

## Food habit of *Platydemus manokwari* De Beauchamp, 1962 (Tricladida: Terricola: Rhynchodemidae), known as a predatory flatworm of land snails in the Ogasawara (Bonin) Islands, Japan

Takashi OHBAYASHI,<sup>1,\*</sup> Isamu OKOCHI,<sup>2</sup> Hiroki SATO<sup>2</sup> and Tsuyoshi ONO<sup>1</sup>

<sup>1</sup> Agricultural Pest Division, Ogasawara Subtropical Branch of Tokyo Metropolitan Agricultural Experiment Station; Tokyo 100–2101, Japan

<sup>2</sup> Department of Forest Entomology, Forestry and Forest Products Research Institute; Ibaraki 305–8687, Japan

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### Abstract

The distribution and food habit of the flatworm species *Platydemus manokwari*, which is known to be a predator of land snails, were examined on Chichijima Island of the Ogasawara (Bonin) Islands, Japan. *P. manokwari* was distributed over a wide area of the island. Few live land snails were found in the area where *P. manokwari* was distributed. Further, it was revealed that *P. manokwari* fed not only on live land snails including predatory species, but also on other food resources such as live flatworms or a land nemertean species and the carcasses of slugs and earthworms. Therefore, *P. manokwari* is expected to survive even if the populations of land snails are almost lost on Chichijima Island in the future, and so will affect the biodiversity of Chichijima Island.

**Key words:** *Platydemus manokwari*; *Euglandina rosea*; *Achatina fulica*; decline of land snails; Ogasawara (Bonin) Islands

### INTRODUCTION

The Ogasawara (Bonin) Islands are located in the northern Pacific Ocean about 1,000 km south of the mainland of Japan. More than 100 species of land mollusks have been recorded on the islands, of which 94% are endemic to the islands (Tomiya and Kurozumi, 1992; Tomiyama, 1994).

However, about 70% of the endemic species have already become extinct (Tomiya, 2002). The decline and extinction of endemic land snails in tropical oceanic islands is a major concern for conservation biology (Clarke et al., 1984; Hopper and Smith, 1992; IUCN/SSC Mollusc Specialist Group, 1995). Furthermore, the population of introduced species such as the giant African snail *Achatina fulica* has also declined in recent years on Chichijima Island (Tomiya, 1991; Ohbayashi, 2002).

The following possible reasons for this decline on Chichijima Island have been pointed out: introduction of the predatory snail *Euglandina rosea* for

the control of *A. fulica* in 1965 (Takeuchi et al., 1991); predation by a predatory flatworm (Okochi et al., 2004); invasion of the alien predatory flatworm *Platydemus manokwari* since the 1990s (Kawakatsu et al., 1999; Tomiyama, 2002); predation by alien rats (Tomiya, 2002); and forest destruction (Tomiya, 2002).

Among them, two invasive aliens, *E. rosea* and *P. manokwari*, could be major reasons because they invaded only Chichijima Island, which would explain the sharp decline of both endemic and exotic snails on Chichijima Island. The most likely cause of the decline of land snails on Chichijima Island is thought to be the invasion of *P. manokwari* in the 1990s (Tomiya, 2002).

Although land snails have already become extinct in most areas on Chichijima Island (Tomiya and Kurozumi, 1992; Tomiyama, 1994), *P. manokwari* remains distributed over these areas (Ohbayashi, 2002). Furthermore, there used to be other land planarians (including snail predators) and land nemertean worms distributed on Chichijima Island (Kawakatsu et al., 1999), but in

\* To whom correspondence should be addressed at: E-mail: Takashi\_Oobayashi@member.metro.tokyo.jp

† Present address: Tokyo Metropolitan Plant Protection Office, 3–8–1 Fujimi-cho, Tachikawa, Tokyo 190–0013, Japan

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recent years there are few in areas where *P. manokwari* has already invaded, suggesting that these land planarians and land nemerteans have been defeated by interspecific competition with *P. manokwari* (Ohbayashi, 2002).

