Taiwania, **52**(2): 145-151, 2007

Land Molluscan Fauna of the Dongsha Island with Twenty New Recorded Species

Shu-Ping Wu[1], Chung-Chi Hwang[2], Hui-Ming Huang[3], Hsueh-Wen Chang[4], Yao-Sung Lin[1,5] and Pei-Fen Lee[1,5,6]

(Manuscript received 19 October, 2006; accepted 10 February, 2007)

ABSTRACT: A thorough field survey concerning the land molluscan fauna of the Dongsha Island in the South China Sea was conducted in summer and fall, 2006. Twenty-six species belonging to thirteen families of land snail were recorded. Of these, 20 species and four families are new records. Emendations of five species from the previous records were also made. Alive adults along with juvenile individuals were collected in most of the species. Since no endemic land snail species was found, we proposed that the plausible origin of these land snails might have dispersed from adjacent localities or via artificial introduction.

KEY WORDS: Land molluscan fauna, Pratas Island, Taiwan, South China Sea, New recorded species.

INTRODUCTION

The Dongsha (Pratas) Island is situated at the western side of the Dongsha reef atoll and is the largest island in the South China Sea. The atoll has a reputation for abundance in fishery resources (Su et al., 1976; Lu and Shieh, 1981). There are several natural resources inventory conducted in the island and adjacent waters (Chang et al., 1995; Chen et al., 1991; Chiang, 1975; Huang et al., 1994; Jeng et al., 2005; Severinghaus et al., 2005). Of these previous studies recording land and aquatic fauna as well as flora, a total of 11 species from nine families of land snails were recorded (Chang et al., 1995).

In the preparation for the establishment of the Dongsha Marine National Park, investigations and fieldwork surveys concerning biological resources, archaeologies and anthropogeography were carried out recently. This study represents an effort on the terrestrial fauna and flora inventory research sponsored by the Construction and Planning Agency, Ministry of the Interior. In particular, we conducted a thorough inventory on the land molluscan fauna in the Dongsha Island and studied the distribution and taxonomy of these species. We also discussed the origin, dispersal pathway and biogeography of the snails.

1. Institute of Ecology and Evolutionary Biology, National Taiwan University, 1, Sec. 4, Roosevelt Rd, Taipei 106, Taiwan.
2. Department of Bioresources, Da-Yeh University, 112, Shan-Jiau Rd, Da-Tusen, Changhua 515, Taiwan.
3. Department of Life Science, Fu-Jen Catholic University, 510, Chung Cheng Rd., Hsinchuang, Taipei County 242, Taiwan.
4. Department of Biological Sciences, National Sun Yat-sen University, 70, Lien-hai Rd. Kaohsiung 804, Taiwan.
5. Department of Life Sciences, National Taiwan University, 1, Sec. 4, Roosevelt Rd, Taipei 106, Taiwan.
6. Corresponding author. Tel: 886-2-33662469; Fax: 886-2-23623501; Email: leepf@ntu.edu.tw

MATERIALS AND METHODS

Study Area

The Dongsha Island (116°43'51"E, 20°42'52"N) is located at the northern part of the South China Sea, 430 km off Kaohsiung City, Taiwan (Lee et al., 2006; Fig. 1). The island is horseshoe-shaped with a lagoon opening to the west, measured 2800 m diagonally from east to west and approximately 860 m from north to south. The total surface area of the cay measured 1.74 km^2 and the lagoon 0.64 km^2. The highest altitude above sea level is 7 meters; the annual average atmospheric temperature was recorded at 25.3°C. Despite the 1350 mm of annual rainfall, no native freshwater ponds or streams were found on the island. As the island is located in the northern Torrid Zone, the typical climate is scorching hot, regardless of day or night, and humid with tropical monsoon. The island is not layered by soil, instead it is covered by fine sands and weathered dead corals and shells. The vegetation mainly consisted of coastal shrubs and low shrubberies such as Screw Pine (*Pandanus odoratissimus*), Hainan Naupaka (*Scaevola hainanensis*), Hauil Fig Tree (*Ficus septica*) (Huang et al., 1994). Much of the

