ACTA
PROTOZOOLOGICA

Acta Protozool. (2011) 50: 339–343
http://www.eko.uj.edu.pl/ap
doi: 10.4467/16890027AP.11.031.0068

Short communication

Growth Characteristics of *Ephelota gigantea*: a Pest to Seaweed Culture along the Northeastern Coast of Japan

Toshimasa KOBAYASHI[1,2], Nobuyuki NAKANO[1], Takaaki MUTO[3] and Yoshinari ENDO[3]

[1]Iwate Fisheries Technology Center, Kamaishi, Japan; [2]Present address: Iwate Inland Fisheries Technology Center, Hachimantai, Japan; [3]Laboratory of Biological Oceanography, Graduate School of Agricultural Science, Tohoku University, Sendai, Japan

Summary. Suctorians of the genus *Ephelota* are stalked ciliates and ectocommensals of marine invertebrates and plants. *Ephelota gigantea* has long been known as a major nuisance to the cultured seaweed industries in the coastal area of northeastern Japan. However, little is known about its life history, so *in situ* growth experiments were performed in the vicinity of wakame (*Undaria pinnatifida*) long-line culture in Iwate Prefecture, and the development of swarmers was investigated in the laboratory. The stalk elongated first, followed by enlargement of body length and body width, with body width increasing linearly with time. Over 5–6 days, *E. gigantea* increased 4–5-fold by external budding. Such an experiment was carried out for the first time for *E. gigantea* and possibly for any *Ephelota* species. The information obtained is important not only in understanding the life history of this species but also for understanding the interactions with host organisms.

Key words: *Ephelota gigantea*, suctorian, ectocommensal, growth characteristics, wakame.

INTRODUCTION

Ephelota suctorians constitute one of 8 genera of the family Ephelotidae, and are ectocommensals on various marine invertebrates and fouling organisms (Dovgal 2002, Lynn 2008). In coastal areas of northeastern Japan, especially off Iwate Prefecture, they cause great damage to cultured wakame (*Undaria pinnatifida*) because damaged *Ephelota* cells release an unpleasant odor and stalks of *Ephelota* remain on wakame fronds even after boiling, which greatly diminishes the commercial value of wakame. The occurrence of *Ephelota* suctorians on wakame is sporadic, so it is difficult to predict when and where they will occur, but the damage caused can exceed 2 hundred million yen (2.5 million US$). The sporadic nature of *Ephelota* infestation has impeded detailed studies of its basic biology through experimental study. However, wakame culture is extensive along the Pacific coast of northeastern Japan, which presented opportunities for the present study.

Short-term observations in the sea and laboratory experiments on *Ephelota* suctorians were performed to obtain information on its growth and reproduction rates. *Ephelota* suctorians have been studied for their morphology (e.g. Grell and Meister 1984, Grell and

Address for correspondence: Yoshinari Endo, Laboratory of Biological Oceanography, Graduate School of Agricultural Science, Tohoku University, Sendai, 981-8555, Japan; Fax: +81-22-717-8734; E-mail: yendo@bios.tohoku.ac.jp

Benwitz 1984), taxonomy (e.g. Chen *et al*. 2008a, b), and attachment to other organisms (e.g. Fernandez-Leborans and Tato-Porto 2000, Fernandez-Leborans 2009), but to date there have been no experimental studies on the growth rates of any *Ephelota* suctorians to our knowledge.

MATERIALS AND METHODS

Five pieces of plastic net (Trical net, Takiron Co. Ltd., 20 × 37.5 cm) were suspended at 1.5 m depth from long-line wakame culture on 12 and 15 April 2010 in the coastal area of Taro, Iwate Prefecture (39°44′N, 141°59′E), and 1–4 nets were retrieved after 1, 3, 4 and 7 days for the 12 April series; after 1 and 4 days for the 15 April series. The surface water temperature ranged from 5.2 to 7.7°C (mean 5.7°C) during the suspension. Cell dimensions (body length, body width and stalk length, Fig. 1b) were measured for individual attached *Ephelota* suctorians, and reproductive state was checked under a light microscope. The growth of trophont was estimated from the most developed individual observed each retrieval day, because attached trophonts have various time elapsed after settlement. Number of individuals measured each day ranged from 4 to 12.

