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Gorgonophilus canadensis n. gen., n. sp. (Copepoda: Lamippidae), a Gall Forming Endoparasite in the Octocoral *Paragorgia arborea* (L., 1758) from the Northwest Atlantic

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Abstract

Description of a new genus and species of lamippid copepod from the Atlantic coast of Canada. The copepod was found in galls on the deep-water gorgonian *Paragorgia arborea* collected from ~500 m depth in the Northeast Channel (between Nova Scotia and Georges Bank) and the Davis Strait area (west of Greenland). The copepod induces gall formation in its host. Twenty-three galls from four coral colonies have been inspected. The galls contained a total of 76 copepods and 172 egg-sacks. The morphology of the copepod and the galls with content are described. The female copepod is unusually large and there is a considerable size difference between the female (8.5 mm) and the male (2.3 mm) compared to other lamippid species. Infection of this endoparasite seems to have little effect on the host. The morphological characteristics of the ten genera that are presently included in the family Lamippidae are discussed.

Keywords: *Gorgonophilus canadensis*, Gall-forming lamippid, copepod, *Paragorgia arborea*

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1. Introduction

The Lamippidae form a family of Copepoda that is exclusively endoparasitic in Octocorallia, some gallicolous, others living within polyps or the solenial canals connecting them, or embedded in the coenenchyme (Bouligand, 1960, 1966).

At present there are nine genera in this family (Stock, 1973, 1988; Grygier, 1983): *Enalcyonium* Olsson, 1869, *Isidicola* Gravier, 1914, *Lamippe* Bruzelius, 1858, *Lamipella* Bouligand & Delamare Deboutteville, 1959, *Lamippina* Bouligand, 1960, *Lamippula* Bouligand, 1966, *Linaresia* de Zulueta, 1908, *Magnippe* Stock, 1978, and *Sphaerippe*, Grygier, 1983. The family Lamippidae was divided into two subfamilies by Stock (1988): the Linaresiinae, in which the female has a stelliform body and the mouth is reduced to a simple orifice and the Lamippinae with fusiform bodies (both sexes) and a prominent buccal cone (both sexes). The great majority of the species are described from shallow-water temperate or tropical octocorals which are better studied. This is a description of a new genus and species found in the deep-water gorgonian *Paragorgia arborea* (L., 1758), with notes on its ecology.

2. Material and Methods

The material consists of 23 galls from four colonies of *Paragorgia arborea*. The colonies were collected autumn 2001 during a groundfish survey conducted by Department of Fisheries and Oceans (Canada) in the Davis Strait area west of Greenland (Stations OA tow 13 and 16), and as part of a coral survey in the Northeast Channel (R637 and R640) (Table 1). In the Davis Strait colonies were collected by means of otter trawl and in the Northeast Channel the ROV (remotely operated vehicle) 'ROPOS' was used to collect coral colonies. Eight galls were from two white *Paragorgia* colonies (R640 and OA tow 16) and 15 were from two red colonies (OA tow 13 and R637) (Table 2). Aboard the vessels, the colonies were immediately frozen in plastic bags. Before the inspection of galls, the corals were thawed in salt water and the parts with galls were cut off and transferred to a 4% formaldehyde seawater solution.

3. Descriptive Part

Gorgonophilus, new genus

Diagnosis

Lamippid (subfamily Lamippinae) copepods that are endoparasitic within galls on the gorgonian *Paragorgia arborea*. The female is at least three times

Table 1. Locations and depths of stations from which the four colonies of *Paragorgia* with galls were collected, and the number of galls.

Station	Latitude	Longitude	Depth	No. galls
OA Tow 13	67°34'N	58°28'W	560 m	6
OA Tow 16	67°51'N	59°08'W	520 m	5
R637	42°02'N	65°34'W	475 m	9
R640	41°60'N	65°39'W	445 m	3

Table 2. Content of galls formed and inhabited by *Gorgonophilus canadensis* on red and white colonies of *Paragorgia arborea*.

