50. Isolation of Toxic and Potentially Toxic Sesqui- and Monoterpenes from the Tropical Green Seaweed *Caulerpa taxifolia* Which Has Invaded the Region of Cap Martin and Monaco[1])

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The green seaweed *Caulerpa taxifolia* (VAHL) C. AGARDH (Caulerpales), which, after its recent accidental introduction, is growing in the region of Cap Martin much more vigorously than in the tropics, is shown to contain the known sesquiterpenic toxins caulerpenyne (**1**) – in larger amounts than in tropical Caulerpales – and oxytoxin 1 (**2**). Novel, potentially toxic products isolated in small amounts from this seaweed include the sesquiterpenes taxifolial A (= (5*E*)-6,10-dimethyl-2-[(*E*)2-oxoethylidene]undeca-5,9-dien-7-yne-1,3-diyl diacetate; **3**), taxifolial B (= (1*E*,6*E*,10*E*)-3-[(*Z*)-acetoxymethylidene]-7,11-dimethyl-12-oxododeca-1,6,10-trien-8-yne-1,4-diyl diacetate; **4**), 10,11-epoxycaulerpenyne (= (1*E*,6*E*)-3-[(*Z*)-acetoxymethylidene]-10,11-epoxy-7,11-dimethyldodeca-1,6-dien-8-yne-1,4-diyl diacetate; 1:1 diastereoisomer mixture; **5**), and taxifolial C (= (2*Z*,6*E*)-3-formyl-7,11-dimethyldodeca-2,6,10-trien-8-yne-1,1,4-triyl triacetate; **6**), besides, as the first example of a monoterpene from the Caulerpales, taxifolial D (= (2*Z*)-3,7-dimethylocta-2,6-dien-4-ynal; **7**).

1. Introduction. – The introduction in a marine area of a new seaweed may constitute a hazard because of the competition of the new species for space and resources [1]. If the new species is one of the rare toxic seaweeds [2], there is also the risk that the toxins may enter the marine food chain *via* grazers or filter feeders [3]; otherwise, by deterring potential grazers, the toxins may help spreading of the seaweed.

We are now faced by such a problem following the invasion of the tropical toxic [4] *Caulerpa taxifolia* (VAHL), C. AGARDH along the eastern Mediterranean coasts of France [1] and owing to prospects that it could rapidly colonize the whole Mediterranean because of its surprising resistance to winter temperatures, efficient systems of reproduction, and more vigorous development than in the tropics [1].

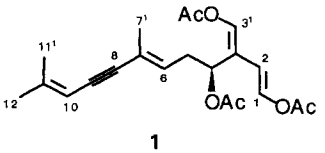
Tropical and subtropical green seaweeds of the order Caulerpales generally contain sesquiterpene or diterpene enol-acetates or their unmasked aldehydic form [4]. These compounds are deterrent, or toxic, toward fish, sea urchin larvae, bacteria, and fungi, thus aiding these algal species to endure the great pressure in the tropics for food and space [4]. Mediterranean species of Caulerpales are also known. But although *Caulerpa prolifera* of the southern coast of Sicily produces the toxic [4] sesquiterpene enol-acetate caulerpenyne (**1**) [5a] and although *Udotea petiolata* of the Bay of Naples produces both the aldehydic diterpene petiodial and the enol-acetate aldehydic diterpene udoteal [5b]

[1]) Presented, in part, by *F.P.* at the 'Table Ronde sur l'Invasion de l'Algue Tropicale *Caulerpa taxifolia* en Méditerranée', Carrefour Universitaire Méditerranéen, Nice, December 16, 1991.

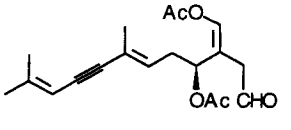
which were also found with tropical Caulerpales [4], these Mediterranean Caulerpales do not constitute a hazard having a limited, steady distribution and growing at small size.

Because of this situation and prospects, we were urged to start a program of investigation of *C. taxifolia* which has invaded the Mediterranean region of Cap Martin and Monaco [1]. We report here on the results of the first part of this program which concerns the isolation and structural elucidation of terpenoids of this seaweed recently acclimatized to the waters of the Côte d'Azur. We found that not only the production of caulerpenyne (**1**) per unit weight of seaweed is higher than for the Caulerpales in the tropics, but novel aldehydic terpenes are also produced which might be toxic. One of these is volatile and is the first monoterpene ever found in the Caulerpales.

