Journal of
Plankton Research

academic.oup.com/plankt

J. Plankton Res. (2020) 1–4. doi:10.1093/plankt/fbaa047

BRIEF COMMUNICATION

Growth and ingestion rates of the freshwater jellyfish *Craspedacusta sowerbii*

GUILLAUME MARCHESSAUX[1,*] **AND MICKAËL BEJEAN**[2]

[1]UNIVERSITÉ DE FRANCHE-COMTÉ – LABORATOIRE CHRONO-ENVIRONNEMENT, UMR CNRS/UFC6249, F-25211 MONTBÉLIARD CEDEX, FRANCE AND [2]MUSÉUM DE BESANÇON, 99 RUE DES FUSILLÉS, LA CITADELLE, 25000 BESANÇON, FRANCE

*CORRESPONDING AUTHOR: guillaume.gmarchessaux@gmail.com

Received June 3, 2020; editorial decision September 10, 2020; accepted September 10, 2020

Corresponding editor: Beatrix E. Beisner

The invasive freshwater hydromedusa *Craspedacusta sowerbii* Lankester, 1880 (phylum Cnidaria, class Hydrozoa, family Olindiidae) is native from East Asia but for more than 20 years, reports of this species have been increasing in Europe, North America, and Australia. Due to the sporadic presence of the medusa stage and difficulties in the sample polyp stage, there is a lack of data on the physiological parameters of *C. sowerbii* and its potential impact. We present data on growth and ingestion rates of the medusa stage measured at 29°C, temperature at which polyps are maintained in the Cinéaqua Aquarium (Paris). Medusa growth increased from 0.60 ± 0.08 to 9.0 ± 2.1 mm (mean: 0.28 ± 0.26 mm d^{-1}), and gonads appeared after 11.5 ± 3.0 days. Ingestion rates increased significantly from 28 ± 16 prey ind^{-1} d^{-1} (<1 mm) to 442 ± 170 prey ind^{-1} d^{-1} (>7 mm).

KEYWORDS: hydromedusa; physiology; invasive jellyfish

This study was conducted within the framework of development of a culture protocol for the freshwater jellyfish, *Craspedacusta sowerbii* (Marchessaux and Bejean, in review). Little data exist on the growth and ingestion of this species in the literature. We present exploratory data at 29°C, warm temperatures corresponding to the bloom periods.

The growth of 40 jellyfish, produced from polyps, was measured for 32 days. Medusas were individually placed in 50 mL polypropylene vials (*LABCON*®) of filtered osmosis freshwater (60 µm mesh). The water volume was adapted to the size: 20 mL for newborn medusas (<1 mm), 40 mL for bell diameter (B) from 1 to 3 mm, 50 mL for B between 3 mm and 6 mm, 100 mL for B > 6 mm. Vials were placed in a closed water bath at 29°C to limit temperature variations. Medusas were daily fed for 2 hours with a known number of *Artemia salina* nauplii (30 for bell diameter < 1 mm; 50 for 1 mm and 3 mm; 80 for > 3 mm; *Ocean Nutrition*™, nauplii length: 430 µm) rinsed three times with freshwater to eliminate salt. After 2 hours had elapsed, the water was changed and

available online at academic.oup.com/plankt

Table I: Data on gonads development for Craspedacusta sowerbii medusas

Temperature (°C)	Total number of medusas	Number with gonads	Percentage with gonads	Mean days to gonad appearance	Mean number of gonads per medusa	Mean bell diameter (mm) at gonad development
29	40	38	95	11.5 ± 3.0	4 ± 0	3.4 ± 0.5

the number of *Artemia* ingested determined. Bell diameter (B, mm) and the number of tentacles (N_T) were also measured. Ingestion rate (I, prey ind^{-1} d^{-1}) was calculated from the following formula (de Lafontaine and Legett, 1987):

$$I = \frac{\mathcal{N}i - \mathcal{N}\text{end}}{t \times \mathcal{N}_{\text{predators}}} \times 24,$$

where $\mathcal{N}_i$ is initial number of nauplii, $\mathcal{N}_{\text{end}}$ is final number of nauplii, $\mathcal{N}_{\text{predators}}$ is number of medusas in the vial and $t$is the duration of the experiment (hours).

