

## New Terpene Hydrocarbons from the Alligatoridae (Crocodylia, Reptilia)

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Received February 28, 2002

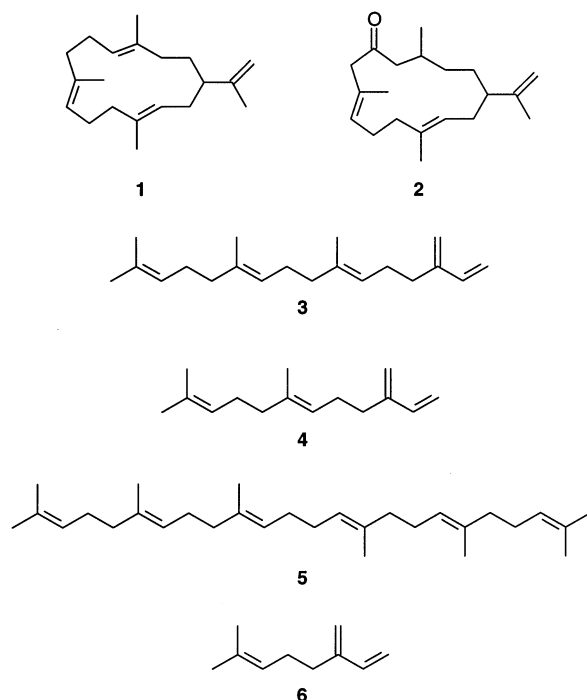
The contents of the paracloacal gland secretions of the alligatorids *Alligator mississippiensis*, *A. sinensis*, *Paleosuchus palpebrosus*, and *P. trigonatus* were investigated. Novel acyclic hydrocarbon terpenes with a rare trisubstituted 2,4-diene system were identified in the secretions of *A. sinensis*, *P. palpebrosus*, and *P. trigonatus*. The structures of the monoterpene (2*E*,4*E*)-3,7-dimethyl-2,4-octadiene (**9**) and the sesquiterpene (2*E*,4*E*,7*S*)-3,7,11-trimethyl-2,4-dodecadiene (**14**) were proven by synthesis and gas chromatography on a chiral phase. Several other new terpenes (**11**, **16**, **17**, **18**, **19**, and **20**) related to these components also were present in the secretions, as well as the known compounds myrcene (**6**), (*E*)- $\beta$ -farnesene (**4**), (*E*)- $\beta$ -springene (**3**), squalene (**5**), cembrene A (**1**), and 11,12-dihydrocembren-10-one (**2**).

The paracloacal glands of crocodylians, a putative source of pheromones, produce a variety of lipids, including compounds rare or unique among vertebrates.<sup>1</sup> Alligators and caimans (Alligatoridae), in which the chemistry of skin gland secretions has been studied most extensively, are known to contain some unusual terpenoids. In the Chinese alligator (*Alligator sinensis* Fauvel), cembrene A (**1**) and a related ketone, 11,12-dihydrocembren-10-one (**2**), have been observed in adult males, but not females.<sup>2</sup> In immature American alligators (*A. mississippiensis* (Daudin))<sup>3</sup> and in adult smooth-fronted caimans (*Paleosuchus trigonatus* (Schneider)), a major glandular component was identified as (*E,E*)- $\beta$ -springene (**3**),<sup>4,5</sup> a diterpene homologue of (*E*)- $\beta$ -farnesene (**4**). We report here on our analysis of *Alligator* spp. and *Paleosuchus* spp. and on the identification of additional terpene hydrocarbons from *A. sinensis*, *P. trigonatus*, and the dwarf caiman (*P. palpebrosus* (Cuvier)), including several new natural products. We also provide further information on the occurrence among the sexes and age-classes of some terpenoids previously reported from alligatorids. Both morphological and molecular data establish *Alligator* and *Paleosuchus* as distantly related genera of extant Alligatoridae.<sup>6</sup> Our results provide a broader picture of the distribution of hydrocarbon terpenoids within this family, and they extend the known distribution of some compounds among the sexes and age-classes of these taxa.

### Results and Discussion

Glandular secretions obtained from captive-reared subjects were analyzed by GC–MS. Our results (see Table 1) confirm the identity of several terpenoids previously reported from the paracloacal glands of *Alligator* spp. and *Paleosuchus* spp. (*E*)- $\beta$ -Farnesene (**4**) was observed in immature *A. mississippiensis*, in a female and in immature *P. trigonatus*, and in all samples of *A. sinensis* and *P. palpebrosus*; it was not detected in adult *A. mississippiensis* or in a male *P. trigonatus*, which curiously was devoid of hydrocarbons.

$\beta$ -Springene (**3**) had been reported as a major component of male and female *P. trigonatus*<sup>4,5</sup> and immature, but not



adult, *A. mississippiensis*.<sup>3</sup> We confirmed this diterpene in female *P. trigonatus* and as a major component of immature *A. mississippiensis*. We also observed **3** in male, female, and immature *P. palpebrosus*. Trace quantities of this compound were detected in an adult female *A. sinensis*, providing the only evidence of it in this species.

