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NEW RECORDS OF THREE DEEP-SEA BATHYMODIOLUS MUSSELS (BIVALVIA: MYTILIDA: MYTILIDAE) FROM HYDROTHERMAL VENT AND COLD SEEPS IN TAIWAN

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Acknowledgements

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NEW RECORDS OF THREE DEEP-SEA *BATHYMODIOLUS* MUSSELS (BIVALVIA: MYTILIDA: MYTILIDAE) FROM HYDROTHERMAL VENT AND COLD SEEPS IN TAIWAN

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Key words: new record, *Bathymodiolus*, deep-sea, hydrothermal vent, cold seep, Taiwan.

ABSTRACT

The deep sea mussel genus, *Bathymodiolus* Kenk & Wilson, 1985, contains 31 species, worldwide. Of which, one endemic species (*Bathymodiolus taiwanesis*) was reported from Taiwan (MolluscaBase, 2018). Herein, based on the mitochondrial COI results, we present 3 new records of the *Bathymodiolus* species from Taiwan, namely *Bathymodiolus platifrons*, *Bathymodiolus securiformis*, and Sissano *Bathymodiolus* sp.1 which were collected from vent or seep environments at depth ranges of 1080-1380 m. Therefore, a total of four species in the genus of *Bathymodiolus* are now known from Taiwan.

I. INTRODUCTION

The genus of *Bathymodiolus* (Family: Mytilidae) consists of species entirely living at hydrothermal vent or cold seep environments. This genus, *Bathymodiolus,* has 31 deep-sea species worldwide (MolluscaBase, 2018). To date, *Bathymodiolus taiwanesis* (von Cosel, 2008) is the only reported species of this genus from Taiwan. It was collected from hydrothermal vents near Kueishan Islet off the northeast coast of Taiwan at depths of 200-355 m.

Along with traditional morphological classification, molecular techniques are commonly used to study the taxonomy and phylogenetic relationships of deep sea mussels. Recently, the complete mitochondrial genomes have been sequenced from mussels of *Bathymodiolus japonicus*, *B. platifrons* and *B. septemdierum* (Ozawa et al., 2017). Even more, the whole genome of *B. platifrons* was reported with sequence length of 1.64 Gb nucleotides (Sun et al., 2017).

Since 2013, under the Phase II National energy program of "Gas hydrate investigation and survey", deep sea cold seep environments offshore of Taiwan were explored. A series of deep-sea cruises were conducted and *Bathymodiolus* mussels were collected. Here, three new records were reported based on the sequenced results of COI gene.

II. MATERIALS AND METHODS

Specimens of *Bathymodiolus platifrons*, *Bathymodiolus securiformis*, and *Bathymodiolus* sp. were collected from hydrothermal vent (Okinawa Trough) or cold seeps (Formosa Ridge, Four Way Closure Ridge) at depths of 1000-1300 m (Fig. 1). Voucher specimens were preserved in 70% ethanol and deposited in the National Museum of Natural Science (NMNS), Taichung, Taiwan (see Table 1).

Crude DNA was extracted using the Tissue & Cell Genomic DNA Purification Kit (GeneMark, DP021-150), following the manufacturer's instructions. Part of adductor muscles or mantle tissues (5-25 mg) were homogenized with extraction solution and proteinase K, incubated at 60°C, about 2-3 hours. Samples were then lysed and centrifuged several times to precipitate nuclei and debris. Finally, 50 μl double-distilled water was added

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Table 1. List of sampling dates and sites of *Bathymodiolus* mussels. N: sample size.

Species	Sampling site		Cruise	Latitude, Longitude	Depth (m)	Date	N
Bathymodiolus platifrons	Formosa Ridge	39-2	SO 227	22°06.94′N; 119°17.12′E	1079	2013.04.27	2
		42-2	SO 227	22°06.97′N; 119°17.13′E	1150	2013.04.29	1
		50-1	SO 227	22°06.93′N; 119°17.12′E	1122	2013.05.01	2
	Four Way Closure Ridge	-	OR3-1994	22°03.51′N; 119°48.02′E	1300	2017.05.03	1
		Dive 3	OR3-2025	20°03.50′N; 119°48.03′E	1350	2017.09.27	1
		Dive 4	OR3-2025	20°03.50′N; 119°48.02′E	1347	2017.09.28	2
	Okinawa Trough	-	OR1-1139	24°50.74′N; 122°41.99′E	1383	2016.06.12	1
		-	OR1-1202	-	-	2018.07	2
Bathymodiolus securiformis	Four Way Closure Ridge	-	OR3-1994	22°03.51′N; 119°48.02′E	1300	2017.05.03	2
Sissano *Bathymodiolus* sp.1	Formosa Ridge	42-2	SO 227	22°06.97′N; 119°17.13′E	1150	2013.04.29	2