2. Results and Discussion. – The terpenes **2**–**7** of *C. taxifolia* collected at Cap Martin, isolated from chromatographic fractions of different polarity (see *Exper. Part*), can be grouped together according to their structural difference with respect to caulerpenyne (**1**) [5a]. Thus, oxytoxin 1 (**2**), already isolated from the sacoglossan opisthobranch mollusc *Oxynoe olivacea* of the Bay of Naples [6], can be considered as a merely deprotected form of **1**, while in the conjugated aldehyde taxifolial A (**3**), a double-bond shift is also involved which changes the enol-ester into an allylic-ester functionality, thus making **3** isomeric with **2**. Taxifolial B (**4**), and the diastereoisomer mixture **5**, formally are oxidized forms of **1**. Taxifolial C (**6**) may be formally viewed as an oxidized form of **3**. Finally, the monoterpenic aldehyde taxifolial D (**7**) may be considered as either a degradation product of **1** or a precursor of it. The structural assignments of the terpenes **1**–**7** are all based on spectral analyses and comparisons.



1



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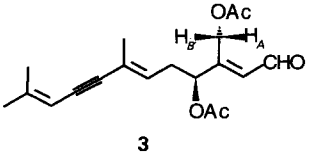

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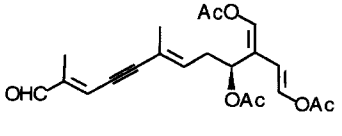

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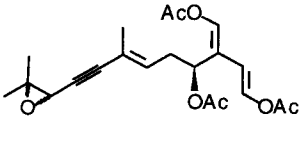
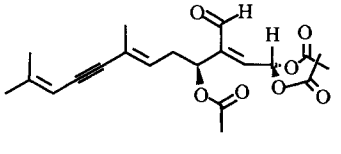


1:1 diastereoisomeric mixture

5



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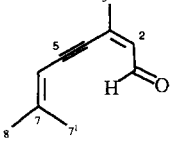

7

Our ^{1}H-NMR, UV, MS and chiroptical data for caulerpenyne (**1**) [5a] and oxytoxin 1 (**2**) [6] match those reported. However, from our ^nJ ^{1}H,^{13}C-COSY study [7], the original assignments of C(3) and C(7) of **2** [6] must be reversed; a similar study (*Table*) allows us to assign all C-atoms for caulerpenyne (**1**)[2]), which was only partly done before [5a]. Incidentally, the large ^1J(H,C) couplings for C(1) and C(3^1) of **1** (see *Table*) reflect the presence of enol-ester functionality.

The NMR resonances for the branched C(4)–C(12) portion of taxifolial A (**3**)[3]) (see *Table* and *Exper. Part*) are nearly superimposable to those for the same portion of **2** and **1**. The other resonances of **3** differ sharply from those of **2**: the *ddd* and the br. *d* at δ(H) 3.13 and 2.98, respectively for 2 H–C(2) and the *s* at δ(H) 7.17 for H–C(3^1) of **2** are replaced in **3** by an *ABX* system at δ(H) 4.75 (H_A–C(3^1)), 4.59 (H_B–C(3^1)), and 6.03 (H–C(2)). This implies a shift of a double bond with conjugation to the aldehyde group and saturation at C(3^1) which deprives the compound of the enol-acetate moiety. Conjugation of the aldehyde function of **3** is confirmed by the high-field resonance of the aldehydic C-atom and the low-field resonance of C(3) as compared to the corresponding C-atoms

Table. *^{13}C-NMR Data for Caulerpenyne* (**1**)[a]), *Taxifolial A* (**3**)[b]), *Taxifolial B* (**4**)[b]), *10,11-Epoxy-caulerpenyne* (1:1 mixture; **5**)[b]), *Taxifolial C* (**6**)[b]), *and Taxifolial D* (**7**)[a])

