Rumphellolides A—F, Six New Caryophyllane-Related Derivatives from the Formosan Gorgonian Coral *Rumphella antipathies*

Ping-Jyun Sung, Li-Fan Chuang, Jimmy Kuo, Jih-Jung Chen, Tung-Yung Fan, Jan-Jung Li, Lee-Shing Fang, and Wei-Hsien Wang

National Museum of Marine Biology and Aquarium; Checheng, Pingtung 944, Taiwan, R.O.C.: b Institute of Marine Biotechnology, National Dong Hwa University; Checheng, Pingtung 944, Taiwan, R.O.C.: c Department of Pharmacy, Tajen University; Pingtung 907, Taiwan, R.O.C.: d Institute of Marine Biodiversity and Evolution, National Dong Hwa University; Chen-cheng, Pingtung 907, Taiwan, R.O.C.: e Department of Sport, Health, and Leisure, Cheng Shiu University; Niaosong, Kaohsiung 833, Taiwan, R.O.C.: and f Department of Marine Biotechnology and Resources, National Sun Yat-sen University; Kaohsiung 804, Taiwan, R.O.C.

Received March 6, 2007; accepted June 1, 2007

Six new caryophyllane-related natural products, including two carboxylated sesquiterpenoids, rumphellolides A (1) and B (2), and four norsesquiterpenoid alcohols, rumphellolides C—F (3—6), were isolated from the Formosan gorgonian coral *Rumphella antipathies*. The structures of the above new natural products were established on the basis of extensive spectral data analysis. Rumphellolides A (1), D (4), E (5), and F (6) showed weak antibacterial activity.

Key words rumphellolide; caryophyllane; sesquiterpenoid; gorgonian; *Rumphella*; antibacterial activity

In our screening for bioactive substances from the Formosan octocorals, we reported a series of interesting terpenoid and steroid metabolites from the octocorals *Briareum* sp., *Briareum excavatum*, *Juncella fragilis*, and *Alcyonium* sp. In continuation of our study of bioactive substances from Formosan marine invertebrates, from the gorgonian coral, *Rumphella antipathies* (phylum Cnidaria, order Gorgonacea, suborder Holaxonia, family Gorgonidae), collected from Taiwanese waters, we reported a series of interesting terpenoid and steroid metabolites from the gorgonian coral, *Rumphella antipathies* (phylum Cnidaria, order Gorgonacea, suborder Holaxonia, family Gorgonidae), collected from Taiwanese waters, we have isolated six new natural products including two carboxylated sesquiterpenoids, rumphellolides A (1) and B (2), and four norsesquiterpenoid alcohols, rumphellolides C—F (3—6) (Fig. 1). In previous studies, there was only one report focused on the chemical components of gorgonian coral *Rumphella aggregata*. Organic extracts from the gorgonian belonging to the *Rumphella* genus in ecology and medical use, also were reported. The caryophyllane-type natural products also were rarely found in marine organisms. In this paper, we describe the isolation, structure characterization, and biological activity of the new natural products 1—6. The structures of 1—6 were elucidated on the basis of extensive spectral data analysis. Antibacterial activity of these compounds toward the Gram-negative bacteria, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Vibrio parahaemolyticus* and the Gram-positive bacterium *Staphylococcus aureus* is also reported.

**Results and Discussion**

The minced tissues of *R. antipathies* were successively extracted with a mixture of MeOH and CH₂Cl₂ (1:1). The residue was further partitioned between n-hexane and 9:1 MeOH–H₂O; the MeOH–H₂O phase was diluted to 1:1 MeOH–H₂O and partitioned against CH₂Cl₂. The CH₂Cl₂ layer was separated on silica gel and purified by HPLC to afford rumphellolides A—F (1—6).