The food habit of *P. manokwari* has not been investigated previously in sufficient detail. Waterhouse and Norris (1987) noted, as a personal communication from Winsor (1985), that *P. manokwari* feed on anything other than live land snails, while Kaneda et al. (1990) reported that *P. manokwari* preyed only on live land snails. Furthermore, Hopper and Smith (1992) suggested that *P. manokwari* also feeds on another alien predatory snail, *E. rosea*, but this has not been verified. It is important to clarify the food habit of *P. manokwari* and interspecific relationships among *P. manokwari* and other predators for the conservation of endemic land snails.

This study was undertaken to clarify the food habit of *P. manokwari*, and to confirm the interactions between other predators of land snails.

## MATERIALS AND METHODS

**Distribution and field observation of the food habit of *P. manokwari*.** All studies were conducted on Chichijima Island, the largest island in the Ogasawara (Bonin) Islands.

We searched under stones and logs in the daytime of the years 1995, 1998, 2002, 2003, and 2004 (29 times in total, covering spring to winter, and search areas and months differed with years). The sites where both land snails and flatworms were recorded (whether at the same time or not) were regarded as areas of coexistence at the time of the search. We also conducted nighttime observations of the forest floor (once in the month in December 1998 and once every month from January to July, 2004), and recorded the sites where *P. manokwari* and live land snails were detected. During the survey of the distribution of *P. manokwari*, we recorded the species preyed by the animal.

We also used 20 cm×20 cm mesh bags made of 5 mm nylon mesh as attractant traps in which one live *A. fulca* (shell height: over 40 mm) was put. The traps were set on the forest floor near a road (45 sites) from March to May 1998, checked every few weeks, and the sites where *P. manokwari* was detected were recorded.

**Feeding tests.** Five species of live flatworms (*Bipalium kewense* (adults), *Bipalium* sp. (adults), *Platydemus* sp. -1 (adults), *Platydemus* sp. -2 (adults), and *Australopacifica* sp. (adults)), one species of live land nemertean (*Geonemertes pelaensis* (adults)), six species of live land snails and slugs (*Achatina fulica* (juveniles and adults), *Limax marginatus* (adults), *Deroceras laebe* (adults), *Euglandina rosea* (juveniles and adults), *Bradybaena similaris* (adults), and *Acusta despecta sieboldiana* (juveniles and adults)), and earthworms (*Haplotaxida* spp. (adults), dead or alive) were tested as the prey of *P. manokwari* (Table 1). Species of flatworms and land nemerteans were identified according to Kawakatsu et al. (1999).

One specimen of *P. manokwari* (body length: over 30 mm) and one specimen of a test animal species were put together in a plastic cup (ø90 mm, 40 mm height) in which a paper towel moistened with distilled water was laid. They were kept at 25°C under room light conditions, and predation was checked every day for 10 d.

Predation was detected by direct observation during the daytime (every hour from 07:00–23:00), and by video camera (SONY CCD-TRV86PK) recording during the night (23:00–07:00).

Cannibalism of *P. manokwari* was also tested. One, three or five specimens of mature *P. manokwari* (collected at different sites of Chichijima Island, body length: over 30 mm) were put in a plastic cup (ø80 mm, 25 mm height) in which a paper towel moistened with distilled water was laid, and were checked every day for 10 d (25°C, room light conditions).

## RESULTS

### Distribution and field observation of the food habit of *P. manokwari*

*P. manokwari* is distributed over a wide area of Chichijima Island, except for the east and south coast areas (Fig. 1). In contrast, endemic snails are distributed only in the east and south coast areas (Fig. 1).

In nine sites of the 37 sites where *P. manokwari* was recorded, land snails and *P. manokwari* coexisted, but at the other 28 sites, only *P. manokwari* was recorded. Therefore, it was difficult to find live land snails in the area where *P. manokwari* was detected (Fig. 1), and only one trap (set at Kita-