Cembrene A (**1**) from the paracloacal glands had been reported in adult male *A. sinensis*, where it was found to comprise 2% of a dichloromethane extract.<sup>2</sup> We observed this diterpene in both male *A. sinensis* and, in lesser abundance, one pooled sample of females. As with **3** in *A. mississippiensis*, compound **1** was most abundant in immature *A. sinensis*. We also observed it in females of *P. palpebrosus* and *P. trigonatus* and, again in greater abundances, in immatures of both species. 11,12-Dihydrocembren-10-one (**2**), which like its parent compound also had been known only from male *A. sinensis*,<sup>2</sup> was confirmed in both males of this species and, in trace amounts, immatures.

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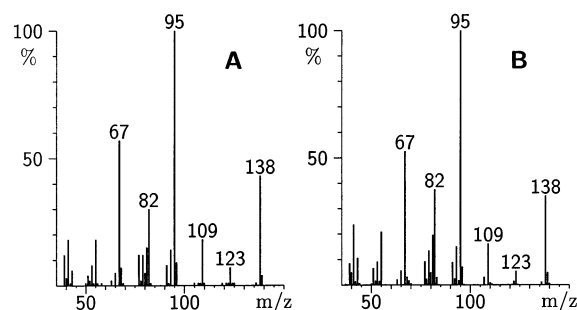
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**Table 1.** Distribution of Terpene Hydrocarbons in Paracloacal Gland Secretions of Male (m), Female (f), and Unsexed Immature *Alligator* and *Paleosuchus* spp.<sup>a</sup>

compound	<i>A. mississippiensis</i>			<i>A. sinensis</i>			<i>P. palpebrosus</i>			<i>P. trigonatus</i>		
	m (1)	f (1)	i (3)	m (2)	f (3)	i (8)	m (1)	f (1)	i (4)	m (1)	f (1)	i (4)
<b>1</b>	—	—	—	4.66	0.21	40.22	—	0.05	7.15	—	0.42	6.13
<b>2</b>	—	—	—	27.96	4.01	1.04	—	—	—	—	—	—
<b>3</b>	—	—	17.02	—	t	—	0.61	10.44	3.99	—	13.03	1.23
<b>4</b>	—	—	t	0.07	0.04	t	0.35	0.07	2.32	—	0.46	0.96
<b>5</b>	—	—	—	—	—	t	0.09	0.31	3.51	—	5.00	3.70
<b>6</b>	—	—	—	—	—	—	—	—	—	—	t	t
<b>9</b>	—	—	—	t	t	—	t	—	—	—	0.01	—
<b>11</b>	—	—	—	t	t	—	t	—	—	—	t	—
<b>14</b>	—	—	—	0.17	0.27	—	0.84	0.11	—	—	—	—
<b>16</b>	—	—	—	0.06	0.11	—	0.22	0.08	—	—	—	—
<b>17</b>	—	—	—	0.04	0.16	—	0.27	0.07	—	—	—	—
<b>18</b>	—	—	—	t	0.06	—	0.05	t	—	—	—	—
<b>19</b>	—	—	—	—	0.11	—	—	—	—	—	—	—
<b>20</b>	—	—	—	—	0.04	—	—	—	—	—	—	—

<sup>a</sup> Median content (%) of the total secretion. t: < 0.01%, —: not detected. The number of individuals analyzed is indicated in parentheses.

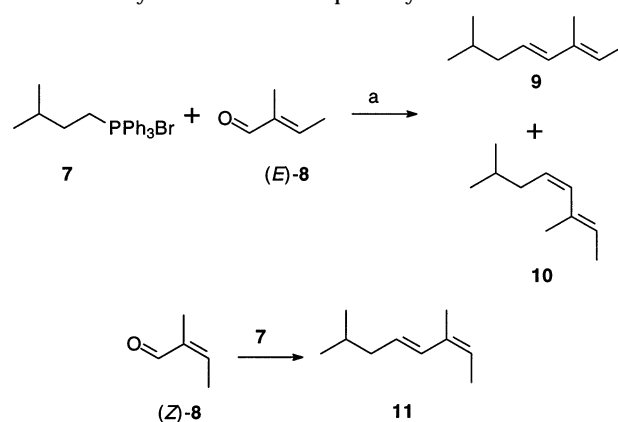


**Figure 1.** Mass spectra of compounds **A**, identified as (2*E*,4*E*)-3,7-dimethyl-2,4-octadiene (**9**), and **B**, identified as (2*Z*,4*E*)-3,7-dimethyl-2,4-octadiene (**11**).

Squalene (**5**) is a common vertebrate skin product, but among alligatorids it had been reported only in *Caiman* spp.<sup>1</sup> We observed squalene primarily in female and immature *Paleosuchus* spp. Myrcene (**6**), which has not previously been reported from reptiles, was detected by us in trace amounts in a male *P. palpebrosus* and immature *P. trigonatus*.

