical*, on fine suspended particulate matter. *P. damicornis*, *M. digitata*, and *A. millepora* ingestion rates increased linearly from 1 to 30 mg l^{-1} of the fine suspended particle, whereas *P. cylindrical* reached its plateau at 4–8 mg l^{-1} particle concentrations. The differences in feeding capability are due to differences in feeding mechanisms, morphology, variable sizes, number of tentacles and polyps, differences in coelenterates cnidom, prey type and size, water flow, depth, temperature, and light availability. Any changes of these parameters affect coral feeding rate and the plateau (Leversee 1976; Lasker 1981; Clayton and Lasker 1982; Okamura 1987; Dai and Lin 1993; Sebens et al. 1997, 1998; Piniak 2002; Tsounis et al. 2006; Picciano and Ferrier-Pages 2007).

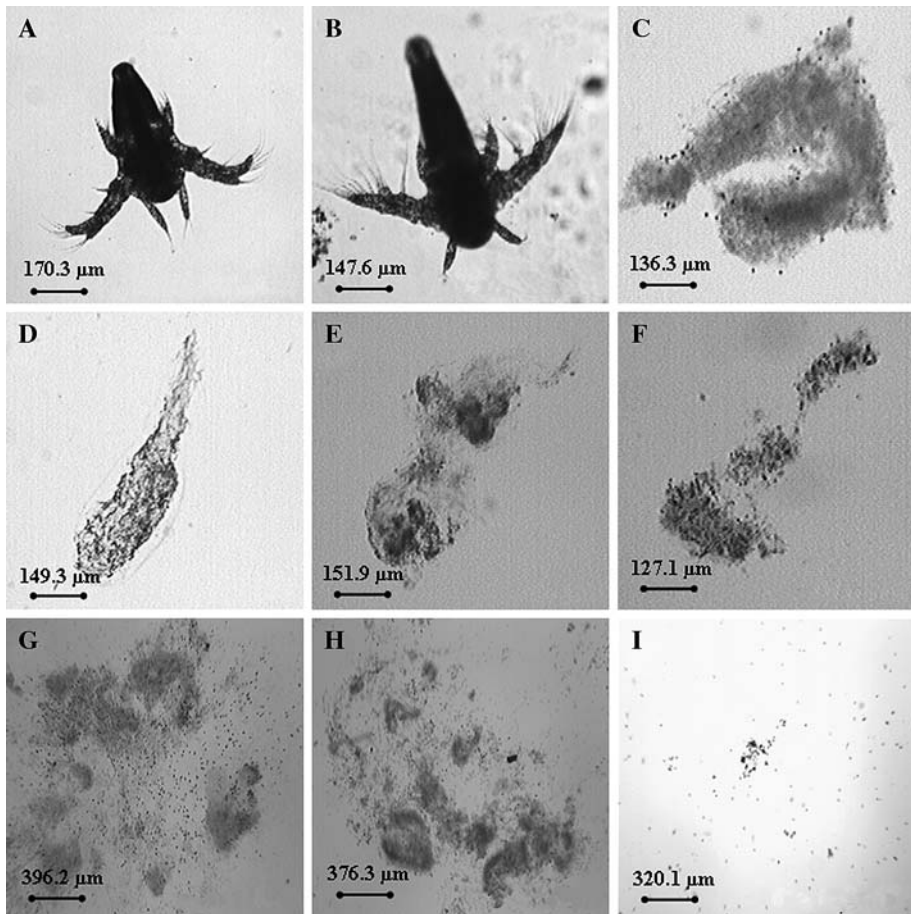


Fig. 3 (a) *Artemia salina* nauplii (control). Contents withdrawn from corals' gastrovascular cavity at (b) 10 min, (c) 30 min, (d) 60 min, (e) 90 min, (f) 120 min, (g) 180 min, and (h) 420 min after feeding. (i) Contents withdrawn from controls' gastrovascular cavity (coral starved for 1 week)

Heterotrophic feeding of coral is affected by light. Ferrier-Pages et al. (1998) reported the ingestion rate of *S. pistillata* decreased when light intensity increased. Under dark conditions, *S. pistillata* polyps were fully expanded but remained closed most of the time under light conditions. Clayton and Lasker (1982) found that *P. damicornis* feeding capacity was not affected by short-term dark conditions. *G. fascicularis* feeding rate was not significantly different under light and dark conditions, as the coral was maintained in dark conditions for a few hours only. However, *G. fascicularis* feeding saturation occurred earlier under light conditions. With light provision, coral feeding rates decreased on day 2 and increased again on day 4 (Fig. 2). Feeding rates of coral fed under dark conditions achieved feeding satiation after 3 days of feeding, decreased after day 3, and increased again at day 6. *G. fascicularis* fed actively under light conditions. Polyp tentacles were fully extended to enhance prey capture. *G. fascicularis* consumes more nauplii density under light conditions for the first day, and feeding rates decreased gradually until day 4. Coral feeding exhibits a rhythmic trend. Lasker et al. (1982) indicated that *Hydra viridis* feeding rhythm was 4.8 h and the consumption reduced during the second feeding.