Rumphellolide A (1) was obtained as a white powder. The HR-ESI-MS data recorded at *m/z* 275.1625 established the molecular formula of 1 as C₁₆H₂₃O₂ (Calcd for C₁₆H₂₃O₂·Na, 275.1623). Thus four degrees of unsaturation were determined for 1. The IR spectrum showed bands at 3400—2400 (br.) and 1706 cm⁻¹, consistent with the presence of carboxylic acid in 1. In the ¹³C-NMR spectrum of 1 (Table 1), a carbonyl resonance appeared at δ 180.4 (s), supporting the presence of a carboxylic acid group. Thus the ¹³C-NMR data accounted for one degree of unsaturation and required 1 to be tricyclic. The ¹H-NMR spectrum also showed the presence of three methyl groups (Table 2), including two methyls (δ 0.98, 3H, s, H₃-15; 0.96, 3H, s, H₃-14) attached to a quaternary carbon and a methyl (δ 1.29, 3H, s, H₃-12) attached to an oxygenated quaternary carbon. A trisubstituted epoxide group was confirmed by the signals of an oxyxymehtine (δH 2.93, 1H, dd, J = 11.2, 4.0 Hz, H-5; 64.7, d, C-5) and an oxygen-bearing quaternary carbon (δC 60.1, s, C-4) for the characteristic signals of an epoxide group. In addition, five pairs of methylene protons (δ 1.72, 1H, m, H-2α; 1.46, 1H, m, H-2β; 2.09, 1H, m, H-3α; 1.02, 1H, m, H-3β; 1.21, 1H, m, H-6α; 2.26, 1H, m, H-6β; 2.11, 1H, m, H-7α; 1.79, 1H, m, H-7β; 1.51, 1H, dd, J = 10.4, 8.0 Hz, H-10α; 1.42, 1H, d, J = 10.4 Hz, H-10β) and three aliphatic methine protons (δ 1.91, 1H, brt, J = 9.6 Hz, H-1; 2.56, 1H, dt, J = 6.4, 6.0 Hz, H-8; 2.51, 1H, m, H-9) were observed in the ¹H-NMR spectrum of 1.

The gross structure of 1 and all of the ¹H- and ¹³C-NMR data of 1 are shown in Fig. 1 (A). The gross structure of 1 and all of the ¹H- and ¹³C-NMR data of 1 are shown in Fig. 1 (A).
data associated with the molecule were determined by 2D-NMR studies, including 1H–1H COSY, HMQC, and HMBC experiments. The 1H-NMR coupling information in the 1H–1H COSY spectrum of 1 enabled identification of the C-1/C-2/C-3, C-5/C-6/C-7/C-8/C-9, and C-1/C-9 units (Fig. 2). These data, together with the HMBC correlations between H-1/C-3, C-8, C-9; H2-2/C-1, C-3, C-4, C-9; H 2-3/C-1, C-2, C-4, C-5; H-5/C-6; H 2-7/C-5, C-6, C-8; and H-8/C-6, C-7, C-9 (Fig. 2, Table 3), established the connectivity from C-1 to C-9 within the nine-membered ring. The C-12 methyl attached at C-4 was confirmed by the HMBC correlations between H3-12/C-3, C-4, C-5 and H-3/C-12. The cyclobutane ring, which is fused to the nine-membered ring at C-1 and C-9, was elucidated by the 1H–1H COSY correlations between H-9 and H2-10 and by the key HMBC correlations between H-1/C-11; H-2/C-11; H-8/C-10; and H2-10/C-1, C-8, C-9. The carboxylic acid group positioned at C-8 was confirmed by the HMBC correlation between H-8 (δH 2.56) and the acid carbonyl (δC 180.4, s, C-13). These data, together with the HMBC correlations between H-1/C-14, C-15; H2-10/C-11, C-14, C-15; H-9/C-13; H1-14/C-1, C-10, C-11, C-15; and H-15/C-1, C-10, C-11, C-14, unambiguously established the planar structure of 1.

The relative configurations of five chiral centers at C-1, C-
4, C-5, C-8, and C-9 in 1 were elucidated by the following NOE analysis, as shown in Fig. 3. It was found that H-1 showed strong NOE correlations with H-5 and H2-14. Thus assuming the α-orientation of H-1, H-5 and Me14 should be positioned on the β-face as well. One of the methylene protons at C-2 (δ 1.46) exhibited NOE correlations with H-1 and was assigned as H-2β, while the other (δ 1.72) was denoted as H-2α. The NOE correlation observed between H-2α and H2-15; H-2α and one proton of C-3 methylene (δ 2.09, H-3α); H2-15 and one proton of C-10 methylene (δ 1.51, H-10α); and H2-10 and H-9, reflected the α-orientation of these protons. Also, H1-12 was found to interact with H-3α but not with H-1 and H-5, revealing the trans geometry of the trisubstituted epoxide. Furthermore, H-8 showed an NOE correlation with H-9, but not with H-1, suggesting that the carboxylic acid group attaching at C-8 was positioned on the β face in the nine-membered ring. Thus by the above findings, the structure of 1 was established and the configurations of all chiral centers of 1 were assigned as 1R*,4R*,5R*,8R*,9S*.