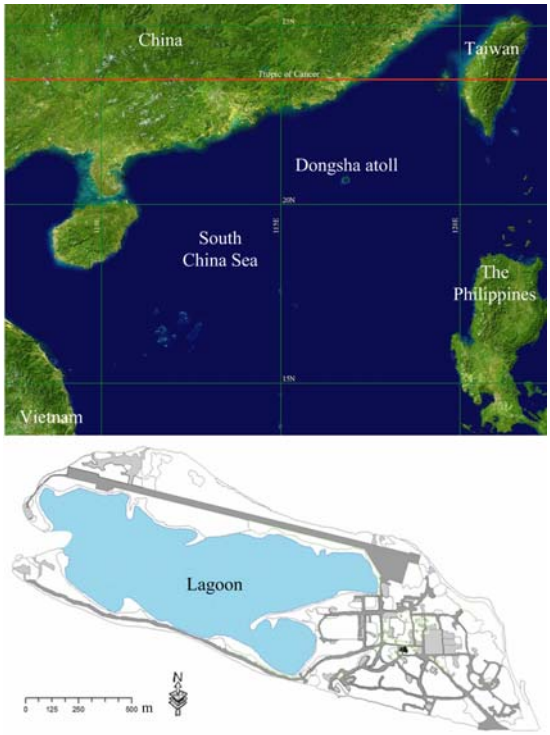

Fig. 1. Geography of the Dongsha Island in the South China Sea with an aerial photo showing the vegetation cover and lagoon.

observed vegetation belonged to a secondary or artificial introduction due to the fishery exploitation during the past hundred years and the military campus upon more than half a century ago.

Samples Collection

The field study of land mollusks was carried out twice, 8-11th August and 5-7th September, 2006. A grid map of the Dongsha Island was generated from a GIS, overlaid with a 1:5,000 aerial photo (Fig. 1), and used as a reference map to record the collection sites. Collection methods were adapted from Chang (1993) and Hawkins et al. (1998) with minor modifications. A series of sieves (10×10 mm, 5×5 mm, 2×2 mm and 1×1 mm) was applied to collect micro land snails in the defoliation layer and sands under low shrubbery woods. Searches for semi-arboreal snails were performed on herbaceous plants and low shrubs. All samples, regardless of dead or alive, slugs or snails were collected and preserved in 95% alcohol, and then brought back to the laboratory for further examination. Detailed records (site, habitat, date and others) of collection were kept by the senior author. The voucher specimens in this study are deposited in the National Taiwan Museum, Taipei (TMMT P0290-P0319).

RESULTS

A total of 26 species in 13 families of land molluscan were found during these surveys in the Dongsha Island (Fig. 2, Table 1). Of these, 20 species and four families were previously unrecorded. The collected specimens were analyzed and compared with those in the study conducted by Chang et al. (1995). As a result, five species were found to be assigned with incorrect scientific names either by wrong identification or nomenclatural act (Table 2). Distinct from the past study, most land snail species were collected alive in our study with the exception of *Assiminea nitida*, *Melampus flavus* and *Zonitoides arboreus*.

The distribution patterns of these land snails on the island are variable. The majority of snails are distributed throughout the whole island such as *Laevicaulis alte*, *Bradybaena similaris*, *Nesopupa yamagutii* and *Achatina fulica*, yet there are a small fraction of snails that only occur in narrow ranges. For instance, species of the family Truncatellidae and Ellobiidae are only found in moist mud of the lagoon area and a few coastal muddy areas of the southern shoreline. The newly recorded bradybaenid snail *Acusta tourannensis*, which is particularly widespread in southeastern Asia, only distributed in a limited shrubbery zone situated at the eastern part of the island. The notoriously invasive *Achatina fulica* was the largest land snail and most abundant in the Dongsha Island. A large number of land hermit crabs (*Coenobita rugosus*) were observed to live in the empty shells of these giant African snails.

The Dongsha Island does not have any endemic or new species, however, one vertiginid snail *Nesopupa yamagutii*, endemic to Taiwan Island, was found in abundance on the island. The helicarionid snail, *Liardetia yaeyamensis* initially distributed from Okinawa Islands to Taiwan was also found in abundance (Chang et al., 1995; Kuroda, 1958; Ueshima, 1989). The rest of the species can be found in the vicinity of sub-tropical and tropical Pacific-Asian areas (Azuma, 1982; Faustino, 1930; Hsieh et al., 2006; Kuroda, 1941, 1958; Masuda and Uchiyama, 2004; Pilsbry and Hirase, 1906; Pilsbry, 1916-1918).