In samples of both *P. trigonatus* and *A. sinensis*, two unknown trace components **A** (retention index *I* 1026) and **B** (*I* 1011) were detected in addition. They eluted shortly after the monoterpene myrcene on an apolar GC phase. The mass spectra of the two compounds are shown in Figure 1. The base peak at *m/z* 95 is formed by a favored loss of a fragment of 43 amu, most probably C<sub>3</sub>H<sub>7</sub>. The spectra were reminiscent of hydrocarbon monoterpenes. Therefore, 3,7-dimethyl-2,4-octadiene was proposed as their structure because allylic bond cleavage can be expected to give rise to a prominent ion at *m/z* 95. For verification of the structures the compounds were synthesized as shown in Scheme 1. Reaction of the ylide derived from 3-methylbutyltriphenylphosphonium bromide (**7**) and tiglic aldehyde (*E*-**8**) furnished a mixture of (2*E*,4*E*)-3,7-dimethyl-2,4-octadiene (**9**) and its (2*E*,4*Z*)-isomer (**10**). Compound **9** showed MS and GC data identical with the later-eluting natural compound **A**, thus confirming the proposed structure and establishing its *E,E*-configuration. The earlier eluting compound **B** showed slightly different GC and MS data compared to **10** (*I* 978). Because it seems unlikely that the natural compounds show a different configuration in both double bonds, we propose (2*Z*,4*E*)-3,7-dimethyl-2,4-octadiene (**11**) as the structure of compound **B**. This was verified by its synthesis using the very unstable aldehyde (*Z*-**8**) as starting material. Because of the many byproducts formed during preparation and reaction of (*Z*-**8**), **11** could

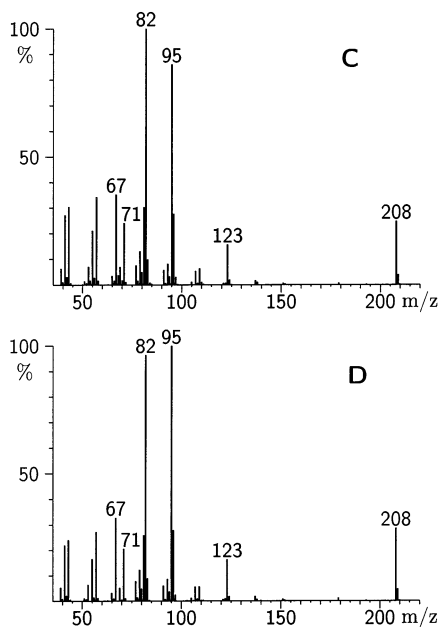
**Scheme 1.** Synthesis of Monoterpene Hydrocarbons<sup>a</sup>



<sup>a</sup> (a): KOtBu.

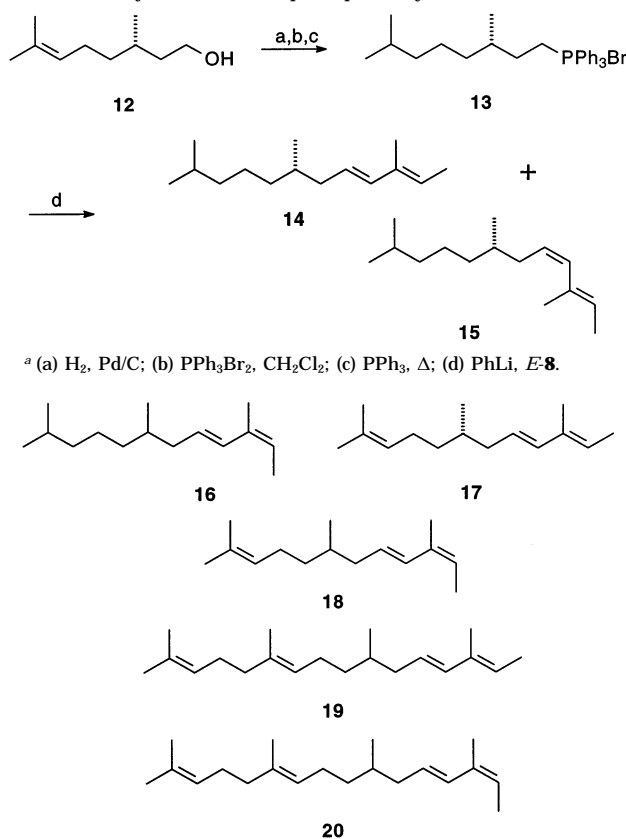
not be obtained in pure form. Nevertheless, the identical retention time and MS data proved our structural assignment of **B** to be correct. Neither compound has previously been reported from a natural source, but they have been prepared synthetically in mixtures or by elaborate routes.<sup>8–10</sup>