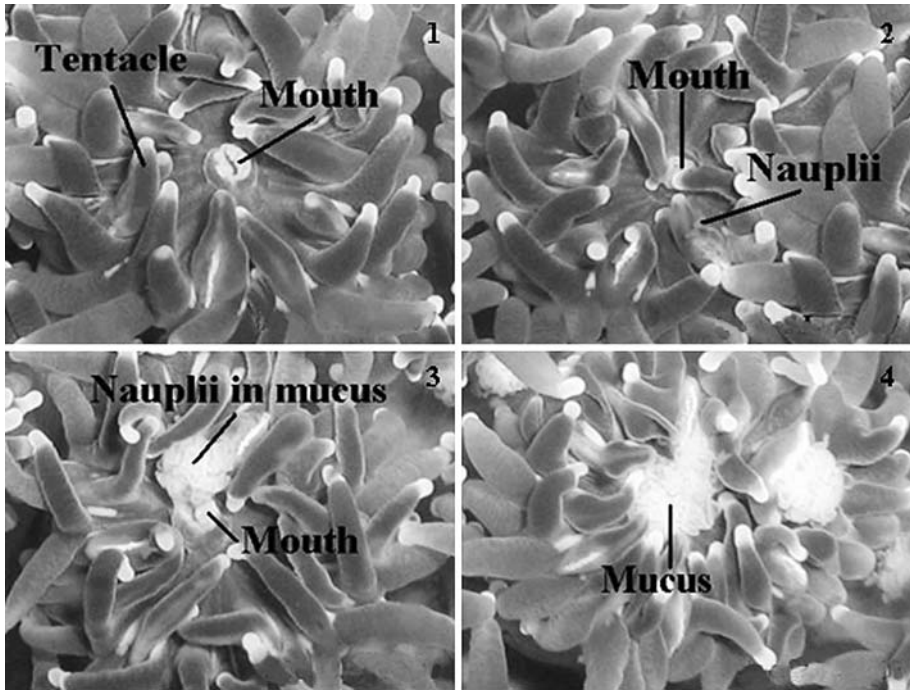


Fig. 4 The process by which *Galaxea fascicularis* preyed on *Artemia salina* nauplii by both tentacular and mucus. (a) *G. fascicularis* with extended polyp tentacles before feeding. (b) Polyps begin to prey on nauplii with tentacles when fed with nauplii. (c) Nauplii are wrapped with mucus and conveyed to the mouth. (d) Nauplii are drawn into the mouth and stomodeum

Dead nauplii were found throughout the feeding experiment, especially when the corals were fed at high nauplii density. *G. fascicularis* preyed on the nauplii with its extended tentacles (Fig. 4). When nauplii density was high, there were more frequent contacts between the nauplii and polyp tentacles. Not all captured nauplii were ingested by the corals. The nauplii may be stung by polyp tentacles, thus causing mortality.

G. fascicularis produced mucus on its fully extended tentacles for better nauplii entrapment (Fig. 4). It has been observed that when corals are fed with high nauplii density, polyps produce greater mucus volume. *A. salina* nauplii were found entrapped by the mucus before being consumed. Ferrier-Pages et al. (1998) reported that mucus produced by polyps was one of the major mechanisms to enhance heterotrophy feeding of corals. The mucus produced by coral is a potential energy sources to the coral itself. It is high in nutritional value and contains wax esters, triglycerides, fatty acids, and other energy-rich compounds (Coffroth 1984).