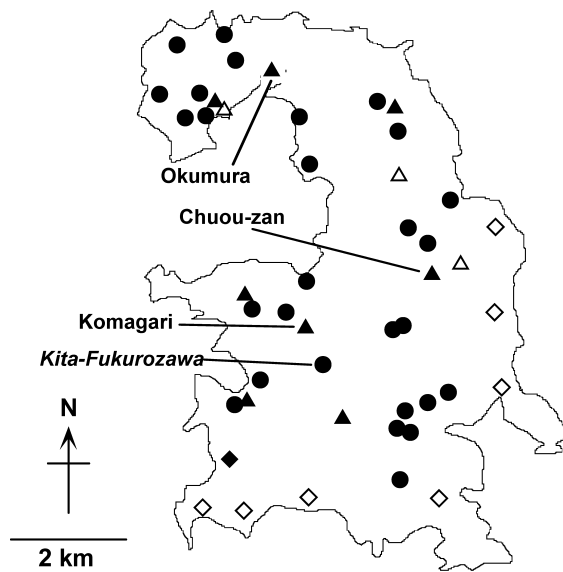


Fig. 1. Distributions of *Platydemus manokwari* and land snails (endemic/exotic) in Chichijima Island (1995–2004). Solid (●/◆/▲) and open (◇/△) symbols show whether *P. manokwari* was recorded or not, respectively. Patterns of symbols are as follows: ●: no snails (both endemic and exotic) were recorded; ◆/◇: endemic snails were recorded; ▲/△: exotic snails were recorded. Points indicated by lines are where predation of *P. manokwari* was recorded. The point “Kita-Fukurozawa” is the point where one of the attractant traps was set).

Fukurozawa) of the 45 traps attracted *P. manokwari* (Fig. 2b).

In the field research, it was observed that *P. manokwari* preyed on live land nemertean (*G. pelaensis*) at Chuou-zan (14 Nov. 2002: Figs. 1 and 2a), attacked live *A. fulica* put in the mesh bag at Kita-Fukurozawa (11 Mar. 1998: Figs. 1 and 2b), fed on the carcass of slug (*Incilaria* sp.) at Chuou-zan (19 Aug. 2002: Figs. 1 and 2c), attacked live *E. rosea* at Okumura (23 Apr. 2002: Figs. 1 and 2d), and fed on the carcass of earthworms (*Haplotaxida* spp.) at Komagari (4 Dec. 1998: Figs. 1 and 2e).

In the case of *E. rosea*, three *P. manokwari* attacked one *E. rosea* at the same time (“gang-attack”: Mead, 1963). The shell height of the *E. rosea* was 57.6 mm, and the wet body weights of the *P. manokwari* were 0.37, 0.27 and 0.21 g, respectively.

### Feeding tests

*P. manokwari* preyed on live land planarians (except *P. manokwari*), live land nemerteans, and live land snails (including *E. rosea*) tested within 10 d

(Table 1). Further, *P. manokwari* fed on the carcass of earthworms within 10 d, but did not prey on live earthworms at all for more than 10 d (Table 1). Cannibalism was not observed at all for more than 10 d.

When *P. manokwari* attacked snails, other planarians and a land nemertean, it followed their trails. When *P. manokwari* fed on land snails, it bent its mid-abdomen and inserted it into the aperture of the prey, then digested the flesh of the snail and sucked (Fig. 3a). Meanwhile, when *P. manokwari* fed on land planarians and land nemerteans, it extruded a proportionately long, white proboscis near the mid-ventral surface of the body, and sucked directly (Fig. 3b).

### DISCUSSION

We confirmed that *P. manokwari* feeds not only on live land snails, but also on other species of live flatworms or land nemerteans, and on the carcasses of slugs and earthworms, both in the field and in captivity.

There used to be other land planarians (such as *Bipalium* sp.) and a land nemertean (*G. pelaensis*) distributed widely on Chichijima Island, but in recent years there are few in areas where *P. manokwari* has already invaded (Kawakatsu et al., 1999; Ohbayashi, 2002). This is in contrast to the abundance of these land planarians and a land nemertean on Hahajima Island, which has not been invaded by *P. manokwari* (Kawakatsu et al., 1999; Okochi et al., 2004). Therefore, these land planarians and land nemerteans may have been consumed by *P. manokwari* on Chichijima Island.

The food habit of *P. manokwari* suggests that the reason why *P. manokwari* still exist in areas where both the number of endemic and exotic land snails has already been reduced may be that *P. manokwari* can use food resources other than live land snails.