C-Atom	**1**[c])	**3**	**4**	**5**	**6**	**7**
C(1)	136.93 (*d*, *J* = 192)	189.44 (*d*)	137.48 (*d*)	137.398 (*d*)	84.52 (*d*)	193.02 (*d*)
C(2)	109.16 (*d*, *J* = 155)	128.92 (*d*)	109.52 (*d*)	109.598 (*d*)	135.49 (*d*)	133.63 (*d*)
C(3)	118.59 (*s*)	153.95 (*s*)	118.82 (*s*)	118.848 (*s*)	142.26 (*s*)	153.37 (*s*)
				118.858 (*s*)		
C(4)	68.80 (*d*, *J* = 155)	72.90 (*d*)	68.53 (*d*)	68.730 (*d*)	69.76 (*d*)	99.24 (*s*)
C(5)	31.99 (*t*, *J* = 129)	32.74 (*t*)	32.57 (*t*)	32.309 (*t*)	32.72 (*t*)	88.71 (*s*)
C(6)	129.77 (*d*, *J* = 157)	129.67 (*d*)	134.57 (*d*)	132.791 (*d*)	129.77 (*d*)	104.71 (*d*)
C(7)	121.53 (*s*)	122.45 (*s*)	121.28 (*s*)	120.811 (*s*)	122.64 (*s*)	143.25 (*s*)
C(8)	94.02 (*s*)	94.49 (*s*)	109.08 (*s*)	87.739 (*s*)	not det.	25.23 (*q*)
C(9)	85.19 (*s*)	86.41 (*s*)	83.84 (*s*)	83.862 (*s*)	not det.	
				83.882 (*s*)		
C(10)	105.24 (*d*, *J* = 162)	106.11 (*d*)	127.94 (*d*)[f])	51.962 (*d*)	106.19 (*d*)	
C(11)	148.10 (*s*)	147.93 (*s*)	147.84 (*s*)	60.098 (*s*)	147.57 (*s*)	
				60.085 (*s*)		
C(12)	24.82 (*q*, *J* = 126)	24.53 (*q*)	192.70 (*d*)	23.143 (*q*)	24.52 (*q*)	
C(3^1)	134.20 (*d*, *J* = 192)	59.06 (*t*)	135.13 (*d*)	135.053 (*d*)	188.53 (*d*)	25.13 (*q*)
C(7^1)	17.74 (*q*, *J* = 128)	17.88 (*q*)	17.27 (*q*)	17.398 (*q*)	17.80 (*q*)	21.60 (*q*)
C(11^1)	20.94 (*q*, *J* = 130)	20.97 (*q*)	11.67 (*q*)	20.328 (*q*)	20.94 (*q*)	
CH_3CO_2–C(1)	20.66 (*q*, *J* = 130)[d])		19.91 (*q*)[d])	19.944 (*q*)[d])	20.11 (*q*)	
					20.00 (*q*)[d])	
CH_3CO_2–C(1)	167.03 (*s*)[e])		167.30 (*s*)[e])	167.273 (*s*)[e])	not det.	
CH_3CO_2–C(4)	20.98 (*q*, *J* = 129)	20.11 (*q*)[d])	20.36 (*q*)	20.382 (*q*)	20.21 (*q*)[d])	
CH_3CO_2–C(4)	169.91 (*s*)	169.50 (*s*)[e])	169.18 (*s*)	169.195 (*s*)	not det.	
				169.181 (*s*)		
CH_3CO_2–C(3^1)	20.65 (*q*, *J* = 130)[d])	20.08 (*q*)[d])	19.74 (*q*)[d])	19.801 (*q*)[d])		
CH_3CO_2–C(3^1)	167.78 (*s*)[e])	169.20 (*s*)[e])	166.36 (*s*)[e])	166.438 (br. *s*)[e])		

[a]) In $CDCl_3$.
[b]) In C_6D_6.
[c]) Within parenthesis: multiplicity, ^1J(C,H) in C_6D_6.
[d])[e]) These signals can be interchanged within the same column.
[f]) Superimposed by the solvent signals; detected from DEPT.

[2]) Structural assignments are discussed in terms of the IUPAC-IUB numbering for acyclic terpenes; systematic names are given in the *Exper. Part*.

[3]) The structures **3**–**6** are not intended to represent the absolute configuration, although, as co-occurring compounds, they probably have the same absolute configuration as caulerpenyne (**1**) [5a].

of **2**. The MS data (*Exper. Part*) further support this assignment, in particular by showing a weak signal for $M^{+\cdot}$ and fragmentation at C(4)–C(5) (*m/z* 133 and 199). The (2*E*,6*E*)-configuration rests on NOE's [8], which also assign H_A and H_B at C(3^1) as well as Me(12) (*Exper. Part*).