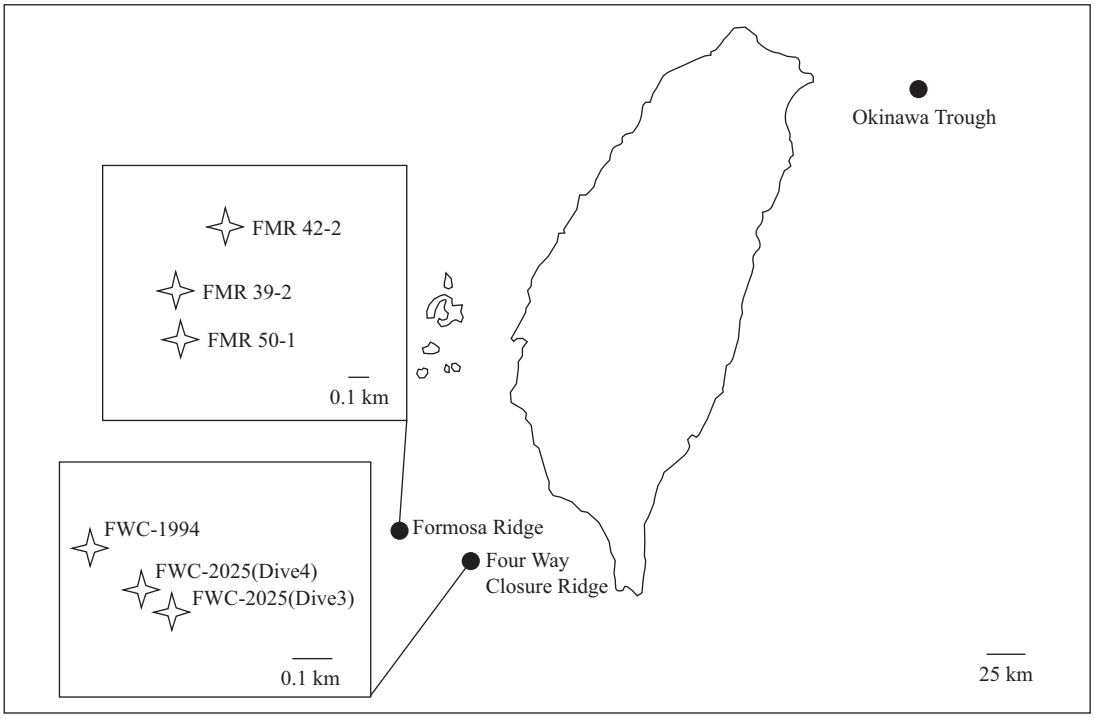

Fig. 1. Map showing collection sites of *Bathymodiolus* mussels.

to the resulting DNA pellets, stored at -20°C for later use.

The sequences of mitochondrial COI were amplified by PCR using the sense primer LCO1490: 5'-ggtcaacaaatcataaagatattgg-3' and the antisense primer HCO2198: 5'-taaacttcagggtgaccaaaaaatca-3' (Folmer, 1994). Amplification was conducted in a thermal cycler (Applied Biosystems 2720), the PCR condition was as follows: initial denaturation step at 94°C for 5 min, followed by another 40 cycles: denaturation at 94°C for 30 s, annealing at 53°C for 30 s and extension at 72°C for 20 s. Then 72°C for 7 min for the final extension step. The amplified DNA was directly sequenced on an automated DNA sequencer (Applied Biosystems 3730xl DNA Analyzer). Additional sequences from NCBI database were also used, and the sequence of *Modiolus nipponicus* (accession number: AB076912.1) was used as the outgroup taxa.

The obtained sequences were aligned using the CLUSTAL W in MEGA v. 6. (Tamura et al., 2013), the Kimura 2-parameter model, and maximum-likelihood (ML) method (Kimura, 1980). Bootstrap probability (BS) estimates (1,000 replicates) (Felsenstein, 1985) were also made to indicate robustness of nodes in neighbour- joining trees.