Host colony	Sample	Gall no.	Egg-sacks	Males	Females	Juv.	No. of 'chimneys'
White	R640	1	5	1	1	0	?
		2	5	1	2	0	?
		3	9	1	2	0	?
Red	OA tow 13	1–6	45	8	10	0	?
White	OA tow 16	1	13	1	3	0	?
		2	9	0	2	0	?
		3	9	0	2	0	?
		4	20	3	3	0	?
		5	4	1	2	0	?
Red	R637	1	4	0	1	0	2
		2	1	0	1	0	1
		3	7	1	1	0	2
		4	1	4	7	0	3
		5	0	0	3	0	3
		6	7	1	1	0	3
		7	18	5	2	1	2
		8	9	1	2	1	1
		9	6	0	1	0	2
Total		23	172	28	46	2	19
No./gall			7.5	1.2	2.0		2.1

the size of the male. Both sexes with a fusiform body and buccal cone. Female with distinct lateral lobes on both sides of cephalon (Figs. 1B, 2A); typically, cephalothorax is curved down in front of central part of body (Fig. 1A). Body of male only slightly curved (Fig. 3A) with less distinct lobes on cephalon (Fig. 3B). Both sexes with unsegmented first antenna; second antenna 3-segmented; two pairs of legs with 1-segmented exopodites and 2-segmented endopodites; caudal rami separated, conical with a single terminal seta.

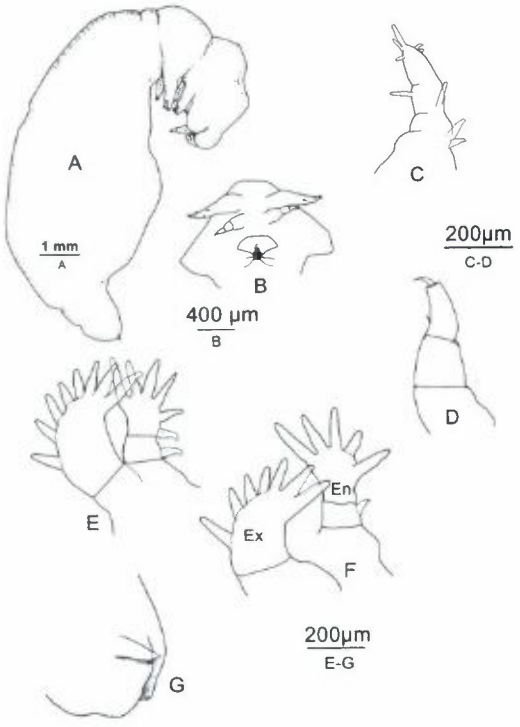

Figure 1. *Gorgonophilus canadensis*, female. A: lateral aspect of female (holotype). B: ventral aspect of cephalon showing cephalic lobes and oral cone. C and D: first and second antennae, respectively. E and F: first and second leg respectively. G: furca lateral aspect.

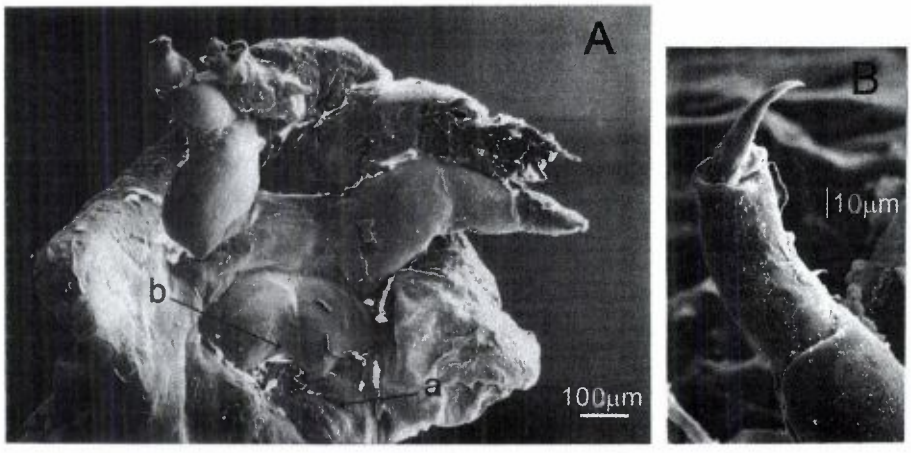

Figure 2. *Gorgonophilus canadensis*, female, scanning electron microscopy photo. A: ventral aspect of cephalon showing oral cone, arrows indicates, a: tong-like element (vestigeal maxilliped?) and b: trapezoidal oral cone. B: second antennae.