DISCUSSION

Chang et al. (1995) postulated that many land snail of the Dongsha Island went through a “colonization-survival and extinction” process, due to most samples collected were dead (4 alive species out of a total of 11 recorded). According to our study,

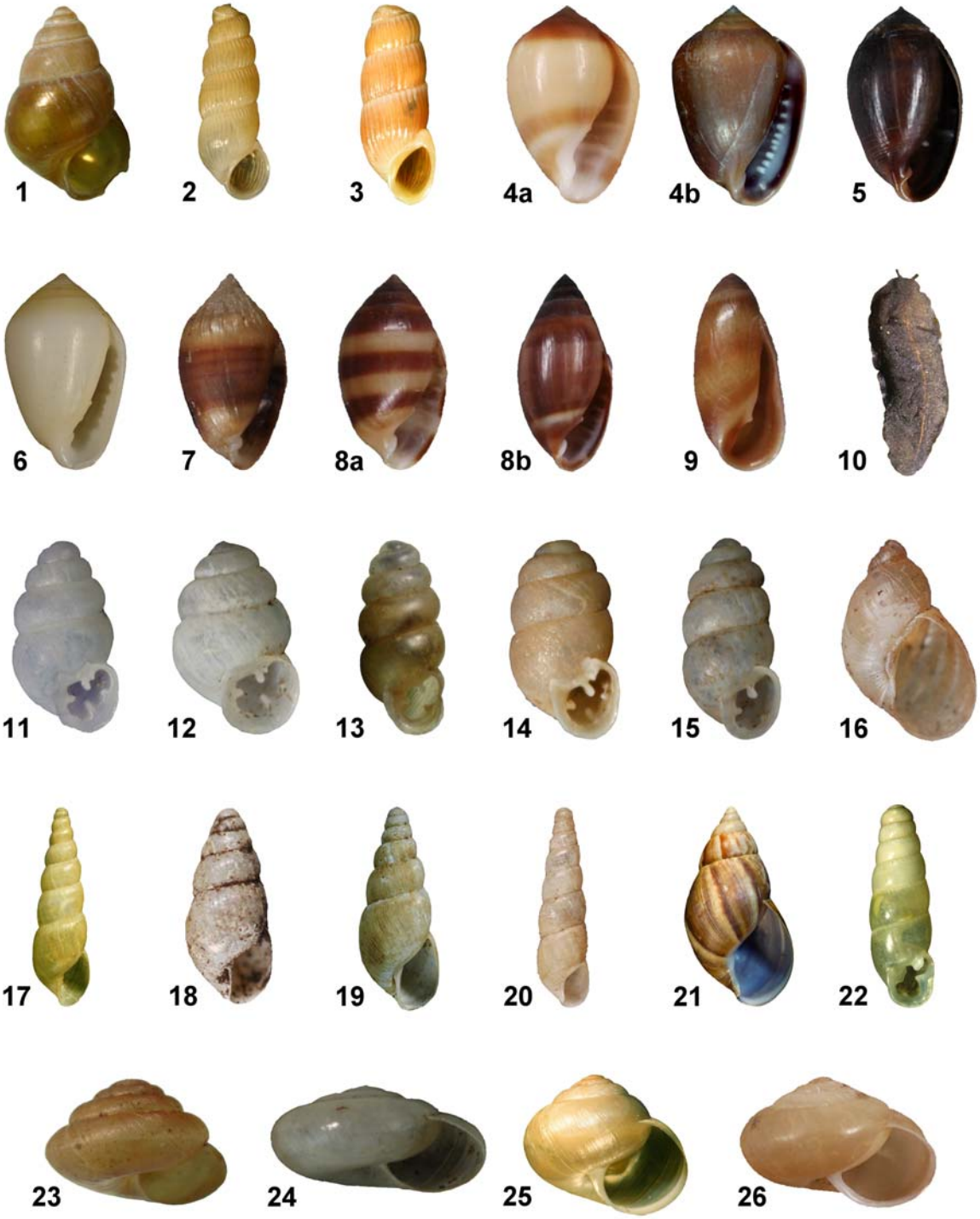

Fig. 2. Land molluscan of the Dongsha Island. 1: *Assiminea nitida* (2.4 mm). 2: *Truncatella guerinii* (10 mm). 3: *T. pfeifferi* (7 mm). 4a: *Melampus castanea* (juvenile, 7 mm). 4b: *M. castanea* (adult, 12 mm). 5: *M. nuxeastaneus* (11 mm). 6: *M. flavus* (15 mm). 7: *M. sculptus* (6.8 mm). 8a, 8b: *M. taeniolatus* (8 mm). 9: *Tralia malanastoma* (5.8 mm). 10: *Laevicaulis alte* (52 mm). 11. *Gastrocopta pediculus* (2.5 mm). 12: *G. pediculus ovatula* (2 mm). 13: *G. servilis* (2.4 mm). 14: *Nesopupa yamagutii* (1.8 mm). 15: *Vertigo* sp. (3 mm). 16: *Succinea erythrophana* (9 mm). 17: *Lamellaxis gracilis* (11 mm). 18: *L. turgidulum* (5.6 mm). 19: *Paropeas achatinaceum* (9 mm). 20: *Subulina octona* (16.7 mm). 21: *Achatina fulica* (80 mm). 22: *Indoennea bicolor* (6 mm). 23: *Liardetia yaeyamensis* (3.5 mm). 24: *Zonitoides arboreus* (4.3 mm). 25: *Acusta tourannensis* (20 mm). 26: *Bradybaena similaris* (14 mm).

Table 1. A checklist of the land snail species from the Dongsha Island.

Family	Species	Abundance class	Habitat	Status
Assimineidae*	*Assiminea nitida* (Pease, 1864)	Uncommon	Mud, under rocks or sea weeds	*
Truncatellidae	*Truncatella guerinii* A. & J. B. Villa, 1841	Uncommon	Mud, under rocks or sea weeds	*
	Truncatella pfeifferi Martens, 1860	Abundant	Mud, under rocks or sea weeds	* #
Ellobiidae*	*Melampus castanea* (Mühlfeld, 1818)	Uncommon	Mud, under rocks or sea weeds	*
	Melampus nuxeastaneus Kuroda, 1949	Uncommon	Mud, under rocks or sea weeds	*