III. TAXONOMY

The resulting sequence length of COI for *Bathymodiolus*

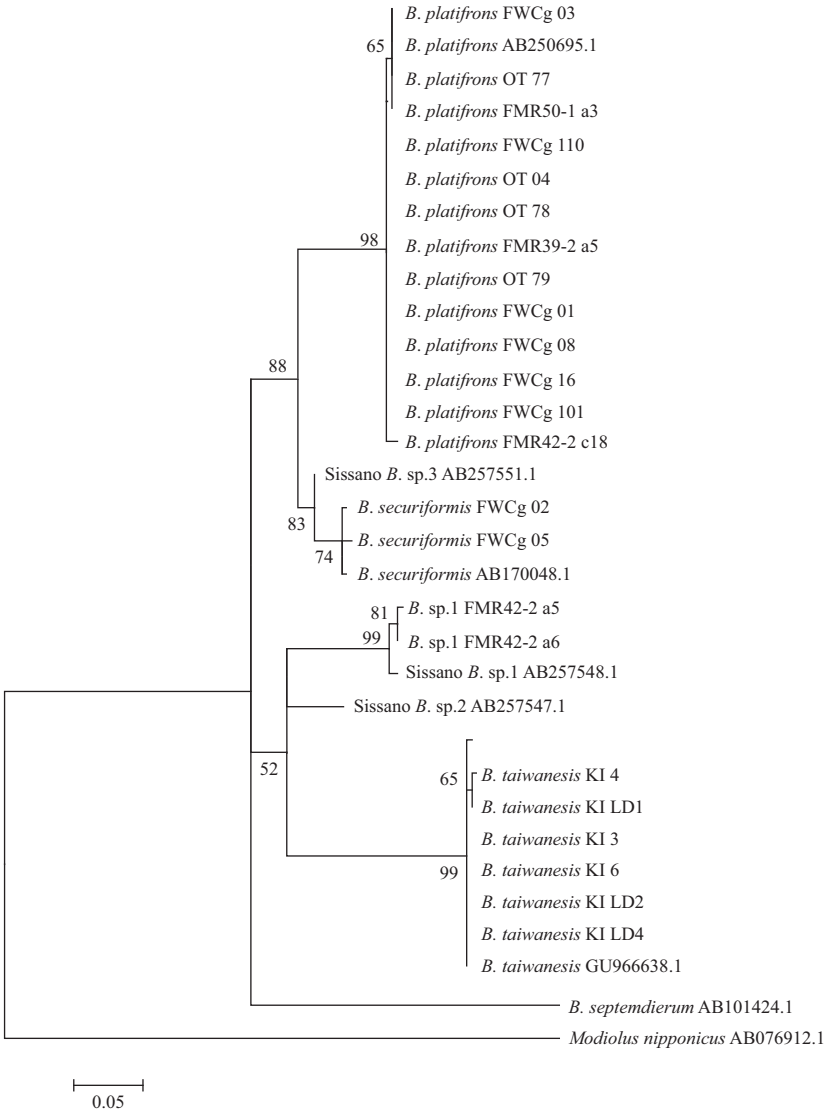

Fig. 2. The maximum-likelihood tree based on mitochondrial COI sequences obtained from *Bathymodiolus* mussel specimens from Taiwan, and combined with additional sequences from NCBI database. FMR: Formosa Ridge; FCWg: Four Way Closure Ridge; KI: nearby Kueishan Islet; OT: Okinawa Trough.

mussels was approximately 710 bp nucleotides. And, the COI sequences of examined species are provided in Appendix 1. Neighbour-Joining (NJ) analysis on COI gene from seven *Bathymodiolus* species grouped the same species into one sub-clade with bootstrap support of 74-99% (Fig. 2). The unknown *Bathymodiolus* sp. collected from Formosa Ridge was grouped to the clade of Sissano *Bathymodiolus* sp.1. Based on the results, a total of three *Bathymodiolus* new records were obtained. The descriptions of the three *Bathymodiolus* mussels are as follows.

Family Mytilidae Rafinesque, 1815
Genus *Bathymodiolus* Kenk & Wilson, 1985
Bathymodiolus platifrons Hashimoto & Okutani, 1994 (Fig. 3)

Bathymodiolus platifrons Hashimoto & Okutani, 1994: 64, fig. 2; pl. 1, figs. 1-2; pl. 2, fig. 3; pl. 3, fig. 1; Sasaki, Okutani and Fujikura 2005: 87, fig. 5D; Kurozumi, 2017: 1172, pl. 476, fig. 5

Type depository

Holotype, NSMT (National Science Museum, Tokyo)-Mo 70026

Type locality

Okinomiya Bank, Sagami Bay, Japan, 1180 m, seep

Material examined.

2 specimens from Okinawa Trough (24° 50.7408′N, 122° 41.9991′E), depth 1383 m (OR1-1139, June 12, 2016); 4 specimens from Four Way Closure Ridge (22°03.507′N, 119° 48.016′E), depth 1300 m (OR3-1994, May 3, 2017); 2 specimens from Formosa Ridge 39-2 (22° 6.94′N, 119° 17.12′E), depth 1079 m (RV SONNE cruise SO227, April 27, 2013), 1

(a) Formosa Ridge (SL = 76.83 mm) (b) FourWay Closure Ridge (NMNS-7993-010) (SL = 56.11 mm) (c) OkinawaTrough (SL = 85.87 mm)

Fig. 3. ***Bathymodiolus platifrons*, exterior and interior view of left valve. Scale bar 5 mm.**

specimens from Formosa Ridge 42-2 (22° 06.971′N, 119° 17.133′E), depth 1150 m (RV SONNE cruise SO227, April 29, 2013), 2 specimens from Formosa Ridge 50-1 (22° 06.930′N, 119° 17.119′E), depth 1122 m (RV SONNE cruise SO227, May 1, 2013).

Measurements of selected specimens.

Cruise	Museum code	Sampling code	Shell length (mm)	Shell height (mm)	Shell width (mm)
SO227	NMNS-7993-002	50-1 a14	53.27	30.32	24.40
SO227	NMNS-7993-003	39-2 a15	62.48	34.99	27.04
SO227	NMNS-7993-004	39-2 a5	63.06	31.13	24.38
SO227	NMNS-7993-005	42-2 c18	50.89	30.30	22.44
SO227	NMNS-7993-006	50-1 a3	107.18	51.97	44.33
OR3-1994	NMNS-7993-007	FWCg 01	83.60	40.16	36.61
OR3-2025	NMNS-7993-008	FWCg 08	69.85	36.60	27.88
OR3-2025	NMNS-7993-009	FWCg 16	81.17	39.99	30.86
OR3-2025	NMNS-7993-010	FWCg 101	56.11	33.05	22.39
OR1-1139	NMNS-7993-013	OT 04	51.11	28.84	22.71
OR1-1202	NMNS-7993-014	OT 78	53.66	30.28	23.48
OR1-1202	NMNS-7993-015	OT 79	16.79	9.75	7.04

Distribution

Distribution in Northwest Pacific. In methane seep environments: Sagami Bay, Myojin Knoll, Four Way Closure Ridge and Formosa Ridge; in hydrothermal vent: Okinawa Trough. Depth ranges 1000-1500 m (Kyuno et al., 2009; Kurozumi, 2017; Sasaki et al., 2005).