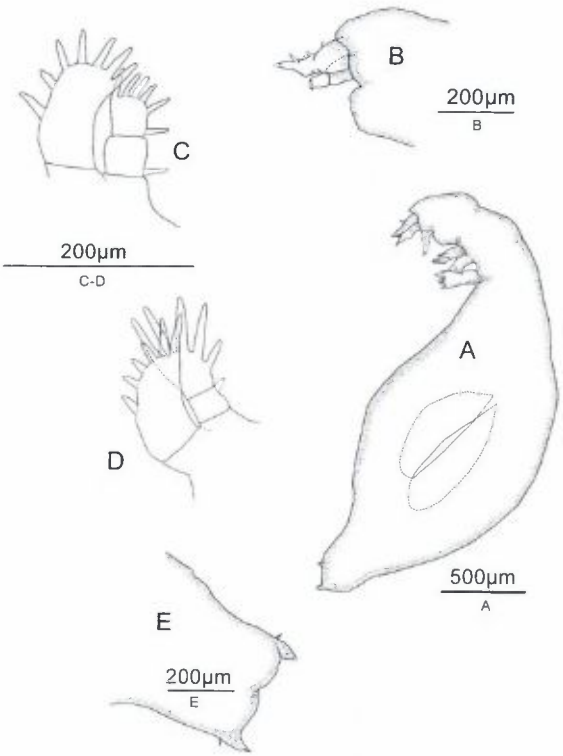

Figure 3. *Gorgonophilus canadensis*, male. A: lateral aspect of male (paratype) showing developing spermatophores. B: lateral aspect of cephalon showing antennae. C and D: first and second leg respectively. E: cauda, ventral aspect.

Maxillipeds vestigial?, small protruding tongue-like elements are seen in SEM (Fig. 2A); Legs 1 and 2 of both sexes with palmately arranged digitations on distal segments (Figs. 1E,F, 3C,D, 4F), each digitation terminating in a spine; exopodites with more spines than endopodites.

Remarks

The family Lamippidae was reviewed by Bouligand (1966). He recognised only two genera *Lamippe* (including the subgenera *Lamippe, Lamippula, Lamippina, Lamippella, Enalcyonium* and *Isidicola*) and *Linaresia*. Stock (1973) reestablished all these genera and presented a key for distinguishing them. Stock (1988) proposed to divide the family into two sub families Linaresiinae and Lamippinae. Aside from the work of Bouligand (1966) and Stock (1973 and 1988), no recent review has been made of the genera. Thus it is difficult to establish a new genus with high degree of certainty. However, the present form could not be assigned to any of the existing genera as described by Stock (1973).

Table 3. The morphological characteristics of the 10 genera in the family Lamippidae. Information is compiled from Stock (1973, 1988) and Grygier (1980) with information on the new genus *Gorgonophilus* included. All characters concerns both sexes except body form. *: acicula is a minute needle-like structure (Bouligand, 1966).

Subfamily	Linaresiinae		Lamippinae							
Genus	*Linaresia*	*Magnippe*	*Lamippe*	*Isidicola*	*Lamippina*	*Lamippula*	*Enalcyonium*	*Lamippella*	*Sphaerippe*	*Gorgonophilus*
Body female	x	x								
Stelliform										
Fusiform			x	x	x	x	x	x	x	x
Mouth										
Simple	x	x								
Complex			x	x	x	x	x	x	x	x
Maxillipeds										
Present			x	x						
Vestigial					x					x?
Absent						x	x	x	x	
Antenna1										
Clearly segmented					x	x	x		x	
Weakly segmented			x	x				x		
Fused			x	x						x
Antenna2										
Clearly segmented					x	x	x			x
Weakly segmented			x					x	x	
Fused				x						