On the other hand, on Hahajima Island, other species of predatory flatworms (such as *Bipalium* sp., *Platydemus* sp. -1, and *Australopacifica* sp.) eradicated endemic snails but are coexisting with exotic snails because they need live snails as food (Okochi et al., 2004).

We also confirmed that *P. manokwari* feeds on *E. rosea*, a predatory land snail, both in the field and in captivity, suggesting that *P. manokwari* may be a major reason why *E. rosea* populations have de-

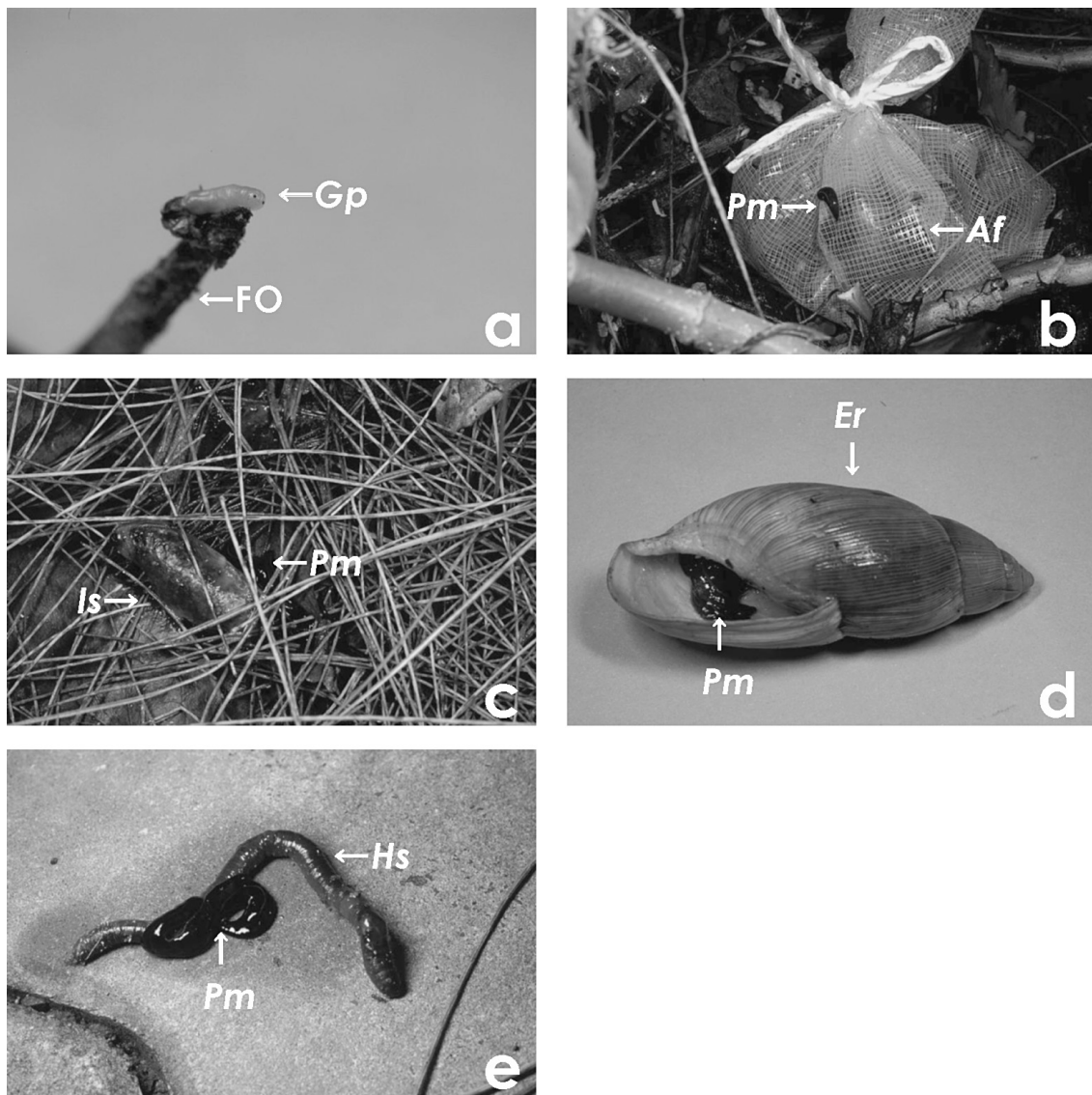


Fig. 2. Feeding on various food resources by *Platydemus manokwari* (Pm) on Chichijima Island. a: Head region of land nemertine (*Geonemertes pelaensis*: Gp, photograph in the laboratory, FO: forceps holding the head region); b: live *Achatina fulica* (Af) put in mesh bag; c: carcass of slug (*Incilaria* sp.: Is); d: live *Euglandina rosea* (Er, photograph in the laboratory); e: carcass of earthworm (*Haplotaxida* sp.: Hs).

creased on Chichijima Island, as well as those in other tropical oceanic islands such as Guam (Hopper and Smith, 1992).

Therefore, as *P. manokwari* can use various food resources, this flatworm is expected to survive in the future and make it difficult for the land snails of Chichijima Island to survive.

Furthermore, adults of *P. manokwari* were not observed to cannibalize each other. This suggests that there may be no chance of population limitation by cannibalism.

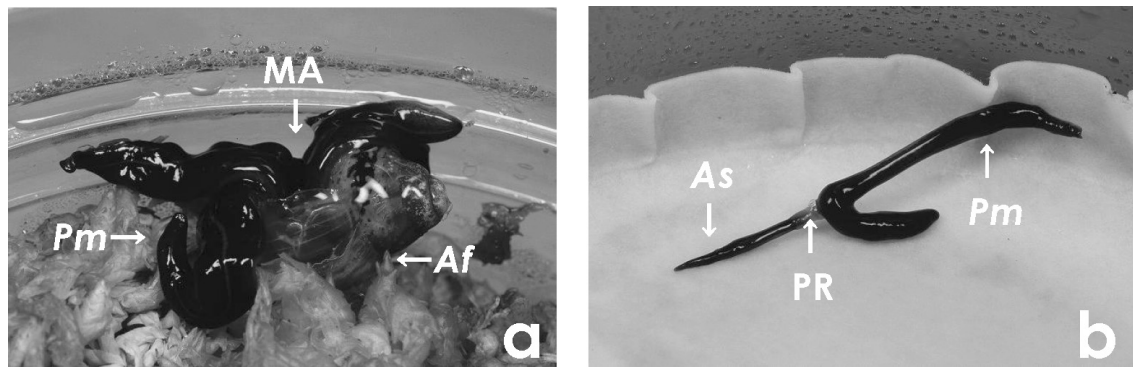