Diagnosis

Shell inflated, modioliform, rounded-triangular. Umbones prosogyrated, nearly subterminal. Umbonal ridge prominent. Anterior portion of shell low and narrow. Posterior margin broadly rounded, ventral margin slightly concave or nearly straight. Posterodorsal corner weakly angulated. Priostracum smooth and brown.

Description

Shell large, up to 107.2 mm, height/length ratios 0.48-0.60; and width/length ratios 0.38-0.46.

Remarks

The occurrence of *Bathymodiolus platifrons* has been reported by Lin et al., 2007) from Formosa Ridge. The present material was deposited in the NMNS [see page 2], Taichung, Taiwan.

Bathymodiolus securiformis
Okutani, Fujikura & Sasaki, 2004 (Fig. 4)

Bathymodiolus securiformis - Okutani, Fujikura and Sasaki, 2004: 105 (Okutani et al., 2003), figs. 4C, D, 7C, D, 8, 9.; Sasaki, Okutani and Fujikura 2005: 87 (Sasaki et al., 2005), Fig. 5E; Kurozumi, 2017: 1172 (Kurozumi, 2017), pl. 477, fig. 2.

Type depository.

Holotype, UMUT (University Museum of the University of Tokyo)-RM 28478

Type locality

Kuroshima Knoll off the Yaeyama Islands, Okinawa, 644 m, seep

Material examined

2 specimens, Four Way Closure Ridge (22°03.507′N, 119° 48.016′E), depth 1300 m (OR3-1994, May 3, 2017).

Measurements of selected specimens.

Cruise	Museum code	Sampling code	Shell length (mm)	Shell height (mm)	Shell width (mm)
OR3-1994	NMNS-7993-011	FWCg 02	37.91	15.86	11.84
OR3-1994	NMNS-7993-012	FWCg 05	71.11	29.28	21.91

Distribution

Presently known from methane seep sites at Kuroshima Knoll and Nankai Trough in Japan, Four Way Closure Ridge in Taiwan. Depth ranges 624 m and 1300 m (Kurozumi, 2017; Okutani et al., 2003; Sasaki et al., 2005).

(a) NMNS-7993-001 (SL = 37.91 mm) (b) SL = 53.55 mm

Fig. 4. ***Bathymodiolus securiformis,*** **exterior and interior view of left valve, from Four Way Closure Ridge. Scale bar 5 mm.**

(a) Exterior and interior view of left valve (NMNS-7993-001) (SL = 31.23 mm) (b) Exterior and interior view of right valve (SL = 41.05 mm)

Fig. 5. Sissano *Bathymodiolus* sp.1, from Formosa Ridge. Scale bar 5 mm.

Diagnosis

Shell long, inflated, modioliform, oblong. Anterior portion of shell low and narrow, posterior higher and wider. Anterior margin rounded. Postero-dorsal angle rounded. Priostracum smooth, dark brown but olive brown along the ventral margin.

Description

Shell long but narrow, height/length ratios 0.41 & 0.42; width/length ratio 0.31.

Sissano *Bathymodiolus* sp.1 (Fig. 5)

Sissano *Bathymodiolus* sp.1 - Fujita et al., 2009: 123 (Fujita et al., 2009) [unidentified and undescribed mussel, sequence data only]

Holotype. Not-assigned
First record locality. Sissano, Papua New Guinea, 1646 & 1881 m, seep

Material examined

2 specimens from Formosa Ridge 42-2 (22°06.971′N, 119° 17.133′E) at a depth of 1150 m (RV SONNE cruise SO227, April 29, 2013).

Measurements of selected specimens.

Cruise	Museum code	Sampling code	Shell length (mm)	Shell height (mm)	Shell width (mm)
SO227		42-2 a5	41.05	22.90	18.44
SO227	NMNS-7993-001	42-2 a6	31.23	18.32	24.40

Distribution

Known from methane seep sites Papua New Guinea and Formosa Ridge in Taiwan. Depth range 1150-1881 m (Fujita et al., 2009; Kyuno et al., 2009).

Diagnosis

Shell inflated, modioliform, rounded-triangular. Umbones prosogyrated, nearly subterminal. Umbonal ridge significantly prominent. Dorsal margin nearly straight, posterior margin rounded and ventral margin slightly concave. Postero-dorsal corner weakly angulated. Priostracum smooth and yellow.

Description

Shell short but wide, height/length ratios 0.56 & 0.59; width/length ratio 0.45 & 0.78.

Remarks

This unidentified species was firstly collected from Sissano, Papua New Guinea and examined by the sequence of COI gene (Fujita et al., 2009).