The NMR spectra of taxifolial B (**4**[3]; see *Table* and *Exper. Part*) resemble in general those of **1**, except for both the deshielding of H–C(10) and the replacement of the ^{13}C-NMR signal of the Me(12) group by an aldehydic *d*, which, on the basis of NOE's (*Exper. Part*), can be assigned to C(12). Extended conjugation of the aldehyde function is reflected in a strong UV absorption band at λ_{max} 306 nm (*Exper. Part*). Although $M^{+\cdot}$ of **4** was not detected, the MS data further support the structural assignment by showing peaks deriving from $M^{+\cdot}$ by loss of one or more ketene units and/or one or more AcOH units (*Exper. Part*).

The NMR spectra of 10,11-epoxycaulerpenyne (**5**[3]); see *Table* and *Exper. Part*) also resemble in general those of **1**, although many ^{1}H- and some of the ^{13}C-signals of **5** are split, indicating a 1:1 diastereoisomer mixture; amazingly, the ^{1}H-resonances are more affected than the ^{13}C-resonances, which poses quite stringent requirements of NMR resolution. Considering only one series of the NMR signals of **5**, it can be noticed that in **5** a 2,2-dimethyloxirane group has replaced the isopropylidene group of **1**. The MS of **5** (*Exper. Part*) reveals ions for the loss of AcOH, AcO·, and/or ketene, while $M^{+\cdot}$ was not detected.

Although the exiguous amount of taxifolial C (**6**[3]) extracted from *C. taxifolia* prevented the detection of the ^{13}C-NMR resonances for the acetylene and acetyl C-atoms, the presence of the acetylene moiety is supported by an intense MS signal at *m/z* 133 for the C(4)–C(12) fragment, like for **1**–**3**, C(1) and C(2) are assigned from ^1J(C,H) data obtained *via* the HMQC pulse sequence [9], while the chemical shift of C(1) (see *Table*) is in accordance with data for geminal diacetates [10]. Moreover, the chemical shifts of H–C(1) and H–C(3^1) (see *Exper. Part*) are in accordance with data of (*Z*)-4,4-bis(acetyloxy)-2-methyl-but-2-enal [11], and the (*Z*)-configuration at C(2) is unequivocally supported by a strong NOE between H–C(1) and H–C(3^1). In agreement, molecular-mechanics calculations indicate that the lowest-energy conformer corresponds to *Formula* **6**. All these data support the proposed structure **6** for taxifolial C, although its spectral analysis is not as thorough as that of the other terpenoids presented here.

Taxifolial D (**7**) is a volatile, optically inactive compound for which the NMR spectra (see *Table* and *Exper. Part*) immediately reveal a monosubstituted isopropylidene and a 3-substituted 3-methylbut-2-enal group which can be interconnected through an acetylenic unit. This makes up the C(5)–C(12) portion of **1**, with the first C-atom oxidized to an aldehydic function, however. (*Z*)-Configuration at C(2) of **7** is based on a positive NOE between H–C(2) and Me(3^1). Conjugation of the aldehyde function throughout the whole system is reflected in strong UV absorptions at λ_{max} 322 and 355 nm (*Exper. Part*). Further support for the proposed structure is given by the MS (*Exper. Part*) which shows both an intense $M^{+\cdot}$ and a $[M-H]^+$ ion. A synthetic compound with the gross structure of **7**, probably a *cis/trans*-mixture, was reported [12]. As far as the conformation of taxifolial D is concerned, a positive NOE between Me(7^1) and the aldehydic proton suggests that the planar conformation indicated in *Formula* **7** must be appreciably populated. Molecular-mechanics calculations are in agreement with this view, giving similar strain and total energies for this conformer and the one with the isopropylidene group on the opposite side of the plane generated by a rotation about the C(5)–C(6) bond of 180°, while all conformers with the isopropylidene group out of this plane are of increasingly higher energies as the rotation angle increases.

3. Biogenesis and Conclusions. – Co-occurrence of caulerpenyne (**1**) and the taxifolials A–D (**3**, **4**, and **6**, resp.) in *C. taxifolia* suggests a common biogenesis: caulerpenyne (**1**) may be the biogenetic precursor of taxifolial B (**4**), while the diastereoisomer mixture **5** may descend biogenetically from **1** too, although what formally appears as a nonstereoselective-epoxidation product of **1** may be surprising. We want to point out that the problems in identifying **5** as a diastereoisomer mixture *via* NMR analysis (see above) are even more acute considering the lack of separation of the diastereoisomers by chromatographic techniques (see *Exper. Part*). This calls for much attention when judging the diastereoisomer purity of noncyclic compounds, even of natural origin.