Rumphellolide B (2) had the same molecular formula as that of 1, C15H22O3, as determined by HR-ESI-MS, with four degrees of unsaturation. By detailed analysis, the spectral data (IR, MS, 1D-, and 2D-NMR) of 2 were very similar to those of 1 (Tables 1—3). However, the physical state (a colorless oil) and optical rotation value ([(α)]25D 3.9° (c=0.05, CHCl3)) of 2 were substantially different from those of 1 (a white powder, mp 145—146°C, [α]25D 29° (c=0.27, CHCl3)), indicating that these two compounds are isomers. Comparison of the 1H NMR chemical shift of C-13 of 2 (δ 178.6, s) with that of 1 (δ 180.4, s) showed that the relative stereochemistry of C-8 in 2 is of S* form. This observation was further supported by the NOE correlations observed among H-1, H-5, and H-8, in the NOESY experiment of 2 (Fig. 4). It has to be noted that sesquiterpenoids 1 and 2 are the first caryophyllane-type natural products possessing carboxylic acid groups.

The new caryophyllane norsesquiterpenoid, rumphellolide C (3), was isolated as a colorless oil and has a molecular formula C14H22O3, as determined by HR-ESI-MS (m/z Caled: 261.1467, Found: 261.1468, [M+Na]+), indicating four degrees of unsaturation. The presence of hydroxyl and ketone groups in 3 was evidenced by IR absorption at 3442 and 1696 cm⁻¹. The 13C-NMR data (Table 1) showed that 3 had a ketone carbonyl group appearing at δ 212.7 (s, C-8), and this compound must therefore be tricyclic to account for the remaining degrees of unsaturation. A trisubstituted epoxide containing a methyl substituent was deduced from the signals of an oxymethine (δ 3.12, 1H, dd, J=4.8, 4.8 Hz, H-3), a quaternary oxygen-bearing carbon (δc 64.3, C-3), and a methyl singlet resonating at δ 1.31 (3H, s, H2-12) (Table 2). Moreover, protons signals for two tertiary methyls, four methylenes, and three methines including an oxygenated one were further assigned by the assistance of HMBC spectrum. From the 1H-1H COSY and HMBC correlations (Fig. 5, Table 3), the epoxide group positioned at C-3/C-4 and the hydroxyl group positioned at C-5 was established. Furthermore, the C-8 ketone was confirmed by the key HMBC correlations between H-1 (δ 2.17), H2-6 (δ 2.40, 2.40), H2-7 (δ 2.04, 1.87), H-9 (δ 2.95), H2-10 (δ 2.00, 1.57), and the C-8 ketone carbonyl (δ 212.7, s).

The stereochemistry of 3 was elucidated by correlations observed in an NOESY experiment (Fig. 6). In the NOESY spectrum of 3, H-1 gives NOE correlations to H-5 and H2-14, but not with H-3 and H-9, indicating that H-1, H-5, and H2-14 are situated on the same face of the structure and were
assigned as β protons since the H-9 proton is assigned as the α-substituent at C-9. H-12 was found to exhibit a strong NOE correlation with H-3. From consideration of molecular models, H-12 was found to be reasonably close to H-3, when C-12 was α-oriented in the epoxide ring. On the basis of the above observations, the structure of 3 was elucidated unambiguously. The relative configurations of all chiral centers of 3 were assigned as 1R*, 3R*, 4S*, 5R*, 9S*.

Our present study has also led to the isolation of the new norsesquiterpenoid, rumphellolide D (4). Compound 4 has the same molecular formula as that of 3, C14H22O3, as determined by HR-ESI-MS, with four degrees of unsaturation, indicating compounds 3 and 4 are isomers. By detailed spectral data analysis, particularly with 1D- and 2D-NMR data and IR spectrum, compound 4 was found to possess the same substituents as those of 3 (a ketone, an epoxide, and a hydroxyl group). On the basis of 1H–1H COSY spectrum of 4 (Fig. 7), it was possible to establish the sequences of the protons attached to the carbon skeleton of 4. In the HMBC experiment of 4 (Fig. 7, Table 3), the epoxide group was shown to be positioned at C-4/C-5 by the key HMBC correlations between H2-3/C-4; H-5/C-3, C-4; and H-6/C-5. The hydroxyl group positioned at C-6 was further confirmed by the connectivity between the proton of an oxymethine (δH 3.74, H-6) and C-5 and C-8. The relative stereochemistry of 4 was deduced from an NOESY experiment (Fig. 8) and the configurations of five chiral centers including C-1, C-4, C-5, C-6, and C-9 were assigned as R*, R*, S*, S*, S*.