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APPENDIX 1. MITOCHONDRIAL COI SEQUENCES FROM *BATHYMODIOLUS* MUSSELS FROM TAIWAN

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                                 ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....|
                                          10        20        30        40        50        60        70        80        90       100
B. taiwanesis KI 6               GTTTGAGGAT GCTGATTCGT ATTGAATTAG CACGCCCTGG AAGATTTTTA TGTGACTATC AGCTTTATAA TGTAATTGTA ACTGCTCATG CATTGGTTAT
B. taiwanesis KI LD4             GTTTGAGGAT GCTGATTCGT ATTGAATTAG CACGCCCTGG AAGATTTTTA GGTGACGATC AGCTTTATAA TGTAATTGTA ACTGCTCATG CATTGGTTAT
B. platifrons FMR39-2 a5         GTTTGAGGAT GTTGATTCGT ATTGAGTTAG CTCGTCCTGG GAGCTTTTTA GGTGATGATC AGCTTTATAA TGTTATTGTA ACTGCCCATG CACTGGTTAT
B. platifrons FMR42-2 c18        GTTTGAGGAT GTTGATTCGT ATTGAGTTAG CTCGTCCTGG GAGCTTTTTA GGTGATGATC AGCTTTATAA TGTTATTGTA ACTGCCCATG CACTGGTTAT
B. platifrons OT 78              GTTTGAGGAT GTTGATTCGT ATTGAGTTAG CTCGTCCTGG GAGCTTTTTA GGTGATGATC AGCTTTATAA TGTTATTGTA ACTGCCCATG CACTGGTTAT
B. platifrons OT 79              GTTTGAGGAT GTTGATTCGT ATTGAGTTAG CTCGTCCTGG GAGCTTTTTA GGTGATGATC AGCTTTATAA TGTTATTGTA ACTGCCCATG CACTGGTTAT
B. platifrons FWCg 08            GTTTGAGGAT GTTGATTCGT ATTGAGTTAG CTCGTCCTGG GAGCTTTTTA GGTGATGATC AGCTTTATAA TGTTATTGTA ACTGCCCATG CACTGGTTAT
B. platifrons FWCg 110           GTTTGAGGAT GTTGATTCGT ATTGAGTTAG CTCGTCCTGG GAGCTTTTTA GGTGATGATC AGCTTTATAA TGTTATTGTA ACTGCCCATG CACTGGTTAT
B. sp.1 FMR42-2 a5               GGTTGAGGAT ATTAATTCGT ATTGAACTAG CACGCCCCGG TAGATTTTTA GGTGATGATC AGCTTTATAA TGTTATTGTG ACGGCTCATG CGTTGGTTAT
B. sp.1 FMR42-2 a6               GGTTGAGGAT ATTAATTCGT ATTGAACTAG CACGCCCCGG TAGATTTTTA GGTGATGATC AGCTTTATAA TGTTATTGTG ACGGCTCATG CGTTGGTTAT
B. securiformis FWCg 02          GTTTGAGGAT GTTGATTCGT ATTGAATTAG CTCGTCCTGG GAGCTTTTTA GGAGATGACC AGCTTTATAA TGTTATTGTA ACTGCCCATG CATTGGTTAT
B. securiformis FWCg 05          GTTTGAGGAT GTTGATTCGT ATTGAATTAG CTCGTCCTGG GAGCTTTTTA GGAGATGACC AGCTTTATAA TGTTATTGTA ACTGCCCATG CATTGGTTAT

                                 ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....|
                                         110       120       130       140       150       160       170       180       190       200
B. taiwanesis KI 6               AATTTTTTTT ATGGTGATGC CTTTGATAGT GGGTGGTTTT GGAAATTGGC TGCTTCCTCT GATGATAGGT TCAATTGATA TAATTTTTCC TCGTTTAAAT
B. taiwanesis KI LD4             AATTTTTTTT ATGGTGATGC CTTTGATAGT GGGTGGTTTT GGAAATTGGC TGCTTCCTCT GATGATAGGT TCAATTGATA TAATTTTTCC TCGTTTAAAT
B. platifrons FMR39-2 a5         AATTTTCTTT ATAGTAATGC CTTTGATGGT GGGTGGTTTT GGAAATTGGC TACTTCCTTT AATGATAGGT TCAATTGACA TAATTTTTCC TCGTTTAAAT
B. platifrons FMR42-2 c18        AATTTTCTTT ATAGTAATGC CTTTGATGGT GGGTGGTTTT GGAAATTGGC TACTTCCTTT AATGATAGGT TCAATTGACA TAATTTTTCC TCGTTTAAAT
B. platifrons OT 78              AATTTTCTTT ATAGTAATGC CTTTGATGGT GGGTGGTTTT GGAAATTGGC TACTTCCTTT AATGATAGGT TCAATTGACA TAATTTTTCC TCGTTTAAAT
B. platifrons OT 79              AATTTTCTTT ATAGTAATGC CTTTGATGGT GGGTGGTTTT GGAAATTGGC TACTTCCTTT AATGATAGGT TCAATTGACA TAATTTTTCC TCGTTTAAAT
B. platifrons FWCg 08            AATTTTCTTT ATAGTAATGC CTTTGATGGT GGGTGGTTTT GGAAATTGGC TACTTCCTTT AATGATAGGT TCAATTGACA TAATTTTTCC TCGTTTAAAT
B. platifrons FWCg 110           AATTTTCTTT ATAGTAATGC CTTTGATGGT GGGTGGTTTT GGAAATTGGC TACTTCCTTT AATGATAGGT TCAATTGACA TAATTTTTCC TCGTTTAAAT
B. sp.1 FMR42-2 a5               AATTTTTTTT ATAGTTATGC CTTTAATAGT TGGTGGTTTT GGAAATTGGT TACTTCCTTT AATGATAGGT TCAATTGATA TAATTTTCCC TCGTTTGAAT
B. sp.1 FMR42-2 a6               AATTTTTTTT ATAGTTATGC CTTTAATAGT TGGTGGTTTT GGAAATTGGT TGCTTCCTTT AATGATAGGT TCAATTGATA TAATTTTCCC TCGTTTGAAT
B. securiformis FWCg 02          GATTTTTTTT ATAGTTATGC CTTTGATGGT GGGCGGTTTT GGAAATTGGC TACTTCCTTT AATAATAGGT TCAATTGACA TAATTTTTCC TCGTTTAAAT
B. securiformis FWCg 05          GATTTTTTTT ATAGTTATGC CTCTGATGGT GGGCGGTTTT GGAAATTGGC TACTTCCTTT AATAATAGGT TCAATTGACA TAATTTTCCC TCGTTTAAAT