In the secretions of *P. palpebrosus* and *A. sinensis* two sesquiterpenes **C** (*I* 1469) and **D** (*I* 1448) occurred in minor amounts (up to 0.5% of the samples); they showed mass spectra similar to that of **9** (see Figure 2). The ions at *m/z* 71 and 123 point to a saturated isopentyl-end of the molecule. From these data and the strong diagnostic ion at *m/z* 95, 3,7,11-trimethyl-2,4-dodecadiene was proposed as the structure of the natural compounds. The synthesis shown in Scheme 2 proved our assignment. (*S*)-Citronellol (**12**) was converted by hydrogenation and bromination into the respective bromide. After conversion into the alkyltriphenylphosphonium bromide **13**, Wittig reaction with *E*-**8** furnished the desired compound, (2*E*,4*E*,7*S*)-3,7,11-trimethyl-2,4-dodecadiene **14**. The formation of its minor (2*E*,4*Z*)-diastereomer **15** can be suppressed when Schlosser-type reaction conditions are used,<sup>11</sup> changing the **14**/**15** ratio from 2:1 to 94:6. Racemic **14** was synthesized in an identical procedure from *rac*-**12**, thus enabling determination of the absolute configuration of the natural compound. Chiral gas chromatography using a cyclodextrin phase revealed that the natural **14** obtained from *A. sinensis* has an *S*-configuration and is enantiomerically pure (see Figure S1, Supporting Information). The minor natural compound **D** was tentatively identified for similar reasons as explained above in the identification of **B** as (2*Z*,4*E*)-3,7,11-trimethyl-2,4-dodecadiene, **16**.

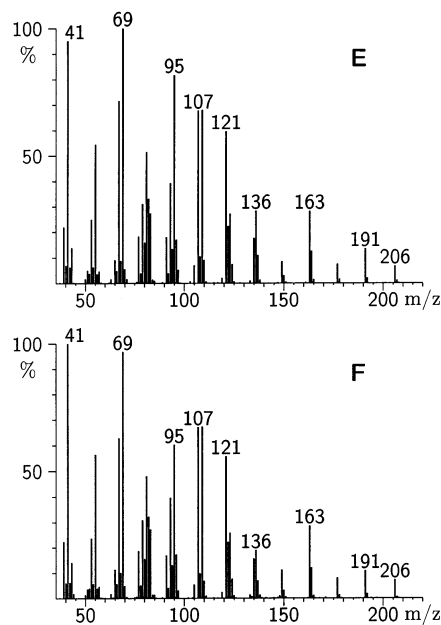


**Figure 2.** Mass spectra of compounds **C**, identified as (2*E*,4*E*)-3,7,11-trimethyl-2,4-dodecadiene (**14**), and **D**, tentatively identified as (2*Z*,4*E*)-3,7,11-trimethyl-2,4-dodecadiene (**16**).

**Scheme 2.** Synthesis of Sesquiterpene Hydrocarbons<sup>a</sup>



The conjugated 2,4-diene system has recently been identified in the related sesquiterpene caparratriene (**17**), which has been isolated from the tree *Ocotea caparrapi* from the Colombian rainforest.<sup>12</sup> The very similar mass spectra of two unknown components **E** (*I* 1507) and **F** (*I* 1486) (Figure 3) in the secretion of *P. palpebrosus* and *A. sinensis* matched the published one of **17**.<sup>13</sup> These compounds thus seem to be diastereomers. The identity of **E** and **17** was proven by synthesis. Thus, (2*E*,4*E*)-3,7,11-trimethyl-2,4,10-dodecatriene (**17**) was synthesized by the

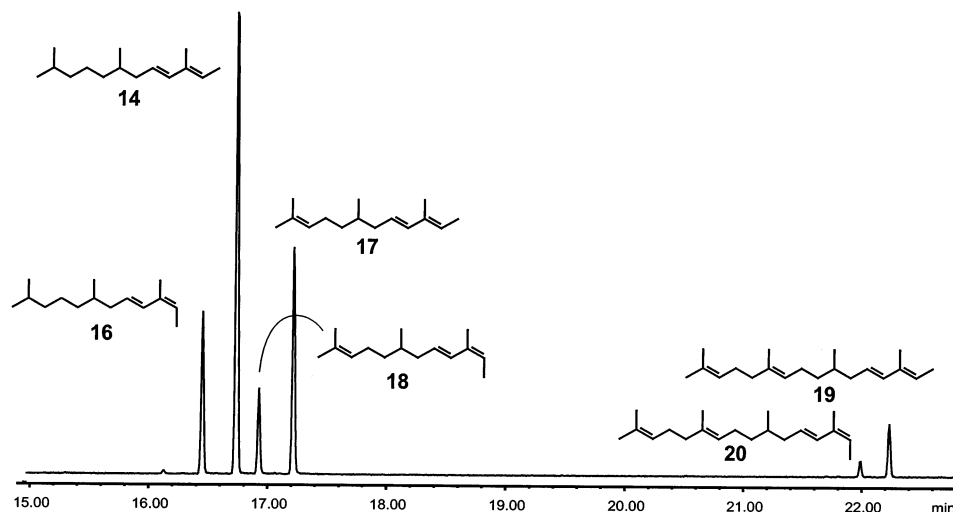


**Figure 3.** Mass spectra of compounds **E** (A), identified as (2*E*,4*E*)-3,7,11-trimethyl-2,4,10-dodecatriene (caparratriene, **17**), and **F** (B), tentatively identified as (2*Z*,4*E*)-3,7,11-trimethyl-2,4,10-dodecatriene (**18**).