Taxifolial D (**7**) may be generated biogenetically from **1** following oxidation at the allylic position C(5) with loss of a prenyl moiety. Formally, however, this monoterpene may be viewed as a precursor of **1** by prenylation at the aldehydic C-atom *via* aldol condensation, dehydration, and addition of AcOH. In any event, occurrence of **7** in the

higher-energy (*Z*)-configuration suggests a non-trivial role for this compound. Taxifolial D (**7**) is responsible, at least in part, for the fragrance of the freeze-dried seaweed, so that other biological roles may be envisaged than that of a toxin. To the best of our knowledge, **7** is the first example of a monoterpene isolated from seaweeds of the order Caulerpales.

In conclusion *C. taxifolia* has adapted so well to the region of Cap Martin that it is both growing more vigorously than in the tropics and producing the toxic metabolite caulerpenyne (**1**) in higher concentration than tropical Caulerpales [4]. In January 1992, at Cap Martin, we measured an amount of fresh *C. taxifolia* ranging from 1.8 to 5.3 kg per m^2 of sea bottom at 5 m depth, which corresponds to 3.5–10.4 g of caulerpenyne (**1**), based on the % of this metabolite in the seaweed collected in July 1991. Evaluation of the toxicity of the new terpenoids reported here is a problem to which our laboratories currently are directing the efforts as well as to the related problem of the amount of taxifolial D (**7**) in fresh *C. taxifolia*; due to the volatility of **7**, heavy losses must in fact have occurred in both the freeze-drying and isolation procedures.

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Experimental Part

1. *General.* All evaporations were carried out at reduced pressure. TLC: *Merck* silica gel *60 PF_{254}*. Flash chromatography (FC): *Merck LiChroprep Si60*, 25–40 μm. HPLC: *Merck LiChrosorb Si60*, 7 μm; *Merck LiChrosorb CN*, 7 μm; in both cases, 25 × 1 cm columns. Polarimetric data: *JASCO-DP-181* polarimeter. UV (λ_{max} in nm, ε in mol^{-1} 1 cm^{-1}): *Perkin-Elmer-Lambda-3* spectrophotometer. NMR[2]): *Varian-XL-300*; ^{13}C at 75.43 and ^1H at 299.94 MHz; δ in ppm rel. to internal Me_4Si (= 0 ppm) and J in Hz; 'small' means $J < 0.5$ Hz; differential NOE [8] is indicated as irradiated proton →% NOE on the observed proton(s); multiplicities and C and H assignments from DEPT [13], $^1H,^1H$-COSY [14], and $^1H,^{13}C$-COSY [7]. EI-MS (*m/z* (%)): *Kratos MS80* with home-built acquisition system. Molecular-mechanics calculations: MMX 3.2, *Serena Software*, Bloomington, Indiana.

2. *Collection and Isolation. C. taxifolia* (VAHL) C. AGARDTH was collected in July 1991 by scuba diving along the eastern side of Cap Martin at a depth of 6 m and was immediately lyophilized. The lyophilized seaweed (281.5 g, corresponding to 2.2 kg of fresh seaweed) was extracted with AcOEt, the solvent evaporated, and the residue (19 g) subjected to FC (silica gel (400 g), petroleum ether/AcOEt 100:0 → 0:100). The residue from the fraction with petroleum ether/AcOEt 5:1 (0.378 g) was subjected to HPLC with hexane/AcOEt 49:1: *taxifolial D* (**7**; t_R 15 min; 5.5 mg, 0.0019% rel. to freeze-dried seaweed). The residue from the fraction with petroleum ether/AcOEt 37:13 gave *caulerpenyne* (**1**; 0.35 g). The fractions with petroleum ether/AcOEt up to 17:8 were evaluated by HPLC to contain 3.95 g of **1**. Total yield of **1** 4.3 g (1.53% rel. to freeze-dried seaweed). The residue from the fraction with petroleum ether/AcOEt 33:17 (0.514 g) was subjected to HPLC (*CN*) with hexane/AcOEt 43:7: *oxytoxin 1* [6] (**2**; t_R 11.8 min; 15 mg, 0.0053%), *10,11-epoxycaulerpenyne* (**5**, 1:1 mixture; t_R 13.2 min; 11.2 mg, 0.0040%), and *taxifolial A* (**3**; t_R 14.5 min; 9.3 mg, 0.0033% rel. to freeze-dried seaweed). The residue from the fraction with petroleum ether/AcOEt 16:9 (0.289 g) was subjected to HPLC (*Si60*) with hexane/AcOEt 4:1: *taxifolial B* (**4**; t_R 13 min; 3.4 mg, 0.0012%) and *taxifolial C* (**6**; t_r 11 min; 0.9 mg, 0.00032% rel. to freeze-dried seaweed).