	Melampus flavus (Gmelin, 1791)	Rare	Mud, under rocks or sea weeds	*
	Melampus sculptus (Pfeiffer, 1855)	Rare	Mud, under rocks or sea weeds	*
	Melampus taeniolatus (Hombron et Jacquinot, 1854)	Uncommon	Mud, under rocks or sea weeds	*
	Tralia malanastoma Garrett, 1873	Uncommon	Mud, under rocks or sea weeds	*
Veronicelloidae	*Laevicaulis alte* (Férussac, 1821)	Common	Ground or under the shrubs	
Pupillidae	*Gastrocopta pediculus* (Shuttleworth, 1852)	Common	Under the shrubs	* #
	Gastrocopta pediculus ovatula (Moellendorff, 1890)	Rare	Under the shrubs	*
	Gastrocopta servilis (Gould, 1843)	Uncommon	Under the shrubs	*
Vertiginidae	*Nesopupa yamagutii* Kuroda, 1941	Common	Under the shrubs	§
	Vertigo sp.	Rare	Under the shrubs	*
Succineidae	*Succinea erythrophana* Ancey, 1883	Common	Under the shrubs or on rocks	*#
Subulinidae	*Lamellaxis gracilis* (Hutton, 1834)	Abundant	Under the shrubs	#
	Lamellaxis turgidulum (Heude, 1841)	Rare	Under the shrubs	*
	Paropeas achatinaceum (Pfeiffer, 1846)	Rare	Under the shrubs	*#
	Subulina octona (Bruguiere, 1792)	Rare	Under the shrubs	*
Achatinidae	*Achatina fulica* Bowdich, 1822	Abundant	Ground or under the shrubs	
Streptaxidae*	*Indoennea bicolor* (Hutton, 1834)	Uncommon	Under the shrubs	*
Helicarionidae	*Liardetia yaeyamensis* (Pilsbry, 1901)	Abundant	Under the shrubs	
Zonitidae*	*Zonitoides arboreus* (Say, 1816)	Rare	Under the shrubs	*
Bradybaenidae	*Acusta tourannensis* (Souleyet, 1842)	Uncommon	Under the shrubs or semi-arboreal	*
	Bradybaena similaris (Férussac, 1822)	Common	Under the shrubs or semi-arboreal	

Abundance class: Abundant > 100; Common = 30-99; Uncommon = 5-29; Rare < 5 of total sampling.
* New record of the Dongsha Island
§ Endemic to Taiwan
# Emendation

Table 2. Emendation of the land snail fauna from the Dongsha Island.