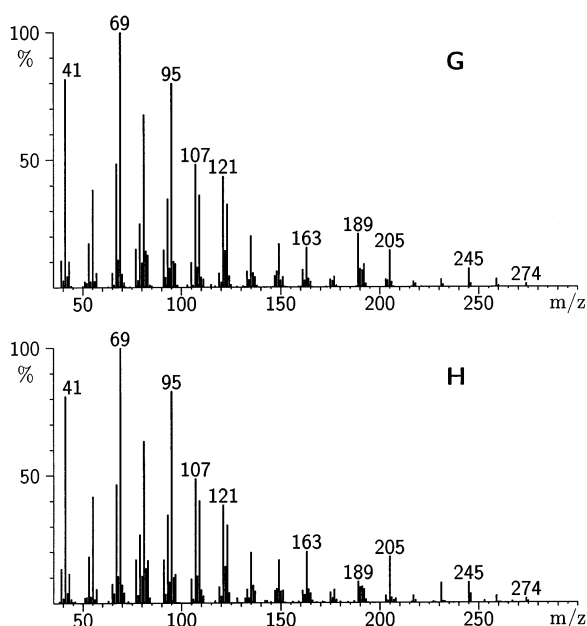
same route as **14**, except for using the phosphonium salt of citronellyl bromide instead of **13** in the Wittig–Schlosser reaction. The GC retention index (*I*) of the later-eluting component **E** was determined to be 1506 on a BPX-5 phase. The minor component **F** has a value *I* of 1485. The difference Δ*I* of 21 units between both isomers is the same as between the related compounds **14** and **16**. From these data the structure of (2*Z*,4*E*)-3,7,11-trimethyl-2,4,10-dodecatriene (**18**) was assigned to **F**. Interestingly, synthetic studies revealed that the absolute configuration of **17** in *O. caparrapi* is *R*.<sup>14,15</sup> The caparratriene from the alligatorids we examined exhibits the opposite *S*-configuration, which was proven by chiral gas chromatography.

Separation of the glandular secretion of *A. sinensis* by column chromatography on silica furnished a fraction containing the compounds **14**, **16**, **17**, **18**, and two later-eluting components, **G** and **H**, with a molecular mass of 274 (Figures 4 and 5). Their mass spectra were very similar, especially in the lower mass region, to those of the caparratrienes.<sup>13</sup> The mass shift of 68 amu together with a diagnostic ion at *m/z* 205 (*M* – 69) pointed to an additional isopentenyl group in the molecules. The occurrence of an ion at *M* – 29, which is surprising, can be seen in all spectra of the compounds reported here. From these results we tentatively conclude that these compounds are (2*E*,4*E*,10*E*)- and (2*Z*,4*E*,10*E*)-3,7,11,15-tetramethyl-2,4,10,14-hexadecatetraene (**19** and **20**), analogous with the other diene terpenes reported here.

Interestingly, great variation in the presence of hydrocarbons was observed among the alligatorids we examined. In *A. sinensis*, compounds **9**, **11**, **14**, and **16**–**20** were observed only in samples of adults from St. Augustine, Florida, while none was observed in other specimens. Compounds **14** and **16**–**18** also were observed in adult *P. palpebrosus* from Florida. Variation in glandular chemistry may be due to differences in diet, holding facilities (indoor versus outdoor), or other aspects of their captive environments. In any case, this is the first report to suggest differences in crocodylian skin gland products at different captive facilities.



**Figure 4.** Gas chromatogram of a fraction obtained from glandular secretion of *Alligator sinensis* by column chromatography on silica.



**Figure 5.** Mass spectra of compounds **G** and **H**, tentatively identified as 3,7,11,15-tetramethyl-2,4,10,14-hexadecatetraenes **19** and **20**.

We have identified new open-chain terpenes in the paraoacal glandular secretions of several alligatorids. They all contain an unusual trisubstituted conjugated diene system, which has so far only rarely been observed in terpenes from other natural sources.

### Experimental Section

**General Experimental Procedures.** The  $^1\text{H}$  (400 MHz) and  $^{13}\text{C}$  (100 MHz) NMR spectra were recorded on a Bruker DRX-400 NMR spectrometer. Chemical shifts are reported in ppm ( $\delta$ ) and referenced to TMS. Assignments of carbons were made by DEPT and HSQC experiments, while diastereomer assignments were corroborated by analysis of coupling constants and NOESY experiments. GC-MS analyses were performed on a Hewlett-Packard 6890 gas chromatograph coupled to a Hewlett-Packard 5973 detector, using a BPX-5 capillary column (0.22 mm  $\times$  25 m, 0.25  $\mu\text{m}$  film) in splitless injection mode. Separations of enantiomers were performed with the same system, equipped with a heptakis(2,6-dimethyl-3-*O*-pentyl)- $\beta$ -cyclodextrin (50% in OV1701) phase<sup>16</sup> operated isothermally at 70  $^\circ\text{C}$ . Helium was used as the carrier gas in all cases.