Several individuals of *Ephelota* suctorians were observed individually for their development. Retrieved nets were cut into several pieces and transferred to plastic cubic culture dishes (18 × 9 × 4 cm) filled with filtered seawater (gravity filtration through sand) and kept at 7°C in an incubator under unfed conditions. Released swarmers were also observed for further development.

RESULTS AND DISCUSSION

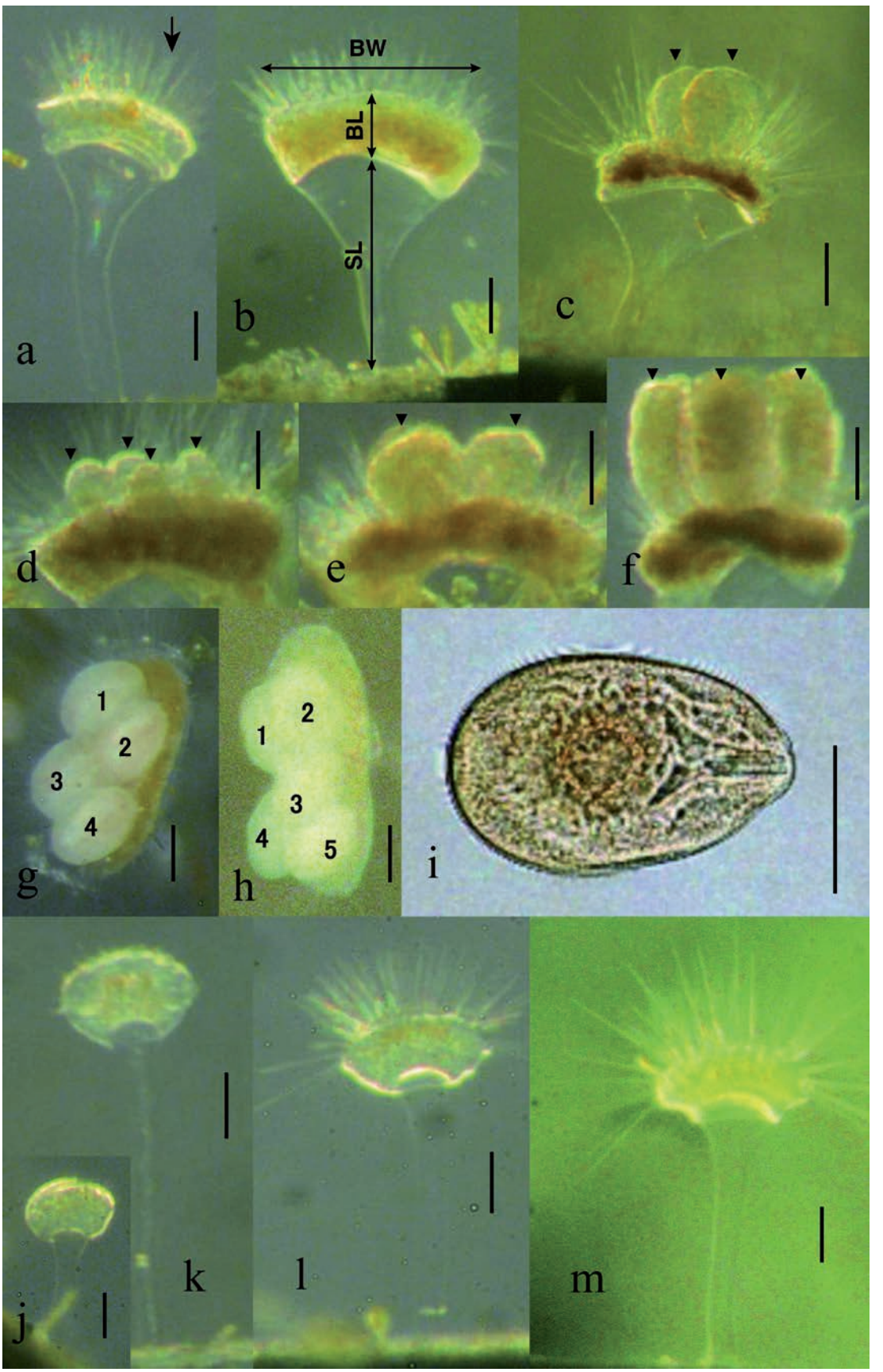
The suctorians that attached to the net were identified as *Ephelota gigantea*, which was described by Noble (1929) as an astonishingly large *Ephelota* species with laterally compressed body supported by a stalk which is spread into a funnel-shaped structure at its proximal end. In 2010, *E. gigantea* was observed to have attached to cultured wakame from mid March to early May in coastal areas of Iwate Prefecture. Since *Ephelota gigantea* was described by Noble (1929), no references to this species appeared until those of Fernadez-Leborans *et al*. (2005), who reported it as an epibiont on the parasitic copepod, *Lepeophtheirus salmonis*; and Fernadez-Leborans and Cárdenas (2009), who reported it as an epibiont on southern king crab *Lithodes santolla*. Wakame culture in Iwate Prefecture has long been suffering from *Ephelota* suctorians and Dr. Ryozo Yagiu identified *E. gigantea* in 1981 as a major nuisance (pers. comm.). This species attaches not only to living organisms but also to pieces of wood and rubber (Kobayashi, unpublished). The most developed individual, after 1 day, had an elongated stalk and semi-transparent pale brown body (Fig. 1a). The body is laterally compressed and prehensile tentacles were visible on the upper side. An individual retrieved 4 days after submergence had an apparently more developed body with a darker brownish color (Fig. 1b). A budding individual was observed for the first time on netting retrieved after 4 days and then incubated for 1 day (Fig. 1c). Budding individuals were also observed among individuals on netting retrieved after 7 days.