Former Record (1995)	Emendation	Account
Truncatellidae		
Truncatella takaoensis	*Truncatella pfeifferi*	Unavailable name
Pupillidae		
Gastrocopta ooi	*Gastrocopta pediculus*	Incorrect identification
Succineidae		
Succinea rubella	*Succinea erythrophana*	Invalid homonym
Subulinidae		
Allopeas javanicum	*Paropeas achatinaceum*	Junior synonym (Naggs, 1994)
Allopeas pyrgula	*Lamellaxis gracilis*	Incorrect identification

23 living species were collected in a 26 species pool and many of them were found along with juvenile individuals. This indicates that most land snails on the island have established an effective reproductive population instead of the random invasion followed by survival and finally extinction model.

We propose that the land snail fauna of the Dongsha Island might originate from two possible pathways, first by dispersal from adjacent islands of south Asia or mainland Asia and secondly by colonization of artificial introduction. Many island organisms migrate or disperse via incidental events (Hengeveld and Hemerik, 2002; Grant, 1998; Whittaker, 1998) such as ocean currents, floating woods or migratory birds that can transfer micro snails across the ocean. Snails of pupillid and vertiginid are commonly widespread species of the tropical Pacific islands belonging to spontaneous dispersal pathway. Furthermore, the semi-terrestrial species or coastal inhabitant pulmonates like truncatellid and ellobiid species are native of the South China Sea. The truncatellid species *Truncatella pfeifferi*, recorded previously as *Truncatella takaoensis* and now emendated, has an abundant population at the lagoon and the seaweed beach on the southern coast. *Truncatella guerinii*, another widely distributed species of the same family, inhabited at brackish water of the Indo-Pacific including Japan, Okinawa Islands, Taiwan, the Philippines, Australia and the Indian

Ocean (Hsieh et al., 2006; Smith, 1992). In Dongsha, *Truncatella guerinii*, a newly recorded species, were found only on the southern beach with significantly small population; none were found in the lagoon area. The semi-terrestrial ellobiid pulmonates were found to share similar habitats with the truncatellid species. Although there were no existing records of this family within the Dongsha Island fauna, we collected six species in the muddy and seaweed coast of the lagoon and the southern beach (Table 1). These native species of the South China Sea can disperse easily from their primary areas to the Dongsha Island.

The second pathway is colonization via artificial introduction intentionally or unintentionally (Barker, 2001; Carlsson et al., 2004). Dongsha has maintained a natural state before 1900 when only Chinese fishermen come for short visits during the operation period. Based on the descriptions by Collingwood (1867), the vegetation was dense and only a scattered usage was evidential. The only large scale development started at the beginning of the 20th century. We suspect that some of the snail species established their population during this period by human introduction. For instance, the giant African snails (*Achatina fulica*) were artificially spread from their African origin and invaded into many South Asian countries including Taiwan for the reason of local food resources (Kuroda, 1958). Moreover, species of the family Subulinidae and Bradybaenidae, such as *Lamellaxis gracilis* and *Bradybaena similaris*, have nearly invaded worldwide through crops or horticulture plants imports (Barker, 2001; Hsieh et al., 2006). The military campus of the Dongsha Island has existed for more than half a century and cultivated a wide variety of crops shipped from the mainland (Huang et al., 1994). Furthermore, the Dongsha Island has been in use by the fishermen from China, Japan and other surrounding countries for the past hundred years (Chen, 1997; Chen and Tang, 1997). The abundant records of shipwreck (C. P. Lee, pers. comm.) in the waters near the island also suggest the possibility.