A. salina nauplii digestibility by *G. fascicularis* is high. The digestion started 10 min after feeding and took about 180 min to complete (Fig. 5). Time for complete digestion was similar to that reported for gorgonian soft coral, *Pseudoplexaura porosa*. (Coffroth 1984). Coffroth (1984) reported that all ingested food was cleared from the gastrovascular gut within 3–4 h. Sebens and Koehl (1984) reported complete digestion of zooplankton by octocorals, *Alcyonium siderium*, was 4–6 h, whereas the hydrocoral *Millepora complanata*, was reported to have 91% digestion after 24 h (Lewis 1992). The discrepancies are due to the fact that coral's digestion time is dependent on several factors, such as polyp size, prey

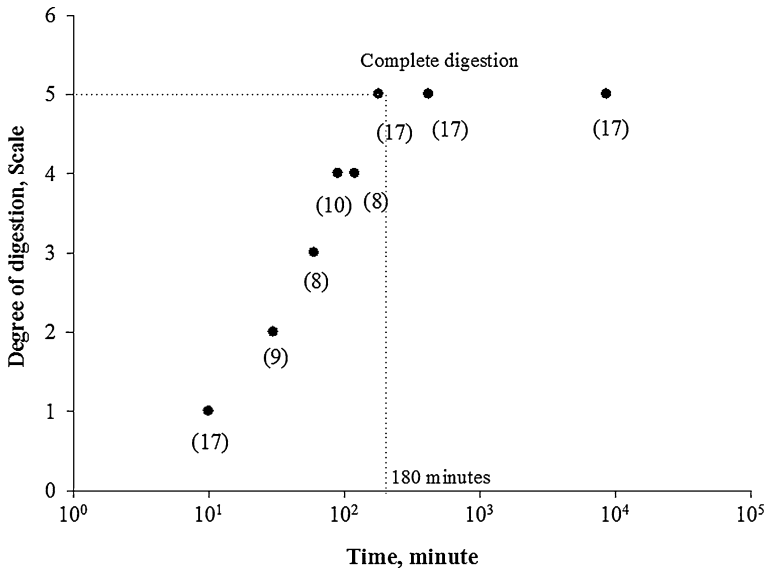


Fig. 5 The degree of digestion of *Artemia salina* nauplii by *Galaxea fascicularis* at different times (min). Sample size of each mode is in brackets. Complete *A. salina* nauplii digestion by *G. fascicularis* was estimated at 180 min after feeding

type, and temperature (Rossi et al. 2004). There are few reports on *A. salina* nauplii digestibility by *G. fascicularis*, but digestibility of *A. salina* nauplii by other organisms is well documented. Martinussen and Bamstedt (1999) reported that *Aurelia aurita* digestion time with *A. salina* was 0.3–3.5 h. Morais et al. (2004) reported higher digestibility of *Artemia* sp. (60% after 24 h) by herring larvae, *Clupea harengus*.

Heterotrophic feeding is essential for corals to overcome any nutrient deficiency, as nitrogen, phosphate, vitamins, and other trace elements are not synthesized through autotrophic feeding. In this case, the amount of *A. salina* nauplii carbon that was transferred to *G. fascicularis* could be extrapolated based on nutrient content. *Artemia* sp. nauplii contained 0.93 µg C ind⁻¹ and 0.20 µg N ind⁻¹ (Evjemo and Olsen 1999). *G. fascicularis* was extrapolated to acquire 106 µg C polyp⁻¹ and 23 µg N polyp⁻¹ per 1-h feeding under light conditions, whereas under dark conditions, 72 µg C polyp⁻¹ and 16 µg N polyp⁻¹ was acquired by *G. fascicularis* after 1-h feeding. Carbon and nitrogen acquisition under light conditions was about double the level of carbon and nitrogen under dark conditions.

Conclusion

A. salina nauplii are well accepted by *G. fascicularis* (digestibility and feeding captivity). It is feasible to use them as biocarriers to supply specific nutrients to *G. fascicularis*. The maximum *G. fascicularis* feeding rate under light and dark conditions was 113.6 ind. polyp⁻¹ h⁻¹ and 76.9 ind. polyp⁻¹ h⁻¹, respectively. Average *G. fascicularis* feeding rate was not significantly different under light and dark conditions. However, coral fed under light conditions achieved earlier feeding satiation compared with coral fed under dark conditions. Based on the rhythmic trend of feeding satiation, *A. salina* nauplii can be fed to

the coral in captivity once every 3 days. Complete *A. salina* nauplii digestion was observed 180 min after feeding.

Acknowledgements The authors thank the Ministry of Higher Education (MoHE), Malaysia, and the University Malaysia Terengganu (UMT) for funding this study. Special thanks to Dr. Chuah Tse Seng for his assistance in biostatistics and Choo Chee Kuang for proofreading the manuscript.

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