Medusa growth measured in our study was from 0.60 ± 0.08 mm (Day 0) to 9.0 ± 2.1 mm (Day 32) (Fig. 1A) with a mean of 0.28 ± 0.26 mm d^{-1} following the same trend as populations in Panama studied by Folino-Rorem et al. (2015). As reported in the literature (Turquin, 2010; Folino-Rorem et al., 2015) and as observed in our study, the newly born medusas measured less than 1 mm and had eight tentacles. Medusas reached a maximum bell diameter of 11.1 mm at 32 days age, longer than those observed at 23°C (∼3.5 mm, 26 days; Folino-Rorem et al. 2015). We observed a linear relationship $N_T = 15.03B + 0.66$; $R^2 = 0.98$ (Fig. 1B) in agreement with the literature (New Zealand: Boothroyd et al., 2002; Panama: Folino-Rorem et al., 2015). Mortality was < 1% during our experiments.

In our study, gonads developed in 95% of individuals with a mean of 11.5 ± 3.0 days ($n = 38$) (Table I); earlier than in the study by Folino-Rorem et al. (2015) at 23–24°C (14.7 ± 0.7 days). Smaller individuals (2.4 ± 0.2 mm) developed gonads in the study by Folino-Rorem et al. (2015) than in ours (3.4 ± 0.5 mm), whereas Lewis et al. (2012) observed gonads for 2 mm length.

To our knowledge, morphological aberrations have not been recorded in *C. sowerbii*. We observed an aberrant N_T (four or six compared to eight tentacles) but no differences in size (∼ 1 mm). Morphological aberrations represented 7.5% of the population (three individuals with four tentacles, and one with six ; mean N_T: 4.7 ± 1.2). This phenomenon was observed in other species of the Olindiidae family, notably *Gonionemus vertens*. Marchessaux et al. (2017) reported aberrant radial canals and gonad number in 10% of the population in the Berre Lagoon (France), whereas a 2.1% rate was observed in Massachusetts (USA; Carman et al., 2019). We did not observe any umbrella eversions (Folino-Rorem et al., 2015) likely due to the volume of water in our experimental flasks which was adapted to the size of the individuals.

Like many species of the family Olindiidae, the feeding behavior of *C. sowerbii* was described as individuals parachuting upside down through the water column with extended tentacles allowing the capture of prey on the descent (Pennak, 1989; Dumont, 1994). This dropping posture created vortices around the umbrella, which increases the efficiency of prey capture (Colin et al., 2006; Lucas et al., 2013). In accordance with Smith and Alexander (2008), we noticed that medusas occasionally lay on the bottom of the flasks, with their tentacles and manubrium facing up while feeding. In our study, the ingestion rate increased significantly (analysis of variance, Bonferroni post hoc test, $P < 0.05$) with bell diameter from 28 ± 16 prey ind^{-1} d^{-1} (< 1 mm) to 442 ± 170 prey ind^{-1} d^{-1} (>7 mm). Ingestion rates were higher in our study at 29°C than the values obtained by Folino-Rorem et al. (2015) at lower temperatures (24°C): ∼ 24 prey ind^{-1} d^{-1} (0.6–1 mm)m ∼ 68 prey ind^{-1} d^{-1} (2–3 mm) and ∼ 74 prey ind^{-1} d^{-1} (>4 mm). Our experimental data suggests that *C. sowerbii* can significantly decrease zooplankton populations. Our study showed a rapid growth of jellyfish and a decrease in prey stock between 3.9% (B, < 1 mm) and 60.0% (B = 7–8 mm) at 29°C, favorable temperature for blooms. During warmer periods, medusas mainly consumed little prey (0.2–2 mm) and can killed larger (>8 mm) organisms (Spadinger and Maier, 1999; Boothroyd et al., 2002; Smith and Alexander, 2008).

Native to China (Didžiulis, 2006), *C. sowerbii* has invaded freshwater bodies in Europe, North America and Australia (Boothroyd et al., 2002; Carlton, 2003; Arov, 2004; El Moussaoui and Beisner, 2017; Marchessaux et al., 2020). It is important to focus on the biological invasion processes of this organism when it becomes established to understand its role in the ecological functioning of the plankton food web (Ricciardi, 2015). Despite including only one temperature, our study presents complementary knowledge about the growth and ingestion rate of this species during warmer period. Further study of metabolism (growth, ingestion, respiration/excretion) needs to be developed at different