The ecology in an island is both fragile and vulnerable (Grant, 1998; Whittaker, 1998). Dongsha has gone through tremendous changes since early 20th century due to the massive mining by the Japanese, and heavily exploitation of fishery byChina, Vietnam, Hong Kong, and Taiwan. It is for this reason that the island and its adjacent waters were proposed to become a National Park. As the current plan, the park will become fully in operation in early 2007 and will not open for tourism in the first five years for the purpose of ecological recovery. However, we expect to see a large number of tourists and various pollutions once the park is open to the public that will bring unexpected impact to this small island. To better preserve the natural resources in the island, we suggest a detailed, systematic and long-term monitoring on the fauna and flora in the island, not just conducting biological resources inventory.

ACKNOWLEDGMENTS

We thank Y.-Y. Lian and J.-W. Lin for field assistances. The Coast Guard Administration of Executive Yuan provides logistic supports. This study was partially supported by the Construction and Planning Agency, Ministry of the Interior (PG9506-0334) and the National Science Council, Taiwan, ROC.

LITERATURE CITED

Azuma, M. 1982. Colored Illustrations of the Land Snails of Japan. Hoikusha, Osaka, Japan. 343pp. (in Japanese)

Barker, G. M. 2001. The Biology of Terrestrial Molluscs. CABI Publishing, Wallingford, UK. 558pp.

Hengeveld, R. and L. Hemerik. 2002. Biogeography and dispersal. In: Bullock, J. M., R. Kenward and R. S. Hails (eds.), Dispersal Ecology. Blackwell Publishing, MA, USA. pp. 303-326.

Carlsson, N. O. L., C. Bronmark and L. A. Hasson. 2004. Invading herbivore: the golden apple snail alters ecosystem functioning in Asian wetlands. Ecology **85**:1575-1580.

Chang, H.-W. 1993. Ecological methods for study non-marine mollusks. Chin. Biosci. **36**: 65-70. (in Chinese)

Chang, H.-W., C.-C. Hwang, K.-C. Liu and K.-M. Chang. 1995. The Land Molluscan Fauna of Tung-Sha Island, the South China Sea. Bul. of. Mala., ROC **19**: 83-88.

Chen, L.-S., K.-T. Shao, L.-S. Fang and L.-T. Her. 1991. Preliminary checklist of fishes from the waters at Tung-Sha Tao (Pratas Island), South China Sea. Acta Oceanogr. Taiwanica **27**: 98-121.

Chen, C.-Y. 1997. The preliminary archeological investigation of Dongsha and NanSha Taiping Islands. Bull. Inst. Hist. Philol. Acad. Sinica **68**: 449-502. (in Chinese)

Chen, C.-Y. and Z.-D. Tang. 1997. Change in natural ecology, environmental and anthropogeography of Tung-Sha Island within the past century. Bull.

Natl. Cent. Lib. (Taiwan Branch) **3**: 85-95. (in Chinese)

Chiang, Y.-M. 1975. A general survey of Tung-Sha Tao. part II. marine plants. Institute of Oceanography, National Taiwan University, Special Publication No. **8**: 16-22.

Collingwood, C. 1867. The natural history of Pratas Island, in the China Sea. Q. J. Sci.: 145-152.

Faustino, L. A. 1930. Summary of Philippine land shells. Philipp. J. Sci. **42**: 85-198.

Grant, P. R. 1998. Evolution on Island. Oxford Univ. Press, NY, USA. 334pp.

Hawkins, J. W., M. W. Lankester and R. R. A. Nelson. 1998. Sampling terrestrial gastropods using cardboard sheets. Malacologia **39**: 1-9.

Hsieh, B.-C., C.-C. Hwang and S.-P. Wu. 2006. Landsnails of Taiwan (2nd ed.), Forestry Bureau Council of Agriculture, Executive Yuan, Taipei, Taiwan. 277pp. (in Chinese)

Huang, T.-C., H.-F. Huang, T.-H. Hsieh, K.-C. Yang and C.-C. Liu. 1994. The flora of Tungshatao. Annu. Taiwan Mus. **37**: 89-106. (In Chinese, English abstract)

Jeng, M.-S., K.-T. Shao, C.-F. Dai, C.-P. Chen, S.-M. Lin and P.-J. Meng. 2005. Marine resources inventory of Dongsha Marine National Park. Ministry of the Interior, Taipei, Taiwan. 195pp.