In conclusion, it has been confirmed that the in-

troduced predatory flatworm *P. manokwari* presently poses a major threat to the survival of both the endemic and exotic land snails, including *E. rosea* on Chichijima Island at present. This animal may also cause a reduction of other land snail predators such as other flatworms. Therefore, *P. manokwari* threatens the biodiversity of Chichijima Island.

It is important to take measures to prevent the further invasion of *P. manokwari* to other islands for the conservation of endemic land snails, land planarians, and land nemertine. Such action is also

Table 1. Predation on various food resources in captivity by *Platydemus manokwari*

Food resources	Size (mm) <sup>a</sup>	N <sup>b</sup>	Number of prey	Days to start of preying
Live land planarians				
<i>Bipalium kewense</i>	>60	2	1 <sup>c</sup>	1
<i>Bipalium</i> sp.	>25	6	5 <sup>d</sup>	1–6
<i>Platydemus manokwari</i>	>30	4	0	—
<i>Platydemus</i> sp. -1	>15	1	1	1
<i>Platydemus</i> sp. -2	>35	4	4	1–10
<i>Australopacifica</i> sp.	>15	1	1	1
Live land nemertine				
<i>Geonemertes pelaensis</i>	>25	3	3	2–6
Live land snails and slugs				
<i>Achatina fulica</i>	<5, >50	4	4 <sup>e</sup>	6–7
<i>Limax marginatus</i>	>25	2	2	1
<i>Deroceras laebe</i>	>15	7	7	1–3
<i>Euglandina rosea</i>	<5, >50	2	2 <sup>e</sup>	1–5
<i>Bradybaena similaris</i>	>10	1	1	2
<i>Acusta despecta sieboldiana</i>	<5, >20	5	5 <sup>e</sup>	1–7
Earthworm				
<i>Haplotaxida</i> spp. (live)	>50	5	0	—
<i>Haplotaxida</i> spp. (dead)	>50	5	5	1