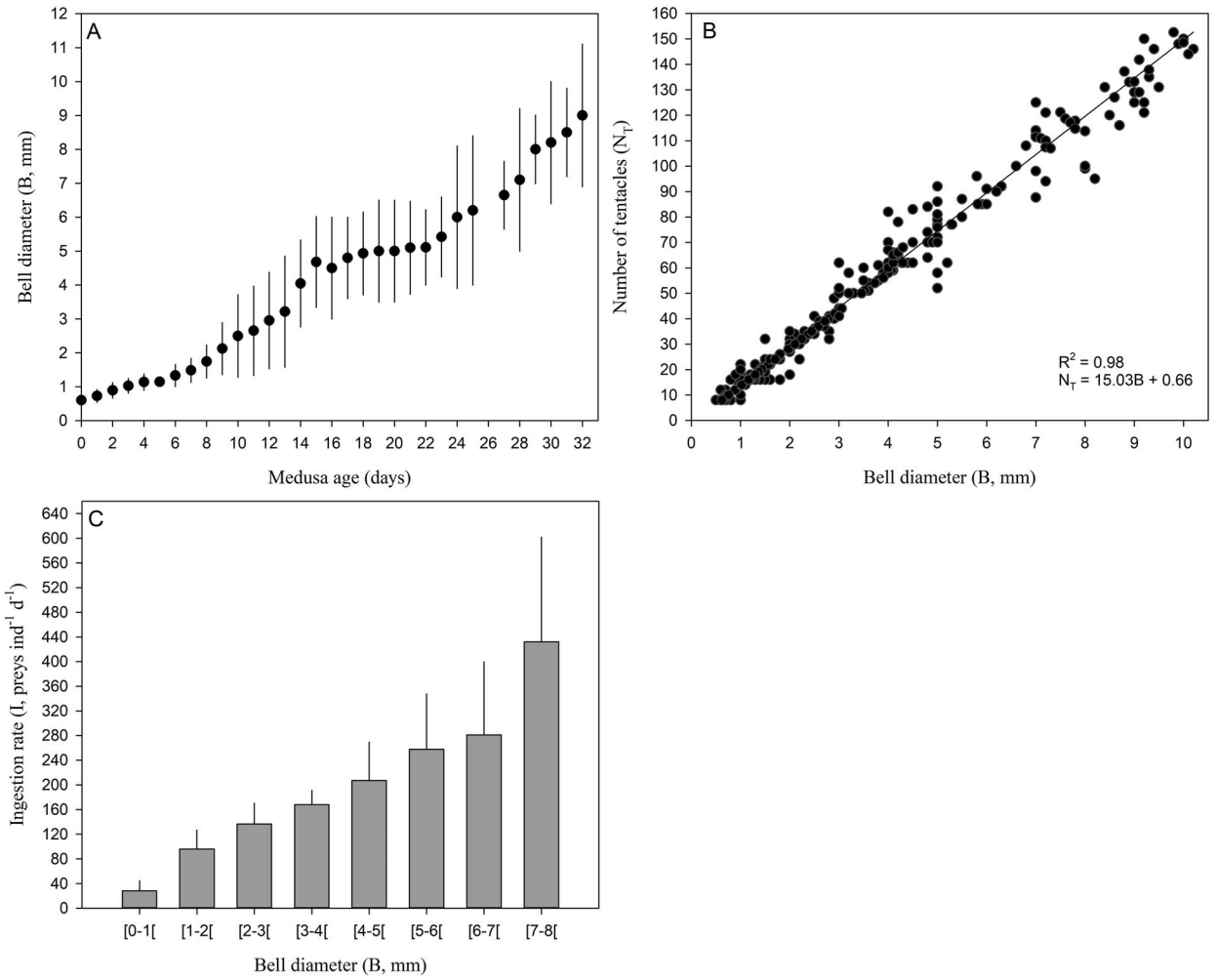

Fig. 1. Medusa growth measured at 29°C for 32 days (**A**), N_T as a function of bell diameter (B, mm) (**B**), and daily ingested preys (I, preys ind^{-1} d^{-1}) per medusa (mean ± SD) as a function of bell diameter at 29°C, $n = 40$. Craspedacusta population studied was originated from the Cinéaqua Aquarium (Paris).

temperatures to determine the potential impact of *C. sowerbii* on ecosystem functioning.

ACKNOWLEDGEMENT

Thank you to Etienne Bourgouin from the aquarium of Paris Cinéaqua for his advice and the donation of polyps.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Arov, I. (2004) On finding jellyfish genus *Craspedacusta* in Eastern Siberia. http://zooex.baikal.ru/bidermat/craspedacusta.htm (consulted on 14 October 2019).