Kuroda, T. 1941. A catalogue of molluscan shells from Taiwan (Formosa), with description of new species. Memoirs of the Faculty of Science and Agriculture, Taihoku Imperial University **22**: 65-216. (in Japanese)

Kuroda, T. 1958. The land shell fauna of Japan and adjacent areas (4). Venus **20**:132-151. (in Japanese)

Lee, P.-F., J.-Y. Ko, Z.-R. Ko and Y.-Y. Lian. 2006. Dongsha: An introduction to Dongsha Marine National Park, Taiwan. Construction and Planning Agency, Ministry of the Interior, Taipei, Taiwan. 183pp.

Lu, T.-H. and J.-F. Shieh. 1981. The fishing ground exploitation in South China Sea. I. Studying on the fishing efficiency of angling gears in the fishing ground near the Pratas Island. Bull. Taiwan Fis. Res. Inst. **31**: 81-94.

Masuda, O. and R. Uchiyama. 2004. PISCES Ecological Field Guide Series 2 Freshwater Mollusks of Japan. (2) Freshwater Mollusks of Japan. Including Brackish Water Species. PISCES Publishers Co., Tokyo, Japan. pp. 121-149. (in Japanese)

Naggs, F. 1994. The reproductive anatomy of *Paropeas achatinaceum* and a new concept of *Paropeas* (Pulmonata: Achatinoidea). J. Moll. Stud. **60**: 175-191.

Pilsbry, H. A. and Y. Hirase. 1906. Catalogue of the land and fresh-water mollusca of Taiwan (Formosa), with descriptions of new species. Proc. A. N. S. P. **57**: 720-752.

Pilsbry, H. 1916-1918. Manual of Conchology, 2nd series, Vol. 24, Pupillidae (Gastrocoptinae). A. N. S. P. Press, Philadelphia, USA. 380pp.

Severinghaus, L. L., C.-F. Hsieh, M.-M. Yang, I.-M. Tso, H.-Y. Wu and M.-C. Tu. 2005. Terrestrial biological resources inventory of the Dongsha Marine National Park. Ministry of the Interior, Taipei, Taiwan. 82pp. (in Chinese)

Smith, B. J. 1992. Non-Marine Mollusca. In: Houson, W. W. K. (ed.), Zoological Catalogue of Australia AGPS 8, Canberra, AU. 405pp.

Su, W.-C., G.-F. Jane, K.-H. Chan and C.-C. Yes. 1976. Exploiting investigation of the fishing ground of Pratas Islands. Bull. Taiwan Fis. Res. Inst. **27**: 59-65.

Ueshima, R. 1989. Generic position of *Keliella yaeyamensis* Pilsbry, 1901 (Pulmonata: Helicarionidae). Venus **48**: 85-95.

Whittaker, R. J. 1998. Island Biogeography: Ecology, Evolution, and Conservation. Oxford University Press, NY, USA. pp. 64-82, 144-191.

東沙島陸生軟體動物相與二十種新紀錄種

吳書平[(1)]、黃重期[(2)]、黃惠敏[(3)]、張學文[(4)]、林曜松[(1,5)]、李培芬[(1, 5, 6)]

(收稿日期：2006 年 10 月 19 日; 接受日期：2007 年 2 月 10 日)

摘　　要

2006 年夏秋兩季在東沙島進行詳盡的陸生軟體動物相調查，共紀錄 13 科 26 種，其中 4 科 20 種為新紀錄。多數種類發現活體與幼體，5 種舊紀錄種分類誤植亦予以校訂。東沙島無特有種陸生軟體動物，我們推測其種源應由鄰近地區自然擴散播遷或經人為引入。

關鍵詞：陸生軟體動物相、東沙島、臺灣、南中國海、新紀錄種。

1. 國立臺灣大學生態學與演化生物學研究所，106 台北市羅斯福路 4 段 1 號，臺灣。
2. 大葉大學生物資源學系，515 彰化縣大村鄉山腳路 112 號，臺灣。
3. 輔仁大學生命科學系，242 台北縣新莊市中正路 510 號，臺灣。
4. 國立中山大學生物科學系，804 高雄市蓮海路 70 號，臺灣。
5. 國立臺灣大學生命科學系，106 台北市羅斯福路 4 段 1 號，臺灣。
6. 通信作者。Tel: 886-2-33662469; Fax: 886-2-23623501; Email: leepf@ntu.edu.tw