3. *Taxifolial A* (= *(5E)-6,10-Dimethyl-2-[(E)-2-oxoethylidene]undeca-5,9-dien-7-yne-1,3-diyl Diacetate*; **3**). $[\alpha]_D^{20} = -3.9$ ($c = 0.47$, EtOH). UV (EtOH): 269 (17100), 283 (sh). ^1H-NMR (C_6D_6): 9.86 (*d*, $J(1,2) = 7.2$, H–C(1)); 6.03 (*X* of *ABX*, further coupled to H–C(1) and H–C(4), as *dddd*, $J(2,1) = 7.2$, $J(2,4) = J(X,B = J(X,A) = 0.9$, H–C(2)); 5.27 (*ddd*, $J(4,2) = 0.9$, $J(4,5) = 5.7$, 6.0, H–C(4)); 1.58 (*s*, AcO–C(4) or AcO–C(3^1)); 2.21 (*m*, 2 H–C(5)); 5.83 (*tq*, $J(6.5) = 7.5$, $J(6,7^1) = 1.5$, H–C(6)); 5.44 (*qq*, $J(10,12) = J(10,11^1) = 1.3$, H–C(10)); 1.46 (br. *s*, $J(12,10) = 1.3$, $J(12, 11^1)$ small, Me(12)); 4.75 (*A* of *ABX*, $J(A,B) = 14.1$, $J(A,X) = 0.9$, H_A–C(3^1)); 4.59 (*B* of *ABX*, $J(A,B) = 14.1$, $J(B,X) = 0.9$, H_B–C(3^1)); 1.49 (*s*,

AcO–C(3^1) or AcO–C(4)); 1.74 (*dt*, $J(7^1,6) = 1.5$, $J(7^1,5) = 0.9$, Me(7^1)); 1.82 (br. *s*, $J(11^1,10) = 1.3$, $J(11^1,12)$ small, Me(11^1)); NOE: H–C(1)→3.7% on H_A–C(3^1) and 2.8% on H_B–C(3^1); H–C(2) 3.5% on H–C(4) and 1% on 2 H–C(5); H–C(4)→7.1% on H–C(2) and 5.7% on H–C(6); 2 H–C(5)→3.7% on H–C(2), 2.3% on H_B–C(3^1), 1.7% on Me(7^1), and 0.3% on H_A–C(3^1); H–C(6)→5.1% on H–C(4); H–C(10)→3% on Me(12); Me(12)→21% on H–C(10) and 2.1% on Me(11^1); H_A–C(3^1)→8.8% on H–C(1); H_B–C(3^1)→5.2% on H–C(1); Me(7^1)→1.7% on 2 H–C(5). MS: 332 (0.5, M^+), 272 (2.5, $[M - AcOH]^+$), 256 (5), 230 (3), 229 (3), 213 (6), 212 (7), 199 (18), 133 (83), 43 (100).