Table 3. Continued

Subfamily	Linaresiinae		Lamippinae							
Genus	*Linaresia*	*Magnippe*	*Lamippe*	*Isidicola*	*Lamippina*	*Lamippula*	*Enalcyonium*	*Lamippella*	*Sphaerippe*	*Gorgonophilus*
Leg 1 endopods										
Present					x	x	x		x	x
Reduced or absent			x	x		(x)	(x)	x		
Leg 2 endopods										
Present					x	x	x		x	x
Reduced or absent			x	x		(x)	(x)	x		
Caudal asicules*										
Present			x		x	x				
Absent				x			x	x	x	x
Body										
Smooth			x	x	x	x	x			x
With minute papillae								x	x	
Lateral lobes on cephalon										
Present										x

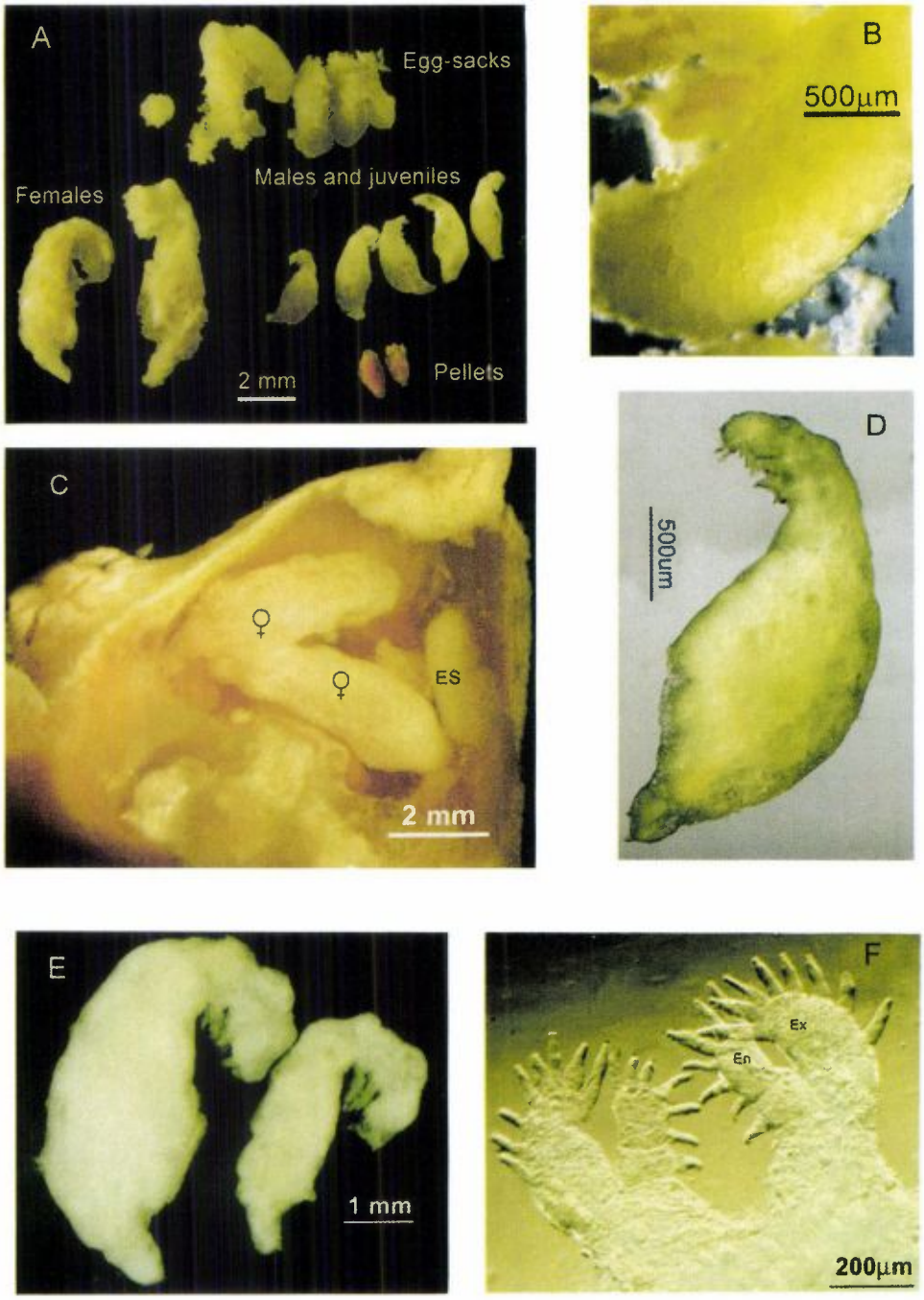

Figure 4. *Gorgonophilus canadensis* photos. A: the content of a particularly large gall. B: Close-up of egg-sack. C: contents of a gall showing two females and an egg-sack (ES). D: male showing normal posture. E: two females showing normal posture. F: first pair of legs showing digitations.