Buds appeared as semi-transparent spherical protuberances at first and grew gradually into opaque prolate spheroids (Fig. 1d–f). Small buds developed into the maximum size within one day. The number of buds was 1–5 per individual (Fig. 1g, h). The most developed individuals are thought to have attached to the net on the first day, so budding seems to have occurred 5–7 days after attachment. Mature buds were released as swarmers (Fig. 1i), a free swimming larval stage of suctorians which possess locomotor ciliature (Dovgal 2002), within several hours at the earliest. A circular structure, the scopula, was observed in the middle of the ventral side of a swarmer, with a posterior groove along the long axis of the cell (Fig. 1i). Swarmers were observed to bear cilia at the periphery. *E. gigantea* died about 6 days after the release of swarmers, without budding again.

Noble (1929) reported that *E. gigantea* produces 1–6 buds. Observations of *E. gigantea* in the present study discovered 4–5 buds, although a small number

▸▸

Fig. 1. Growth and reproduction processes of *Ephelota gigantea* observed *in situ* and in subsequent laboratory experiments. The most developed individuals retrieved after 1 day **(a)**, 4 days **(b)**, and 5 days **(c)** of suspension of netting. SL – stalk length, BL – body length, BW – body width. Development of buds **(d–f)**. Buds viewed from above: individual with 4 buds **(g)** and one with 5 buds **(h)**. Dorsal view of a swarmer **(i)**. This swarmer moved to the left. Development of a settled swarmer **(j–m)**: early stage of stalk elongation **(j)**, later stage of stalk elongation **(k)**, development of prehensile tentacles **(l)**, and widening of cell body and proximal part of stalk **(m)**. Arrow indicates prehensile tentacles; arrowheads indicate buds. Scale bars: 100 μm.



of individuals were observed to produce only 1–3 buds. The latter individuals may have already released several swarmers when observed.

Released swarmers did not swim but sank to the bottom of the culture dish and remained there stationary for 20–30 min. Then they began crawling along the bottom (to the left in Fig. 1i) by moving cilia clockwise, as viewed from above. Swarmers never swam away from the bottom of the culture dish, which is consistent with the observation by Noble (1929), and crawling ceased in about 2 h. This suggests that this species has a limited capability for dispersal, dependent upon transport by water movement. Metamorphosis of the swarmers then began, with extension of the stalk as if to lift the body (Fig. 1j, k). As the stalk elongated, prehensile tentacles developed (Fig. 1l). The proximal end of the stalk widened like a fan (Fig. 1m), a stage reached in less than 12 h since settlement of a swarmer. As described earlier, a settled swarmer grew in 1 day to the stage shown in Fig. 1a, taking about 12 h to grow from the stage shown in Fig. 1m to that shown in Fig. 1a.

From the above observations, it seems that about 5 days are required to develop from the time of settlement of a swarmer on the substrate to the start of budding, and several hours from the release of a swarmer to settlement. Overall, one growth cycle from settlement to the next settlement takes about 5–6 days at the earliest. *Ephelota gigantea* increased 4–5-fold in 5–6 days. In the present study, individuals which released swarmers died without further producing buds under unfed conditions. It is necessary to examine whether or not they can reproduce repeatedly under fed conditions.