**Sample Collection.** Paraoacal gland secretions were obtained during January 1999 at the St. Augustine Alligator Farm (SA), Florida, where subjects were kept year-round in outdoor enclosures and fed nutria (*Myocastor coypus*); at the Bronx Zoo (BZ), New York, where they were kept indoors and fed mice and fish; and at the National Aquarium in Baltimore (NA), Maryland, where they were kept indoors and fed earthworms, crickets, fish, and mice. Secretions from *A. sinensis* were obtained from six adults, each at least 1.2 m (total length), and eight (unsexed) immatures, ranging from 0.5 to 0.9 m. Samples from one adult male, one adult female, and four immatures (0.5 m each) were obtained at SA. Samples from one adult male, two adult females, and four immatures (0.8–0.9 m) were obtained at BZ. Secretions from *A. mississippiensis* were obtained from one adult male, one adult female (each 1.5 m), and three immatures (0.8 m) at SA. Secretions from *P. palpebrosus* were obtained from one adult male (1.1 m) and one adult female (1.2 m) at SA and four immatures (0.2–0.6 m) at BZ. Secretions from *P. trigonatus* were obtained from one adult male (1.5 m) and one adult female (1.4 m) from SA and from four immatures (0.5 m each) from NA.

Secretions of adults and immatures were collected by manually placing pressure on the glands, as described by Ibrahim et al.<sup>3</sup> Secretion samples were placed into glass vials with pentane, and the vials were placed on dry ice. Secretion samples from immatures of each species from each facility were pooled in one vial; samples from individual adults were kept separate, except those from two adult female *A. sinensis* from BZ, which were pooled.

Separation of the secretion of *A. sinensis* was performed by column chromatography on silica (230–400 mesh, 9  $\times$  40 mm) with pentane as eluent.

**Identification of Compounds 1–6.** The known compounds were identified by comparison of mass spectra and retention times with those of standard samples.

**General Procedure for Wittig Reaction of Aldehydes (*E*- and *Z*-8).** A solution of 2.6 mmol of triphenylphosphonium salt **7** or **13** in a 2:1 mixture of THF and 1,2-dimethoxyethane was cooled to  $-70$   $^\circ\text{C}$ , and slowly 2.9 mL of a 1 M solution of lithium hexamethyldisilazide in hexane was added. At this temperature 3.48 mmol of freshly distilled **8** was slowly added and stirred for 18 h after removal of the cooling bath. Water was added and the reaction mixture extracted five times with diethyl ether. The combined organic phases were washed with water and brine and dried with  $\text{MgSO}_4$ . The solvent was removed, pentane added, and the mixture filtered, thus removing triphenylphosphine oxide. The solvent was removed under reduced pressure and the crude product subjected to column chromatography on silica. The resulting 2,4-dienes showed a high tendency to isomerize to the respective 3,5-dienes during chromatography. The products were obtained in a 3:1 (2*E*,4*E*)/(2*E*,4*Z*)-mixture. Attempts to separate the



isomers by argentation chromatography resulted in extensive isomerization, thus making the isolation of pure compounds impossible. NMR data were obtained from mixed samples. Higher (2*E*,4*E*)/(2*E*,4*Z*)-ratios up to 96:4 were obtained using Schlosser-type reaction conditions.<sup>11</sup>

**(2*E*,4*E*)-3,7-Dimethylocta-2,4-diene (9)**: colorless oil; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ 6.04 (1H, d, H-4), 5.54 (1H, dt, *J*<sub>4,5</sub> = 15.5 Hz, *J*<sub>5,6</sub> = 7.5 Hz, H-5), 5.44 (1H, q, H-2), 1.97 (2H, bt, H-6), 1.73 (3H, bs, 3-CH<sub>3</sub>), 1.70 (d, 3H, *J*<sub>1,2</sub> = 7.6 Hz, H-1), 1.63 (1H, m, H-7), 0.89 (6H, d, *J* = 7.6 Hz, H-8 and H-8'); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ 135.7 (d, C-4), 134.5 (s, C-3), 126.0 (d, C-5), 124.3 (d, C-2), 42.3 (t, C-6), 28.8 (d, C-7), 22.3 (q, C-8, C-8'), 13.7 (q, C-1), 12.1 (q, 3-CH<sub>3</sub>); EIMS, see Figure 1; HREIMS *m/z* 138.1399 (calcd for C<sub>10</sub>H<sub>18</sub>, 138.1409).