Gorgonophilus differs from *Linaresia* and *Magnippe* in not having the lateral arms that give the females of these genera stellate appearances. *Lamippe* and *Isidicola* have well-developed maxillipeds, which are vestigial in *Gorgonophilus*. *Lamippina* has well-developed endopodites like those of *Gorgonophilus*, but it also has caudal 'acicules' (minute needle-like spines) described in Bouligand (1966), a condition wanting in *Gorgonophilus*. *Lamippula* lacks maxillipeds but has caudal acicules and long, clearly segmented first and second antennae, contrary to the conditions found in *Gorgonophilus*. *Enalcyonium* is similar to *Lamippula* though lacking caudal acicules, but is distinguishable from *Gorgonophilus* by its clearly segmented first antenna. *Lamippella* lacks maxillipeds and caudal asicules and has poorly segmented antennae. It has reduced, unarmed endopodites on its legs, and circular rows of papillae on the body surface contrasting with the well-armed endopodites and smooth surface of *Gorgonophilus*. *Sphaerippe* is similar to *Lamippella*, though with an armed endopodite, and is distinguished from *Gorgonophilus* by the presence of circular rows of papillae. In addition to these differences, the female of *Gorgonophilus* has well-developed lateral lobes, one on each side of the cephalon, and 2-segmented endopodites. The morphological characteristics of the 10 genera are summarized in Table 3.

Etymology

From Gorgonacea and Greek *philos* (beloved), referring to the order of the host coral *Paragorgia arborea*.

Type-species

Gorgonophilus canadensis, new species.

Gorgonophilus canadensis new species

Material

The holotype (female) and 4 paratypes (2 males and 2 females) have been deposited at Nova Scotia Museum of Natural History, Canada (NSMNH Cat. No. 16631 and 16635, respectively).

Type-locality

Northeast Channel, R640 (41°60'N, 65°39'W) at 445 m depth.

Distribution

Known only from four colonies of *Paragorgia arborea*, two from the Davis Strait and two from the Northeast Channel (Table 1).

Host

Endoparasitic in *P. arborea* and forming galls.

Etymology

Referring to its discovery in Canadian waters.

Description

Female (Figs. 1A–G, 2A,B, 4E,F): Body embryo-shaped and rather bulky, greatest length 8.5 mm, greatest width 3.7 mm, anterior part curved about 120° ventrally relative to posterior. Colour white. The body is covered with membrane-like layers (cuticular casts?) and surface is smooth with spongy appearance. Two pairs of antennae, and two pairs of legs near anterior end, body continuing posteriorly into bi-lobed buttocks-like area with pair of short caudal rami with terminal short setae. Lateral margins of cephalon extended as large triangular lobe on each side (Figs. 1B, 2A). First antenna (Fig. 1C) 0.5 mm long with no clear segmentation, bearing 12 setae. Second antenna (Fig. 1D, 2B) 0.4 mm long, 3-segmented, with third segment claw-like. Oral cone trapezoidal with slit in lower part (Figs. 1B, 2A). Maxillipeds vestigial?, small tongue-like elements are seen in SEM (Fig. 2A). Leg 1 (Figs. 1E, 4F) biramous with 1-segmented exopodites, and 2-segmented endopodites. Exopodite and endopodite terminating in digitations each terminating in a spine. Endopodite with one spine on first segment and six on second segment. Exopodite with seven to eight spines. Leg 2 components are similar to those on leg 1 (Fig. 1F). Endopodite with one spine on first article and five on second article, exopods with 7 spines. Caudal rami (Fig. 1G) separated on buttocks-like lobes, rami small, with a short terminal seta.