The growth of each of three parameters (stalk length, body length and body width) of *E. gigantea* was estimated by plotting the largest values observed on each day (Fig. 2). These measurements revealed that the stalk elongated first, followed by increases in body length and width, which is consistent with the observation described earlier. Stalk length did not increase after the 4th day. Body length increased after the 3rd day with the equation BL = 19.03 + 65.91 d (r = 0.9959, p = 0.0576, n = 3) (with a growth rate of 66 μm d^{-1}), and body width increased linearly from the first day, with the equation BW = 29.73 + 299.98 d (r = 0.9989, p = 0.0011, n = 4) (with a growth rate of 300 μm d^{-1}).

From our growth experiment, it was suggested that stalk elongated somewhat exponentially in the first 4 days and stopped growing after that, while body length and width kept increasing during the experiment (Fig. 2). Among the body parts measured, only the body width increased linearly with time, so this may prove to be a good indicator of growth in this species.

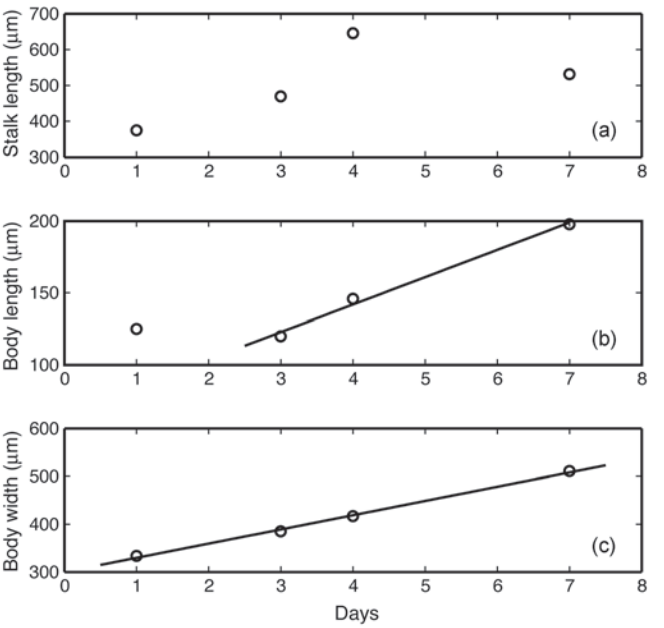


Fig. 2. Growth in stalk length (a), body length (b) and body width (c) of *Ephelota gigantea* shown as the largest value observed in each retrieval day. Stalk length increased somewhat exponentially in the first 4 days but not thereafter. Body length increased from the 3rd day, with the equation BL = 19.03 + 65.91 d (r = 0.9959, p = 0.0576). Body width increased linearly during the whole suspension period, with the equation BW= 29.73 + 299.98 d (r = 0.9989, p = 0.0011).

Measurements of these three parameters showed a significant correlation only between body length and body width and the equation was BW = 1.22 + 191.48 BL (r = 0.5174, p = 0.0002, n = 48) (Fig. 3).

Reproduction and growth of *E. gigantea* were observed at water temperatures of 5–7°C, so it will be necessary in future studies to monitor their performance at different temperatures.

Suctorians are known to have a free-swimming larval stage, called swarmers. In the present study, swarmers of *E. gigantea* crawled on the surface of the substrate rather than swam, which is consistent with the observation of Noble (1929), suggesting that this species has a limited capability for dispersal, dependent upon transport by water movement.

It is already known that *E. gigantea* can reproduce rapidly, since it proliferates among cultured wakame.