Norsesquiterpenoid 5 (rumphellolide E) had the same molecular formula as those of 3 and 4, C14H22O3, as determined by HR-ESI-MS with three degrees of unsaturation, indicating that compounds 3, 4, and 5 are isomers. By detailed 1D- and 2D-NMR data analysis, compound 5 has the same substituents as those of 3 and 4. On the basis of 1H–1H COSY spectrum of 5 (Fig. 9), it was possible to establish the sequences of the protons attached to the carbon skeleton of 5. Furthermore, by comparison the 1H–13C-NMR, 1H–1H COSY, and HMBC spectral data of 5 with those 4, it was revealed that the signals corresponding to the tertiary Me-14 in 4 (δH 1.04, 3H, s, H3-14; δC 29.3, q, C-14) disappeared and were replaced by a hydroxymethylene group in 5 (δH 3.39, 2H, s, H3-14; δC 70.1, t, C-14) and the hydroxymethylene in 4 (δH 3.74, 1H, ddd, J = 8.0, 4.8, 4.8 Hz, H-6; δC 69.0, d, C-6) was replaced by an aliphatic methylene in 5 (δH 1.48, 1H, m, H-6α; 2.41, 1H, m, H-6β; δC 24.6, t, C-6). Furthermore, the proton signals of C-14 hydroxymethylene showed strong correlations with C-1, C-10, C-11, and C-15 in the HMBC experiment of 5 (Fig. 9, Table 3), confirming the 14-hydroxyl group in 5. The relative stereochemistry of 5 was elucidated by an NOESY experiment (Fig. 10), and the results revealed that all the chiral centers of 5 were elucidated as 1R*, 4R*, 5R*, 9S*, 11R*.

Rumphellolide F (6) was obtained as a white powder. The HR-ESI-MS data recorded at m/z 245.1516 established the molecular formula of 6 as C14H22O2 (Calcd for C14H22O2 + Na, 245.1517). Thus four degrees of unsaturation

Fig. 5. 1H–1H COSY and Selective HMBC Correlations (Protons and Quaternary Carbons) of 3

Fig. 6. Selective NOE Correlations of 3

Fig. 7. 1H–1H COSY and Selective HMBC Correlations (Protons and Quaternary Carbons) of 4

Fig. 8. Selective NOE Correlations of 4

Fig. 9. 1H–1H COSY and Selective HMBC Correlations (Protons and Quaternary Carbons) of 5

Fig. 10. Selective NOE Correlations of 5
were determined for 6. The IR spectrum showed bands at 3430 and 1702 cm\(^{-1}\), consistent with the presence of hydroxyl and ketone groups in 6. In the \(^{13}\)C and DEPT spectra of 6 (Table 1), fourteen carbon signals, including three methyls (\(\delta\) 29.1, 21.0, 20.2), four methylenes (\(\delta\) 46.9, 32.0, 26.5, 5.8), four methines (\(\delta\) 58.2, 52.3, 33.8, 25.3), a quaternary carbon (\(\delta\) 36.3), an oxygen-bearing quaternary carbon (\(\delta\) 73.7), and a ketone carbonyl (\(\delta\) 209.3) appeared. Thus the \(^{13}\)C-NMR data accounted for one degree of unsaturation and required 6 to be tricyclic. The \(^1\)H-NMR spectrum of 6 (Table 2) also showed the presence of three methyl groups, including two methyls (\(\delta\) 0.98, 3H, s, H-14; 1.04, 3H, s, H-15) attached to a tertiary carbon and a methyl (\(\delta\) 0.98, 3H, s, H-12) attached to an oxygen-bearing quaternary carbon; four pairs of methylene protons (\(\delta\) 1.85, 1H, m, H-2a; 1.52, 1H, m, H-2β; 2.00, 1H, ddd, \(J = 13.6, 6.4, 1.6\) Hz, H-3t; 1.67, 1H, brt, \(J = 13.6\) Hz, H-3β; 1.91, 1H, brt, \(J = 10.8\) Hz, H-10β; 1.48, 1H, dd, \(J = 10.8, 7.6\) Hz, H-10α; 1.37, 1H, ddd, \(J = 8.8, 6.4, 5.6\) Hz, H-6β; 0.82, 1H, ddd, \(J = 7.2, 6.8, 5.6\) Hz, H-6α); and four aliphatic methine protons (\(\delta\) 1.81, 1H, m, H-1; 1.01, 1H, m, H-5; 1.73, 1H, m, H-7; 3.15, 1H, td, \(J = 10.4, 7.6\) Hz, H-9).