Boothroyd, I. K. G., Etheredge, M. K. and Green, J. D. (2002) Spatial distribution, size structure, and prey of *Craspedacusta sowerbyi* Lankester in a shallow New Zealand lake. *Hydrobiologia*, **468**, 23–32.

Carlton, J. T. (2003) Community assembly and historical biogeography in the North Atlantic Ocean: the potential role of human-mediated dispersal vectors. *Hydrobiologia*, **503**, 1–8.

Carman, M. R., Grunden, D. W., Reddington, E. and Govindarajan, A. F. (2019) Distribution of the highly toxic clinging jellyfish *Gonionemus* sp. around the island of Martha's Vineyard, Massachusetts, USA. *Mar. Biodivers. Rec.*, **12**, 8.

Colin, S. P., Costello, J. H. and Kordula, H. (2006) Upstream foraging by medusae. *Mar. Ecol. Prog. Ser.*, **327**, 143–155.

DE Lafontaine, Y. D. and Leggett, W. C. (1987) Effect of container size on estimates of mortality and predation rates in experiments with macrozooplankton and larval fish. *Can. J. Fish. Aquat. Sci.*, **44**, 1534–1543.

Didžiulis, V. (2006) NOBANIS – Invasive Alien Species Fact Sheet – Craspedacusta sowerbyi. From: Online Database of the North European and Baltic Network on Invasive Alien Species. NOBANIS. 7p. www.nobanis.org.

Dumont, H. J. (1994) The distribution and ecology of the fresh- and brackish water medusae of the world. *Hydrobiologia*, **272**, 1–12.

El Moussaoui, N. and Beisner, B. E. (2017) La méduse d'eau douce *Craspedacusta sowerbii:* espèce exotique répandue dans les lacs du Québec. *Le Naturaliste Canadien*, **141**, 40–46.

Folino-Rorem, N. C., Reid, M. and Peard, T. (2015) Culturing the freshwater hydromedusa, *Craspedacusta sowerbii* under controlled laboratory conditions. *Invertebr. Repr. Dev.*, **60**, 17–27.

Lewis, C., Migita, M., Hashimoto, H. and Collins, A. G. (2012) On the occurrence of freshwater jellyfish in Japan 1928–2011: eighty-three years of records of *Mamizu kurage* (Limnomedusae, Olindiidae). *P. Biol. Soc. Wash.*, **125**, 165–179.

Lucas, K., Colin, S. P., Costello, J. H., Katija, K. and Klos, E. (2013) Fluid interactions that enable stealth predation by the upstream foraging hydromedusa *Craspedacusta sowerbyi*. *Biol. Bull.*, **225**, 60–70.

Marchessaux, G. and Bejean, M. (in review) From frustules to medusas: a new culture system for the study of the invasive hydrozoan *Craspedacusta sowerbii* in the laboratory. *Invertebr Biol.*.

Marchessaux, G., Gadreaud, J. and Belloni, B. (2020) The freshwater jellyfish *Craspedacusta sowerbii* Lankester, 1880: an overview of its distribution in France. *Vie et milieu/Life and Environ.*, **69**, 201–213.

Marchessaux, G., Gadreaud, J., Martin-Garin, B., Thiéry, A., Ourgaud, M., Belloni, B. and Thibault, D. (2017) First report of the invasive jellyfish *Gonionemus vertens* A. Agassiz, 1862 in the Berre Lagoon, southeast France. *BioInvasions Records*, **6**, 339–344.

Pennak, R. W. (1989) Fresh-water invertebrates of the United States. *Protozoa to Mollusca*. 3rd edition, 628 p.

Ricciardi, A. (2015) Ecology of invasive alien invertebrates. In Thorp, J. and Rogers, D. C. (eds.), *Ecology and general biology: Thorp and Covich's freshwater invertebrates*, Academic Press, London, UK, pp. 91–93.

Smith, A. S. and Alexander, J. E. Jr. (2008) Potential effects of the freshwater jellyfish *Craspedacusta sowerbii* on zooplankton community abundance. *J. Plankton Res.*, **30**, 1323–1327.

Spadinger, R. and Maier, G. (1999) Prey selection and diel feeding of the freshwater jellyfish, *Craspedacusta sowerbyi*. *Freshwater Biol.*, **41**, 567–573.

Turquin, M. J. (2010) Progrès dans la connaissance de la métagenèse chez *Craspedacusta sowerbii* (= sowerbyi) (Limnoméduse, Olindiidae). *Bourgogne-Nature*, **9-10**, 162–174.