                                 ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....|
                                         210       220       230       240       250       260       270       280       290       300
B. taiwanesis KI 6               AATTTAAGAT TTTGGTTTTT ACCAGCGTCT CTTTTCACTC TTTTGCTTTC AACATTTATT GAGAGAGGTT CTGGGACTGG TTGGACTTTG TACCCACCTT
B. taiwanesis KI LD4             AATTTAAGAT TTTGGTTTTT ACCAGCGTCT CTTTTCACTC TTTTGCTTTC AACATTTATT GAGAGAGGTT CTGGGACTGG TTGGACTTTG TACCCACCTT
B. platifrons FMR39-2 a5         AATCTAAGGT TTTGGTTTTT GCCCGCATCT CTTTTTACTC TTTTGTTGTC TACATTTATT GAGAGAGGCG CTGGGACTGG TTGAACCTTG TACCCTCCTT
B. platifrons FMR42-2 c18        AATCTAAGGT TTTGGTTTTT GCCCGCATCT CTTTTTACTC TTTTGTTGTC TACATTTATT GAGAGAGGCG CTGGGACTGG TTGAACCTTG TACCCTCCTT
B. platifrons OT 78              AATCTAAGGT TTTGGTTTTT GCCCGCATCT CTTTTTACTC TTTTGTTGTC TACATTTATT GAGAGAGGCG CTGGGACTGG TTGAACCTTG TACCCTCCTT
B. platifrons OT 79              AATCTAAGGT TTTGGTTTTT GCCCGCATCT CTTTTTACTC TTTTGTTGTC TACATTTATT GAGAGAGGCG CTGGGACTGG TTGAACCTTG TACCCTCCTT
B. platifrons FWCg 08            AATCTAAGGT TTTGGTTTTT GCCCGCATCT CTTTTTACTC TTTTGTTGTC TACATTTATT GAGAGAGGCG CTGGGACTGG TTGAACCTTG TACCCTCCTT
B. platifrons FWCg 110           AATCTAAGGT TTTGGTTTTT GCCCGCATCT CTTTTTACTC TTTTGTTGTC TACATTTATT GAGAGAGGCG CTGGGACTGG TTGAACCTTG TACCCTCCTT
B. sp.1 FMR42-2 a5               AATTTAAGAT TTTGGTTCTT ACCAGCGTCT CTCTTTACTC TTCTGTTATC TACATTTATT GAGAGTGGTT CTGGAACTGG TTGAACTTTA TATCCGCCTT
B. sp.1 FMR42-2 a6               AATTTAAGAT TTTGGTTCTT ACCAGCGTCT CTCTTTACTC TTCTGTTATC TACATTTATT GAGAGTGGTT CTGGAACTGG TTGAACTTTA TATCCGCCTT
B. securiformis FWCg 02          AATTTAAGGT TTTGGTTTTT GCCGGCGTCT CTTTTTACTC TTTTGTTATC TACTTTTATT GAGAGAGGCG CTGGAACTGG TTGAACTTTG TACCCCCCTT
B. securiformis FWCg 05          AATTTAAGGT TTTGGTTTTT GCCGGCATCT CTTTTTACTC TTTTGTTATC TACTTTTATT GAGAGAGGCG CTGGAACTGG TTGAACTTTG TACCCCCCTT