The gross structure of 6 was determined by 2D-NMR studies. From the \(^1\)H-\(^1\)H COSY spectrum of 6, it was possible to establish the separate spin system that maps out the proton sequences from H-1/H-2-2; H-2-2/H-2-3; H-5/H-2-6; H-2-10 and the ketone carbonyl observed at \(\delta\) 6.4, 5.6 Hz, H-6). Furthermore, H-5 showed an NOE response with H-1, but not with H-7 and H-12, and H-7 exhibited correlation with H-1/C-11, C-14, C-15; H-2/C-11; and H-9/C-1, C-7 (Fig. 11, Table 3), established, and the configurations of all chiral centers were assigned as \(R*,4R*,5R*,7R*,9S*\). It was found that 6 has been obtained previously by chemical methods.\(^{22}\) However, to the best of our knowledge, rumphellatin F (6) is the first carphyllane-type norsesquiterpenoid with a cyclopropane unit from nature.

In the biological activity testing, compounds 1 and 4 exhibited activity in standard agar disk diffusion assay against \textit{Pseudomonas aeruginosa}, each causing a 10-mm zone inhibition (100 µg/ml). \textit{Vibrio paraaeromelyticus} was inhibited by 4 and 6, the zone being 10- and 15-mm, respectively (100 µg/ml). Natural product 5 has been shown to exhibit antimicrobial activity toward \textit{Escherichia coli} and \textit{P. aeruginosa} at 200 µg/ml (inhibition zone 5-mm, respectively), and 6 was found to inhibit \textit{Staphylococcus aureus} at 100 µg/ml (inhibition 15-mm).

**Experimental**

Melting points were determined on a FARGO apparatus and were uncorrected. Optical rotation values were measured with a JASCO P-1010 digital polarimeter at 25°C. Infrared spectra were obtained on a VARIAN DIGILAB FT S 1000 FT-IR spectrometer. The NMR spectra were recorded on a VARIAN MERCURY PLUS 400 FT-NMR at 400 MHz for \(^1\)H and 100 MHz for \(^13\)C, in CDCl\(_3\), respectively. Proton chemical shifts were referenced to the residual CHCl\(_3\) signal (\(\delta\) 7.26 ppm). \(^1\)C-NMR spectra were referenced to the center peak of CDCl\(_3\) at \(\delta\) 77.1 ppm. ESI-MS and HR-ESI-MS data were recorded on a BRUKER APEX II mass spectrometer. Column chromatography was performed on silica gel (230—400 mesh, Merck, Darmstadt, Germany). TLC was carried out on precoated Kieselgel 60 F254 (0.25 mm, Merck, Darmstadt, Germany) and spots were visualized by spraying with 10% H\(_2\)SO\(_4\) solution followed by heating. HPLC was performed using a system comprising of a HITACH L-7100 pump, a HITACH photo diode array detector L-7455, and a RHEODYNE 7725 injection port. A semi-preparative column (Hibar 250—25 mm, LiChrospher Si 60, 5 µm) was used for HPLC.

**Animal Material**

Specimens of the gorgonian coral \textit{R. antipathes} were collected off the southern coast of Taiwan in May 2004. This organism was identified by comparison with previous description.\(^{13}\) The voucher specimen was deposited in the National Museum of Marine Biology and Aquarium (NMBA).