**(2*E*,4*Z*)-3,7-Dimethylocta-2,4-diene (10)**: colorless oil; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ 5.83 (1H, d, H-4), 5.41 (1H, q, H-2), 5.27 (1H, dt, *J*<sub>4,5</sub> = 7.2 Hz, *J*<sub>5,6</sub> = 11.6 Hz, H-5), 2.13 (2H, bt, H-6), 1.77 (3H, bs, 3-CH<sub>3</sub>), 1.62 (1H, m, H-7), 1.60 (d, 3H, *J*<sub>1,2</sub> = 7.6 Hz, H-1), 0.89 (6H, d, *J* = 6.6 Hz, H-8 and H-8'); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ 133.7 (s, C-3), 133.3 (d, C-4), 128.3 (d, C-5), 124.5 (d, C-2), 37.7 (t, C-6), 29.2 (d, C-7), 22.4 (q, C-8, C-8'), 16.4 (q, 3-CH<sub>3</sub>), 13.5 (q, C-1); EIMS *m/z* 138 [M]<sup>+</sup> (46), 123 (18), 109 (63), 95 (93), 82 (36), 67 (100), 55 (31), 41 (32); HREIMS *m/z* 138.1393 (calcd for C<sub>10</sub>H<sub>18</sub>, 138.1409).

**(2*E*,4*E*)-3,7,11-Trimethyldodeca-2,4-diene (14)**: colorless oil; IR (gas) *ν*<sub>max</sub> 2957, 2931, 1711, 1650, 1460, 1380, 1226, 1160, 960, 792 cm<sup>-1</sup>; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ 6.04 (1H, d, H-4), 5.54 (1H, dt, *J*<sub>4,5</sub> = 15.5 Hz, *J*<sub>5,6</sub> = 7.5 Hz, H-5), 5.44 (1H, q, H-2), 2.19–2.27 (1H, m, H-6), 2.04–2.10 (1H, m, H-6), 1.73 (3H, bs, 3-CH<sub>3</sub>), 1.71 (3H, d, *J*<sub>1,2</sub> = 7.6 Hz, H-1), 1.48 (1H, sept, H-11), 1.45–1.53 (1H, m, H-7), 1.02–1.35 (6H, m, H-8, H-9, H-10), 0.85–0.88 (9H, d, *J* = 6.6 Hz, H-12, H-12', 7-CH<sub>3</sub>); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ 135.7 (d, C-4), 134.3 (s, C-3), 125.9 (d, C-5), 124.3 (d, C-2), 39.3 (t, C-10), 37.0 (t, C-8), 35.9 (t, C-6), 33.5 (d, C-7), 28.0 (d, C-11), 24.9 (t, C-9), 22.6 (q, C-12, C-12'), 19.7 (q, 7-CH<sub>3</sub>), 13.7 (q, C-1), 12.1 (q, 3-CH<sub>3</sub>); EIMS, see Figure 2; HREIMS *m/z* 208.2187 (calcd for C<sub>15</sub>H<sub>28</sub>, 208.2192). The compound rearranged during standing or column chromatography to 3,7,11-trimethyldodeca-3,5-diene: IR (gas) *ν*<sub>max</sub> 2960, 2934, 1650, 1461, 1380, 1041, 956, 843, 723 cm<sup>-1</sup>; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ 5.80 (1H, d, H-4), 5.38–5.46 (1H, m, H-6), 5.27 (1H, m, *J*<sub>4,5</sub> = 11.8 Hz, *J*<sub>5,6</sub> = 15.5 Hz, H-5), 2.02–2.13 (3H, m, H-6, H-2), 1.76 (3H, s, H-13), 1.48–1.58 (1H, m, H-11), 1.05–1.38 (6H, m, H-8, H-9, H-10), 0.94 (3H, t, *J*<sub>1,2</sub> = 7.4 Hz, H-1), 0.84–0.92 (9H, d, H-12, H-12', 7-CH<sub>3</sub>); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ 142.9 (s) 133.4 (d), 128.8 (d), 128.3 (d), 40.5 (t), 36.6 (t), 34.0 (d), 33.7 (d), 28.0 (d), 26.9 (t), 22.7 (q), 22.6 (q), 19.6 (q), 16.5 (q), 12.2 (q); EIMS *m/z* 208 [M]<sup>+</sup> (32), 193 (1), 179 (6), 123 (100), 109 (14), 95 (83), 82 (52), 81 (51), 71 (17), 67 (54), 57 (29), 55 (29), 43 (29), 41 (33).