4. *Taxifolial B* (= *(1*E*,6*E*,10*E*)-3-[(Z)-Acetoxymethylidene]-7,11-dimethyl-12-oxododeca-1,6,10-trien-8-yne-1,4-diyl Diacetate*; **4**). $[\alpha]^{20} = 0$ (589), +3.5 (546), +12.9 (435; $c = 0.17$, EtOH). UV (EtOH): 251 (21300), 306 (15400). ^{1}H-NMR (C_6D_6): 7.93 (*dd*, $J(1,2) = 12.9$, $J(1,3^1) = 0.9$, H–C(1)); 1.57 (*s*, AcO–C(1) or AcO–C(3^1)); 5.73 (br. *dd*, $J(2,1) = 12.9$, $J(2,3^1) = 0.9$, $J(2,4)$ small, H–C(2)); 6.18 (*X* of br. *ABXY*, as br. *t*, $J(4,5) = 7.5$, $J(4,3^1) = 0.9$, $J(4.2)$ small, H–C(4)); 1.67 (*s*, AcO–C(4)); 2.61, 2.44 (*AB* of br. *ABXY*, $J(A,B) = 15.0$, $J(5,4) \approx J(5,6) = 7.5$, 2 H–C(5)); 5.98 (*Y* of br. *ABXY*, as *tq*, $J(6,5) \approx 7.5$, $J(6,7^1) = 1.5$, H–C(6)); 5.83 (*q*, $J(10,11^1) = 1.5$, H–C(10)); 9.04 (*s*, H–C(12)); 7.31 (*ddd*, $J(3^1,2) = J(3^1,1) = J(3^1,4) = 0.9$, H–C(3^1)); 1.53 (*s*, AcO–C(3^1) or AcO–C(1)); 1.72 (*dt*, $J(7^1,6) = 1.5$, $J(7^1,5) = 0.9$, Me(7^1)); 1.89 (*d*, $J(11^1,10) = 1.5$, Me(11^1)); NOE: H–C(10)→22% on H–C(12); H–C(12)→25% on H–C(10). ^nJ ^{1}H,^{13}C-COSY (C_6D_6): within all CH_3CO groups; H–C(2)/C(1); H–C(3^1)/C(3); Me(7^1)/C(7) and C(8); Me(11^1)/C(11) and C(10). MS: 346 (0.3 $[M - CH_2CO]^+$), 328 (0.4, $[M - AcOH]^+$), 286 (3, $[328 - CH_2CO]^+$), 244 (5), 226 (15, $[286 - AcOH]^+$), 215 (7), 199 (4), 198 (5), 197 (7), 157 (12), 148 (11), 147 (7), 133 (8), 115 (17), 43 (100).

5. *1:1 Diastereoisomer Mixture of 10,11-Epoxycaulerpenyne* (= *(1*E*,6*E*)-3-[(Z)-Acetoxymethylidene]-10,11-epoxy-7,11-dimethyldodeca-1,6-dien-8-yne-1,4-diyl Diacetate*; **5**). Data for the 1:1 mixture. $[\alpha]_D = -12.3$ ($c = 0.56$, EtOH). UV (EtOH): 240 (25800). ^{1}H-NMR (C_6D_6): 7.910 (br. *d*, $J(1,2) = 12.9$, $J(1,3^1) = 0.9$, H–C(1)); 1.577, 1.579 (2*s*, 1:1, AcO–C(1) or AcO–C(3^1)); 5.726, 5.728 (2*ddd*, 1:1, $J(2,1) = 12.9$, $J(2,4) = J(2,3^1) = 0.9$, H–C(2)); 6.14 (*Y* of br. *ABXY*, further coupled to both H–C(2) and H–C(3^1), as br. *t*, $J(4,5) = 7.5$, $J(4,2) = J(4,3^1) = 0.9$, H–C(4)); 1.668, 1.670 (2*s*, 1:1, AcO–C(4)); 2.58, 2.44 (*AB* of br. *ABXY*, further coupled to Me(7^1), $J(A,B) \approx 15$, $J(5,4) = 7.5$, $J(5,6) = 7.6$, $J(5,7^1) = 0.9$, 2 H–C(5)); 5.936, 5.941 (*X* of br. *ABXY*, further coupled to Me(7^1), as 2*tq*, 1:1, $J(6,5) = 7.6$, $J(6,7^1) = 1.5$, H–C(6)); 3.09 (br. *s*, $J(10,12)$ and $J(10,11^1)$ small, H–C(10)); 0.940, 0.941 (2 br. *s*, 1:1, $J(12,10)$ and $J(12,11^1)$ small, Me(12)); 7.306, 7.308 (2*ddd*, 1:1, $J(3^1,2) = J(3^1,1) = J(3^1,4) = 0.9$, H–C(3^1)); 1.560, 1.563 (2*s*, 1:1, AcO–C(3^1) or AcO–C(1)); 1.713 (*dt*, $J(7^1,6) = 1.5$, $J(7^1,5) = 0.9$, Me(7^1)); 1.309, 1.315 (2 br. *s*, 1:1, $J(11^1,10)$ and $J(11^1,12)$ small, Me(11^1)); NOE: H–C(2)→11.3% on H–C(3^1); H–C(4)→3.1% on H–C(1); Me(12)→18% on H–C(10) and 0.3% on Me(11^1); H–C(3^1)→14.2% on H–C(2) and 3.2% on H–C(1); Me(11^1)→3.5% on 2 H–C(5). MS: 331 (0.5), 330 (0.5, $[M - AcOH]^+$), 289 (0.8), 288 (1.3), 271 (2.8), 270 (1.4), 246 (4), 213 (10), 199 (18), 159 (15), 157 (22), 150 (11), 149 (6), 133 (31), 115 (31), 91 (30), 43 (100).