                                 ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....| ....|....|
                                         310       320       330       340       350       360       370       380       390       400
B. taiwanesis KI 6               TGTCTTCTTA TACTGGACAT AGCGGCCCAG CCGTAGATAT ATCCTTATTT TCTTTGCATT TAGCAGGTGC TTCTTCTATT GGAGGTTCTA TTAATTTTCT
B. taiwanesis KI LD4             TGTCTTCTTA TACTGGACAT AGCGGCCCAG CCGTAGATAT ATCCTTATTT TCTTTGCATT TAGCAGGTGC TTCTTCTATT GGAGGTTCTA TTAATTTTCT
B. platifrons FMR39-2 a5         TATCTTCTTA CACTGGTCAT AGGGGCCCAG CCGTGGACAT GTCTTTATTT TCTTTACATT TAGCAGGTGC TTCTTCTATT GGTGGTTCAA TTAATTTTTT
B. platifrons FMR42-2 c18        TATCTTCTTA CACTGGTCAT AGGGGCCCAG CCGTGGACAT GTCTTTATTT TCTTTACATT TAGCAGGGGC TTCTTCTATT GGTGGTTCAA TTAATTTTTT
B. platifrons OT 78              TATCTTCTTA CACTGGTCAT AGGGGCCCAG CCGTGGACAT GTCTTTATTT TCTTTACATT TAGCAGGTGC TTCTTCTATT GGTGGTTCAA TTAATTTTTT
B. platifrons OT 79              TATCTTCTTA CACTGGTCAT AGGGGCCCAG CCGTGGACAT GTCTTTATTT TCTTTACATT TAGCAGGTGC TTCTTCTATT GGTGGTTCAA TTAATTTTTT
B. platifrons FWCg 08            TATCTTCTTA CACTGGTCAT AGGGGCCCAG CCGTGGACAT GTCTTTATTT TCTTTACATT TAGCAGGTGC TTCTTCTATT GGTGGTTCAA TTAATTTTTT
B. platifrons FWCg 110           TATCTTCTTA CACTGGTCAT AGGGGCCCAG CCGTGGACAT GTCTTTATTT TCTTTACATT TAGCAGGTGC TTCTTCTATT GGTGGTTCAA TTAATTTTTT
B. sp.1 FMR42-2 a5               TATCTTCATA TACTGGGCAT AGGGGTCCAG CCGTGGATAT ATCCCTATTT TCTTTACATT TAGCTGGTGC TTCTTCTATT GGTGGTTCAA TTAATTTTTT
B. sp.1 FMR42-2 a6               TATCTTCATA TACTGGGCAT AGGGGTCCAG CCGTGGATAT ATCCCTATTT TCTTTACATT TAGCTGGTGC TTCTTCTATT GGTGGTTCAA TTAATTTTTT
B. securiformis FWCg 02          TATCTTCTTA TACTGGTCAT AGGGGCCCAG CCGTGGATAT GTCTTTATTT TCTTTACATT TGGCAGGTGC TTCTTCTATT GGTGGTTCAA TTAATTTTCT
B. securiformis FWCg 05          TATCTTCTTA TACTGGTCAT AGGGGCCCAG CCGTGGATAT GTCTTTATTT TCTTTACACT TGGCAGGTGC TTCTTCTATT GGTGGTTCAA TTAATTTTCT

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                                         410       420       430       440       450       460       470       480       490       500
B. taiwanesis KI 6               TACTAGGATG AAGAACATGT CTGTCGAGAG AATGCGGGGT GAGCGAATGG TTTTGTTCGT CTGATCTATG GCTGTGACGG CGGTTTTATT ATTAGTTTCT
B. taiwanesis KI LD4             TACTAGGATG AAGAACATGT CTGTCGAGAG AATGCGGGGT GAGCGAATGG TTTTGTTTGT CTGATCTATG GCTGTGACGG CGGTTTTATT ATTAGTTTCT
B. platifrons FMR39-2 a5         GACAAGGATG AAGAATATGT CTGTTGAAAG AATGCGAGGG GAGCGGATAG TTTTATTTGT TTGATCTATG GCTGTGACAG CAGTTTTATT ATTAGTTTCT
B. platifrons FMR42-2 c18        GACAAGGATG AAAAATATGT CTGTTGAAAG AATGCGAGGG GAGCGGATAG TTTTATTTGT TTGATCTATG GCTGTGACAG CAGTTTTATT ATTAGTTTCT
B. platifrons OT 78              GACAAGGATG AAGAATATGT CTGTTGAAAG AATGCGAGGG GAGCGGATAG TTTTATTTGT TTGATCTATG GCTGTGACAG CAGTTTTATT ATTAGTTTCT
B. platifrons OT 79              GACAAGGATG AAGAATATGT CTGTTGAAAG AATGCGAGGG GAGCGGATAG TTTTATTTGT TTGATCTATG GCTGTGACAG CAGTTTTATT ATTAGTTTCT
B. platifrons FWCg 08            GACAAGGATG AAGAATATGT CTGTTGAAAG AATGCGAGGG GAGCGGATAG TTTTATTTGT TTGATCTATG GCTGTGACAG CAGTTTTATT ATTAGTTTCT
B. platifrons FWCg 110           GACAAGGATG AAGAATATGT CTGTTGAAAG AATGCGAGGG GAGCGGATAG TTTTATTTGT TTGATCTATG GCTGTGACAG CAGTTTTATT ATTAGTTTCT
B. sp.1 FMR42-2 a5               AACTAGGATG AAGAATATGT CTGTTGAAAG TATACAAGGA GAGCGGATAG TTTTATTTGT TTGATCTATA GCTGTGACAG CAGTTTTATT GTTAGTTTCT
B. sp.1 FMR42-2 a6               AACTAGGATG AAGAATATGT CTGTTGAAAG TATACAAGGA GAGCGGATAG TTTTATTTGT TTGATCTATA GCTGTGACAG CAGTTTTATT GTTAGTTTCT
B. securiformis FWCg 02          GACGAGAATG AAGAATATGT CGGTTGAAAG AATGCGAGGG GAGCGGATAG TTTTATTTGT TTGATCCATG GCCGTAACAG CAGTTTTATT ATTAGTTTCT
B. securiformis FWCg 05          GACGAGAATG AAGAATATGT CGGTTGAAAG AATGCGAGGG GAGCGGATAG TTTTATTTGT TTGATCCATG GCCGTAACAG CAGTTTTATT ACTAGTTTCT