**(2*E*,4*Z*)-3,7,11-Trimethyldodeca-2,4-diene (15)**: colorless oil; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz) δ 5.84 (1H, d, H-4), 5.43 (1H, q, H-2), 5.27 (1H, dt, H-5, *J*<sub>4,5</sub> = 11.9 Hz, *J*<sub>5,6</sub> = 7.3 Hz), 2.06–2.11 (1H, m, H-6), 1.76 (3H, s, 3-CH<sub>3</sub>), 1.69 (3H, d, H-1, *J*<sub>1,2</sub> = 7.1 Hz), 1.42–1.52 (2H, m, H-7, H-11), 1.04–1.34 (6H, m, H-8,

H-9, H-10), 0.84–0.88 (9H, d, *J* = 6.8 Hz, H-12, H-12', 7-CH<sub>3</sub>); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 100 MHz) δ 134.7 (s, C-3), 133.4 (d, C-4), 128.6 (d, C-5), 124.4 (d, C-2), 39.2 (t, C-10), 36.9 (t, C-8), 35.8 (t, C-6), 33.2 (d, C-7), 27.9 (d, C-11), 24.8 (t, C-9), 22.7 (q, C-12, 11-CH<sub>3</sub>), 19.6 (q, 7-CH<sub>3</sub>), 16.5 (q, 3-CH<sub>3</sub>), 13.6 (q, C-1); EIMS *m/z* 208 [M]<sup>+</sup> (29), 123 (16), 107 (15), 95 (100), 82 (98), 71 (25), 67 (45), 57 (33), 43 (37), 41 (37); HREIMS *m/z* 208.2184 (calcd for C<sub>15</sub>H<sub>28</sub>, 208.2192).

**(2*E*,4*E*)-3,7,11-Trimethyl-2,4,10-dodecatriene (17)**: colorless oil; the <sup>1</sup>H NMR and <sup>13</sup>C NMR data are identical to those reported by Palomino and Maldonado.<sup>12</sup> The MS data are identical to those reported by Joulain and König.<sup>13</sup>

**Acknowledgment.** We thank J. Brueggen, J. Darlington, S. Huber, D. Kledzik, W. Puckett, and T. Rexroad (St. Augustine Alligator Farm, FL); J. Behler, W. Holmstrom, and S. Lee (Bronx Zoo, NY); and W. Brown and J. Cover (National Aquarium in Baltimore, MD) for access to crocodylians in their care; and S. Yildizhan for technical assistance. Financial support by the Deutsche Forschungsgemeinschaft and the Fonds der Chemischen Industrie is gratefully acknowledged.

**Supporting Information Available:** Gas chromatographic separations of enantiomers *R*- and *S*-14. This material is available free of charge via the Internet at <http://pubs.acs.org>.

## References and Notes

- Weldon, P. J.; Wheeler, J. W. In *Crocodylian Biology and Evolution*; Grigg, G. C., Seebacher, F., Franklin, C. E., Eds.; Surrey Beatty & Sons: Chipping Norton, 2000; pp 286–296.
- Mattern, D. L.; Scott, W. D.; McDaniel, C. A.; Weldon, P. J.; Graves, D. E. *J. Nat. Prod.* **1997**, *60*, 828–831.
- Ibrahim, S. A.; Avery, J. W.; Weldon, P. J.; Wheeler, J. W. *Z. Naturforsch.* **1998**, *53c*, 201–209.
- Shafagati, A.; Weldon, P. J.; Wheeler, J. W. *Biochem. Syst. Ecol.* **1989**, *17*, 431–435.
- Avery, J. W.; Shafagati, A.; Turner, A.; Wheeler, J. W.; Weldon, P. J. *Biochem. Syst. Ecol.* **1993**, *21*, 533–534.
- Brochu, C. A.; Densmore, L. D., III. In *Crocodylian Biology and Evolution*; Grigg, G. C., Seebacher, F., Franklin, C. E., Eds.; Surrey Beatty & Sons: Chipping Norton, 2000; pp 3–8.
- Niestroj, M.; Neumann, W. P. *Chem. Ber.* **1996**, *129*, 45–61.
- Caporusso, A. M.; Giacomelli, G.; Lardicci, L. *J. Chem. Soc., Perkin Trans. 1* **1981**, 1900–1908.
- Banthorpe, D. V.; Fitton, H.; Lewis, J. *J. Chem. Soc., Perkin Trans. 1* **1973**, 2051–2057.
- Fujita, Y.; Fujita, S.; Okura, H. *Osaka Kogyo Gijutsu Shikensho Kiho* **1974**, *25*, 211–215.
- Schlosser, M.; Tuong, H. B.; Schaub, B. *Tetrahedron Lett.* **1985**, *26*, 311–314.
- Palomino, E.; Maldonado, C.; Kempff, M. B.; Ksebati, M. B. *J. Nat. Prod.* **1996**, *59*, 77–79.
- Joulain, D.; König, W. A. *The Atlas of Spectral Data of Sesquiterpene Hydrocarbons*; E.-B. Verlag: Hamburg, 1998.
- Lí, J.; Liu, Z.; Lan, J.; Li, Y. *J. Chin. Chem. Soc. (Taipei)* **1999**, *46*, 259–262.
- Li, J.; Liu, Z.; Lan, J.; Li, Y. *Chem. Lett.* **1997**, 229–230.
- König, W. A.; Gehrcke, B.; Icheln, D.; Evers, P.; Dönnecke, J.; Wang, W. *J. High Resol. Chromatogr.* **1992**, *15*, 367–372.

NP020073R