<sup>a</sup> Body length (planarians, nemertine, slugs, and earthworm) or shell heights (snails).<sup>b</sup> Number of trials.<sup>c</sup> During experiment, one *Bipalium kewense* dead (not by predation).<sup>d</sup> During experiment, one *Bipalium* sp. dead (not by predation).<sup>e</sup> Both young and adult snails were preyed upon.Fig. 3. Styles of predation by *Platydemus manokwari* (Pm). a: live snail, *Achatina fulica* (Af); b: live land planarians, *Australopacifica* sp. (As). MA: mid-abdomen; PR: proboscis.

required on other tropical oceanic islands of the world.

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## REFERENCES

- Clarke, B., J. Murray and M. S. Johnson (1984) The extinction of endemic species by a program of biological control. *Pacific Science* 38: 97–104.
- Hopper, D. R. and B. D. Smith (1992) Status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H. E. Crampton in 1920. *Pacific Science* 46: 77–85.
- IUCN/SSC Mollusc Specialist Group (1995) Statement of concern and summary of recommendations. *Tentacle* 5: 13.
- Kaneda, M., K. Kitagawa and F. Ichinohe (1990) Laboratory rearing method and biology of *Platydemus manokwari* De Beauchamp (Tricladida: Terricola: Rhynchodemidae). *Appl. Entomol. Zool.* 25: 524–528.
- Kawakatsu, M., I. Okochi, H. Sato, T. Ohbayashi, K. Kitagawa and K. Totani (1999) A preliminary report on land planarians (Tubellaria, Seriata, Tricladida, Terricola) and land nemertine (Enopla, Hoplonemertea, Monostylifera) from the Ogasawara Islands. *Occasional Publications, Biological Laboratory of Fuji Women's College, Sapporo (Hokkaido), Japan* No. 32.
- Mead, A. R. (1963) A flatworm predator of the giant African snail *Achatina fulica* in Hawaii. *Malacologia* 1: 305–311.
- Ohbayashi, T. (2002) *Studies on the Ecology and Control of Achatina fulica in the Ogasawara Islands*. Tokyo Metropolitan Government, Tokyo. 66 pp.+3 pls. (in Japanese).
- Okochi, I., H. Sato and T. Ohbayashi (2004) The cause of mollusk decline in the Ogasawara Islands. *Biodiversity and Conservation* 13: 1465–1475.
- Takeuchi, K., S. Koyano and K. Numazawa (1991) Occurrence of the giant African snail in the Ogasawara (Bonin) Islands, Japan. *Micronesia Suppl.* 3: 109–116.
- Tomiyaama, K. (1991) Terrestrial molluscan fauna of Chichijima Islands, the Ogasawara Islands, with special reference to Ani-jima island. *Ogasawara Research* No. 17/18: 1–31 (in Japanese with English summary).
- Tomiyaama, K. (1994) Factors affecting the extinction of land snails on the Ogasawara Islands. *Venus* 53: 152–156 (in Japanese).
- Tomiyaama, K. (2002) Land mollusks of the Ogasawara Islands—the weakness of Oceanic island species. *Shinrin Kagaku* 34: 25–28 (in Japanese).
- Tomiyaama, K. and T. Kurozumi (1992) Terrestrial mollusks and conservation of their environment in the Ogasawara Islands. *Regional Views* 5: 39–81 (in Japanese with English summary).
- Waterhouse, D. F. and K. R. Norris (1987) *Achatina fulica* Bowdich. In *Biological Control-Pacific Prospects* (D. F. Waterhouse and K. R. Norris eds.). Inkata Press, Melbourne. pp. 265–273.