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                                         510       520       530       540       550       560       570       580       590       600
B. taiwanesis KI 6               TTGCCTGTAT TGGCAGGAGG AATTACTATG TTGATTTTTG ACCGTCATTT TAATACTTCG TTTTATGACC CTAGAGGTGG AGGAGACCCG GTTTTGTATC
B. taiwanesis KI LD4             TTGCCTGTAT TGGCAGGAGG AATTACTATG TTGATTTTTG ACCGTCATTT TAATACTTCG TTTTATGACC CTAGAGGTGG AGGAGACCCG GTTTTGTATC
B. platifrons FMR39-2 a5         TTGCCTGTAT TAGCAGGAGG AATTACCATG TTGATTTTTG ACCGTCATTT CAATACTTCT TTTTATGACC CTAGAGGTGG TGGAGACCCA GTTTTATACC
B. platifrons FMR42-2 c18        TTGCCTGTAT TAGCAGGAGG AATTACCATG TTGATTTTTG ACCGTCATTT CAATACTTCT TTTTATGACC CTAGAGGTGG TGGAGACCCA GTTTTATACC
B. platifrons OT 78              TTGCCTGTAT TAGCAGGAGG AATTACCATG TTGATTTTTG ACCGTCATTT CAATACTTCT TTTTATGACC CTAGAGGTGG TGGAGACCCA GTTTTATACC
B. platifrons OT 79              TTGCCTGTAT TAGCAGGAGG AATTACCATG TTGATTTTTG ACCGTCATTT CAATACTTCT TTTTATGACC CTAGAGGTGG TGGAGACCCA GTTTTATACC
B. platifrons FWCg 08            TTGCCTGTAT TAGCAGGAGG AATTACCATG TTGATTTTTG ACCGTCATTT CAATACTTCT TTTTATGACC CTAGAGGTGG TGGAGACCCA GTTTTATACC
B. platifrons FWCg 110           TTGCCTGTAT TAGCAGGAGG AATTACCATG TTGATTTTTG ACCGTCATTT CAATACTTCT TTTTATGACC CTAGAGGTGG TGGAGACCCA GTTTTATACC
B. sp.1 FMR42-2 a5               TTACCCGTCT TAGCTGGGGG TATCACTATA TTGATTTTTG ATCGTCATTT TAATACTTCT TTTTATGATC CTAGAGGTGG GGGAGATCCA GTTTTATACC
B. sp.1 FMR42-2 a6               TTACCCGTCT TAGCTGGGGG TATCACTATA TTGATTTTTG ATCGTCATTT TAATACTTCT TTTTATGATC CTAGAGGTGG GGGAGATCCA GTTTTATACC
B. securiformis FWCg 02          TTACCTGTAT TAGCAGGAGG AATTACTATG TTGATTTTTG ATCGTCATTT TAACACTTCT TTTTATGACC CTAGGGG--- ----------
B. securiformis FWCg 05          TTACCTGTAT TAGCAGGAGG AATTACTATG TTGATTTTTG ATCGTCATTT TAACACTTCT TTTTATGACC CTAGGGGCGG AGGAGACCCA GTTTTATACC

                                 ....|....| ....|....| ....|...
                                         610       620
B. taiwanesis KI 6               AACATTTGTT TTGATTTTTT GGTCACCC
B. taiwanesis KI LD4             AACATTTGTT TTGATTTTTT GGTCACC-
B. platifrons FMR39-2 a5         AGCATTTGTT TTGATTTTTT GG-CACC-
B. platifrons FMR42-2 c18        AGCATTTGTT TTGATTTTTT GGTCACC-
B. platifrons OT 78              AGCATTTGTT TTGATTTTTT GGTCACCC
B. platifrons OT 79              AGCATTTGTT TTGATTTTTT GGTCACCC
B. platifrons FWCg 08            AGCATTTGTT TTGATTTTTT GGTCACCC
B. platifrons FWCg 110           AGCATTTGTT TTGATTTTTT GGTCACC-
B. sp.1 FMR42-2 a5               AACATTTGTT TTGATTTTTT GGTCAC--
B. sp.1 FMR42-2 a6               AACATTTGTT TTGATTTTTT GGTCAC--
B. securiformis FWCg 02          ---------- ---------- --------
B. securiformis FWCg 05          AACATTTGTT TT-------- --------
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