6. *Taxifolial C* (= *(2*Z*,6*E*)-3-Formyl-7,11-dimethyldodeca-2,6,10-trien-8-yne-1,1,4-triyl Triacetate*; **6**). $[\alpha]^{20} \approx 0$ (589), +15.0 (546), +12.5 (435), −17.5 (365; $c = 0.04$, EtOH). UV (EtOH): 260 (32000), 280 (sh). ^{1}H-NMR (C_6D_6): 8.09 (*d*, $J(1,2) = 8.7$, H–C(1)); 1.49 (*s*, 2 AcO–C(1)); 6.47 (*dd*, $J(2,1) = 8.7$, $J(2,4) = 1.0$, H–C(2)); 5.93 (*td*, $J(4,5) = 5.5$, $J(4,2) = 1.0$, H–C(4)); 1.64 (*s*, AcO–C(4)); 2.45 (br. *dd*, $J(5,6) = 7.5$, $J(5,4) = 5.5$, $J(5,7^1)$ small, 2 H–C(5)); 5.88 (*tq*, $J(6,5) = 7.5$, $J(6,7^1) = 1.5$, H–C(6)); 5.39 (*qq*, $J(10,12) = J(10,11^1) = 1.2$, H–C(10)); 1.45 (br. *s*, $J(12,10) = 1.2$, $J(12,11^1)$ small, Me(12)); 10.27 (*s*, H–C(3^1)); 1.70 (br. *d*, $J(7^1,6) = 1.5$, $J(7^1,5)$ small, Me(7^1)); 1.78 (br. *s*, $J(11^1,10) = 1.2$, $J(11^1,12)$ small, Me(11^1)); NOE: H–C(1)→16% on H–C(3^1); H–C(2)→3% on H–C(4); 2 H–C(5)→6% on H–C(4), 4% on H–C(6), and 2% on Me(7^1)); Me(12)→15% on H–C(10); H–C(3^1)→29% on H–C(1). MS: 330 (10 $[M - AcOH]^+$), 271 (42, $[330 - CH_2CO]^+$), 229 (14, $[330 - AcO]^+$), 228 (13, $[330 - AcOH]^+$), 213 (7), 211 (5), 199 (18), 133 (78, C(3)–C(4) fragment), 43 (100).

7. *Taxifolial D* (= *(2*Z*)-3,7-Dimethylocta-2,6-dien-4-ynal*; 7). UV (EtOH): 259 (22000), 276 (sh), 322 (15800), 355 (6300). ^{1}H-NMR ($CDCl_3$): 10.06 (*d*, $J(1,2) = 8.1$, H–C(1)); 6.12 (*dq*, $J(2,1) = 8.1$, $J(2,3^1) = 1.5$, H–C(2)); 5.48 (*qq*, $J(6,8) = J(6,7^1) = 1.3$, H–C(6)); 1.89 (br. *s*, $J(8,6) = 1.3$, $J(8,7^1)$ small, 3 H–C(8)); 2.14 (*d*, $J(3^1,2) = 1.5$, Me(3^1)); 1.95 (br. *s*, $J(7^1,6) = 1.3$, Me(7^1)); NOE: H–C(2)→1% on Me(3^1); H–C(6)→2% on 3 H–C(8); 3 H–C(8)→8% on H–C(6); Me(3^1)→6% on H–C(2); Me(7^1)→2% H–C(1). MS: 148 (16, M^+), 147 (14, $[M - H]^+$), 133 (40, $[M - CH_3]^+$), 119 (7), 105 (28), 91 (12), 84 (100).

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