**Extraction and Isolation**

The freeze-dried and minced material of \textit{R. antipathes} (wet weight 402 g, dry weight 144 g) was extracted with a mixture of MeOH and CH\(_2\)Cl\(_2\) (1:1) at room temperature. The residue was partitioned between n-hexane and 9: 1 MeOH–H\(_2\)O. The MeOH–H\(_2\)O phase was diluted to 1:1 MeOH–H\(_2\)O and partitioned against CH\(_2\)Cl\(_2\). The CH\(_2\)Cl\(_2\) layer was separated on silica gel and eluted using n-hexane/EtOAc (stepwise, 0—100% EtOAc) to yield four fractions A—D. Fraction A was separated on silica gel eluted using DCM/acetone (stepwise, 20:1—1:1) to
yield fractions A1—A14. Fraction A4 was purified by normal-phase HPLC, using the mixtures of n-hexane and acetone as a mobile phase to afford caryophyllanes 3 (1.5 mg, 6 : 1) and 4 (1.6 mg, 6 : 1—5 : 1). The fraction A4 was separated again on normal-phase HPLC (n-hexane-EtOAc) to give caryophyllanes 1 (2.9 mg, 2 : 1—3 : 2) and 2 (1.3 mg, 3 : 2). Fraction B was chromatographed on silica gel eluted using DCM/acetone (stepwise, 20 : 1—1 : 1) to yield fractions B1—B12. Fraction B9 was purified by normal-phase HPLC, using the mixtures of n-hexane and acetone as a mobile phase to afford caryophyllanes 6 (1.6 mg, 6 : 1) and 5 (0.5 mg, 4 : 1).

Rumphellolide A (1): White powder; mp 145—146 °C; [α]D25 29° (c = 0.27, CHCl3); IR (neat) νmax 3460—2400 (br), 1706 cm−1; 13C-NMR (CDCl3, 100 MHz) and 1H-NMR (CDCl3, 400 MHz) data, see Tables 1 and 2; ESI-MS m/z 275 (M+Na)+ (Calcd for C15H24O3Na, 245.1517). HR-ESI-MS m/z 275.1625 (Calcd for C15H24O3Na, 275.1623). 1H-NMR (CDCl3, 400 MHz) data, see Tables 1 and 2; ESI-MS m/z 275 (M+Na)+; HR-ESI-MS m/z 275.1625 (Calcd for C15H24O3Na, 275.1623).

Rumphellolide B (2): Colorless oil; [α]D25 3° (c = 0.05, CHCl3); IR (neat) νmax 3400—2400 (br), 1705 cm−1; 13C-NMR (CDCl3, 100 MHz) and 1H-NMR (CDCl3, 400 MHz) data, see Tables 1 and 2; ESI-MS m/z 275 (M+Na)+; HR-ESI-MS m/z 275.1625 (Calcd for C15H24O3Na, 275.1623).

Rumphellolide C (3): Colorless oil; [α]D25 3° (c = 0.14, CHCl3); IR (neat) νmax 3442, 1696 cm−1; 13C-NMR (CDCl3, 100 MHz) and 1H-NMR (CDCl3, 400 MHz) data, see Tables 1 and 2; ESI-MS m/z 261 (M+Na)+; HR-ESI-MS m/z 261.1468 (Calcd for C15H24O3Na, 261.1467).

Rumphellolide D (4): Colorless oil; [α]D25 66° (c = 0.17, CHCl3); IR (neat) νmax 3423, 1687 cm−1; 13C-NMR (CDCl3, 100 MHz) and 1H-NMR (CDCl3, 400 MHz) NMR data, see Tables 1 and 2; ESI-MS m/z 261 (M+Na)+; HR-ESI-MS m/z 261.1468 (Calcd for C15H24O3Na, 261.1467).

Rumphellolide E (5): Colorless oil; [α]D25 60° (c = 0.03, CHCl3); IR (neat) νmax 3439, 1690 cm−1; 13C-NMR (CDCl3, 100 MHz) and 1H-NMR (CDCl3, 400 MHz) data, see Tables 1 and 2; ESI-MS m/z 261 (M+Na)+; HR-ESI-MS m/z 261.1466 (Calcd for C15H24O3Na, 261.1467).

Rumphellolide F (6): White powder; [α]D25 15° (c = 0.08, CHCl3); IR (neat) νmax 3430, 1702 cm−1; 13C-NMR (CDCl3, 100 MHz) and 1H-NMR (CDCl3, 400 MHz) NMR data, see Tables 1 and 2; ESI-MS m/z 245 (M+Na)+; HR-ESI-MS m/z 245.1516 (Calcd for C15H24O3Na, 245.1517).

Antimicrobial Assays Natural products 1—6 were assayed for antibacterial activity against the Gram-negative bacteria Escherichia coli, Pseudomonas aeruginosa, and Vibrio parahaemolyticus and the Gram-positive bacterium Staphylococcus aureus. The standard agar diffusion assay was carried out according to the procedure described previously.239

Acknowledgments This research work was supported by grants from the National Science Council (NSC 94-2320-B-291-001-N2 and NSC 95-2320-B-291-001-MY2) and by the intramural funding from the National Museum of Marine Biology and Museum, Taiwan, ROC, awarded to P.-J. Sung.

References