Male (Figs. 3A–E, 4D): Body flask-shaped and fusiform, 2.3 mm long, 1 mm wide, anterior part only slightly bent ventrally (Figs. 3A, 4D). Colour white. Two pairs of antennae and two pairs of legs near anterior end, body continuing posteriorly into bilobed buttocks-like area with a pair of short caudal rami. Lateral margins of cephalon only slightly extended as lobe on each side. First antenna (Fig. 3B) 0.2 mm long, with no clear segmentation and with 10 setae. Second antenna (Fig. 3B) 0.2 mm long, 3-segmented, with third segment claw-like.

Oral cone trapezoidal. Maxillipeds as in female. Leg 1 (Fig. 3C) biramous with 1-segmented exopodites and 2-segmented endopodite. Exopodite and endopodite terminating in digitations. First endopodite with seven spines (Fig. 3C). Exopodite with seven spines. Leg 2 components similar to those on leg 1 (Fig. 3D). Endopodites with six spines and exopodites with six spines. Caudal rami (Fig. 3E) separated on buttocks-like lobes, rami small, unarmed, with terminal seta. Spermatophores 0.64 mm long (Fig. 3A).

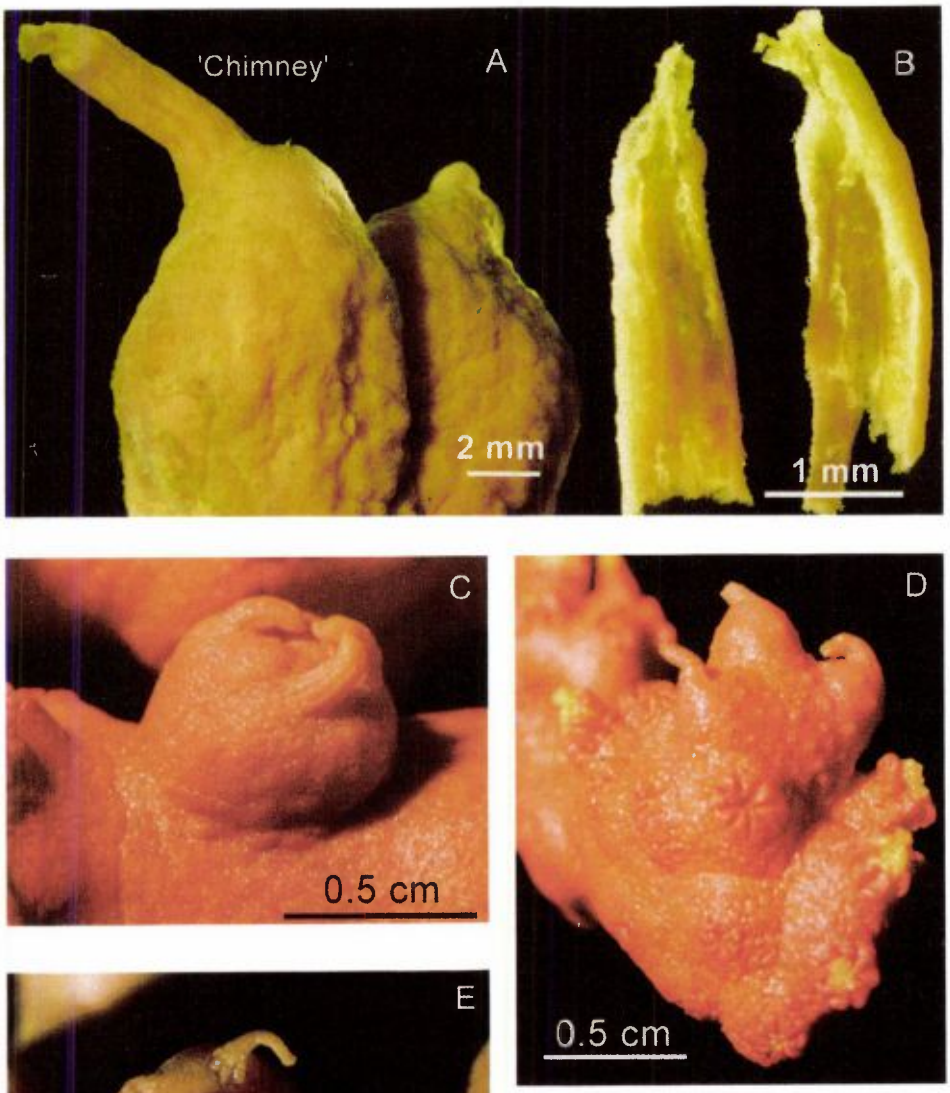

Figure 5. Morphology of galls made by *Gorgonophilus canadensis* on the gorgonian *Paragorgia arborea*. A: typical two-chambered gall with two 'chimneys'. B: a longitudinally cut 'chimney'. C–E: shows the different morphology of galls and their position on the branches of the host coral.

Remarks

Gorgonophilus canadensis is distinguished from other lamippids by its considerable size; the mature female being 3–8 times larger than is common in this family. The prominent lobes on the cephalon in combination with well developed and strongly armed legs and the simple, unarmed cauda, are unique to this species.

Biology

G. canadensis induces gall-formation in *Paragorgia arborea*. In total, 23 galls containing 46 females and 28 males were found on four *P. arborea* colonies (two red and two white). Typically each gall contained two females, one male and seven to eight egg-sacks (Table 2). The content of a particularly large gall is shown in Fig. 4A. The numbers of egg-sacks and males are minimum estimates since the contents of the galls were sometimes hard to distinguish. The eggs were arranged on the periphery along the walls of the gall while the females and male seemed to lie free inside the gall (Fig. 4C). The brittle egg-sacks measured about 2.5 mm in length by 0.8 mm in width and contained ~400 eggs (Figs. 4B,C). Egg size was ~150 µm. Each gall seemed to have no other opening than a chimney-like structure (Fig. 4A,B). The size of the mature female would prevent it from leaving the gall; however nauplius larvae, juveniles and males could escape through the 'chimney'. Very little is known about the life-history of lamippid copepods (e.g. Bouligand, 1960, 1966).