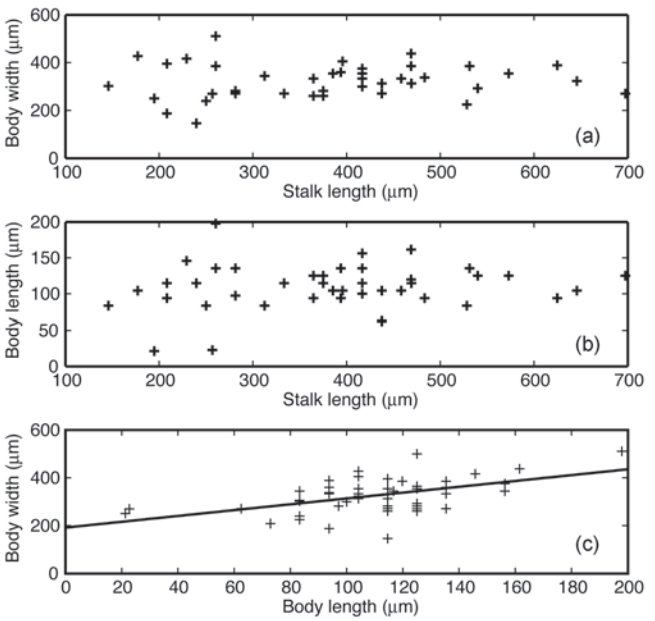


Fig. 3. Relationship between body width and stalk length (a), body length and stalk length (b), and body width and body length (c) of all individuals of *Ephelota gigantea* measured in this growth experiment. A significant relationship was found only between body width and body length, with the equation BW = 1.22 + 191.48 BL ($r = 0.5174$, $p = 0.0002$).

However, the basic growth and reproductive rates of *E. gigantea*, or probably of any *Ephelota* species, were determined for the first time in the present study. Such information is very important in understanding the life history of *Ephelota* suctorians per se and interactions with host organisms such as wakame and crustaceans. It is not known whether *E. gigantea* performs conjugation or forms cysts. Further studies are required to obtain more precise information about its life cycle, but the present study demonstrates that such studies are now feasible.

Acknowledgements. The authors express their sincere gratitude to the members of the Fisheries Cooperative of Taro for their kind assistance in sample collection. We also thank Mr. Takayuki Fujiwara of the Department of Fisheries, Coastal Regional Development Bureau of Iwate Prefecture for his useful suggestions. Dr. Ian G. Gleadall of Tohoku University kindly gave us constructive comments on our manuscript. This work was partly supported by Sanriku Fund.

REFERENCES

Chen X., Song W., Warren A., Al-Rasheid K. A. S., Al-Farraj S. A., Al-Quraishy S. A., Gong J. (2008a) Redefinitions of two marine suctorian ciliates, *Ephelota gemmipara* (Hertwig, 1876) Bütschli, 1889 and *E. crustaceorum* Haller, 1880 (Ciliophora, Suctoria), with a brief description of the asexual reproduction process in *E. gemmipara*. *Acta Protozool.* **47:** 113–124

Chen X., Miao M., Song W., Warren A., Al-Rasheid K. A. S., Al-Farraj S. A., Al-Quraishy S. A. (2008b) Redefinitions of two poorly known marine suctorian ciliates, *Ephelota truncata* Fraipont, 1878 and *Ephelota mammillata* Dons, 1918 (Protozoa, Ciliophora, Suctoria), from Qingdao, China. *Acta Protozool.* **47:** 247–256

Dovgal I. V. (2002) Evolution, phylogeny and classification of Suctorea (Ciliophora). *Protistology* **2:** 194–270

Fernandez-Leborans G. (2009) A review of recently described epibioses of ciliate protozoa on crustacea. *Crustaceana* **82:** 167–189

Fernandez-Leborans G., Tato-Porto M. L. (2000) A review of the species of protozoan epibionts on crustaceans. II. Suctorian ciliates. *Crustaceana* **73:** 1205–1237

Fernandez-Leborans G., Freeman M., Gabilondo R., Sommerville C. (2005) Marine protozoan epibionts on the copepod *Lepeophtheirus salmonis*, parasite of the Atlantic salmon. *J. Nat. Hist.* **39:** 587–596

Grell K. G., Meister A. (1984) Beiträge zur Ultrastruktur der Konjugation von *Ephelota gemmipara* R. Hertwiz (Suctoria). *Protistologica* **20:** 65–86

Grell K. G., Benwitz G. (1984) Die Ultrastruktur von *Ephelota gemmipara* Hertwig und *E. plana* Wailes (Suctoria): Ein Vergleich I. Die Adulte Form. *Protistologica* **20:** 205–233

Lynn D. H. (2008) The Ciliated Protozoa. Characterization, Classification, and Guide to the Literature. 3rd edition. Springer, London

Noble A. (1929) Two new species of the protozoan genus *Ephelota* from Monterey Bay California. *Univ. Calif. Pub. Zool.* **33:** 13–26

Received on 4th July, 2011; revised on 14th October, 2011; accepted on 14th October, 2011