The little information available is on the lifecycle of the gall-forming lamippid *Isidicola antarctica* (Gravier, 1914a,b). This copepod induces gall-formation in the corals *Primnoisis formosa*, Gravier, and *Mopsea gracilis*, Gravier, in Antarctic waters. Gravier (1914a,b) suggests that *I. antarctica* lives the entire life in its gall except as nauplius when it can escape through a polyp of the host. Gravier found nauplius larvae inside eggs but never free in the galls. In contrast to *G. canadensis* the eggs of *I. antartica* are free (not in sacks) in the galls and they are larger (~400 µm) than the eggs of *G. canadensis*. *I. antartica* is also much smaller the largest females are ~1.5 mm long. The galls often contain one female and a smaller male together with several juveniles. Gravier (1914a,b) observed that the ventral side of the copepod was facing towards the interior of the galls. These observations on numbers and position in gall fits well with observations of *G. canadensis* (Figs. 4A,C), however, very large galls may have more than 10 specimens inside (Table 2).

The powerfully armed thoracic legs of *G. canadensis* may be used to scrape tissue from the coral when feeding. Several red pellets were found within the galls, which are probably faecal pellets, not egg sacks (Fig. 4A). The content of the pellets differed greatly from the structure of the opaque egg-sacks. They appear to owe their red colour to pigments that originated from the coral and their content resembled coral tissue. Some of the pellets were found protruding

from the rear end of large females. The thoracic legs together with the antenna might also help the copepod to attach it self to the gall and move around inside as suggested by Gravier (1914a,b) for *I. antartica*.

Effects on host

The galls were typically situated on the distal parts of the branches of the host colony and thus may be exposed to a higher-current environment than more medial portions of the colony. The galls seemed to originate from one to three polyps that had been induced to transform into galls by the copepods (Figs. 5A–E). The surface of the galls differs in structure from uninfected parts of the colony. The galls were typically bi-lobed, presumably resulting from two initial polyps, and each lobe/chamber had at least one 'chimney' connecting the inner chamber of the gall with the surrounding seawater (Figs. 5A,B). The inner chambers of the lobes were interconnected forming a large chamber. The copepods have presumably minimal effect on the coral. Even in the most infected colony with nine galls, *G. canadensis* affected only 20 polyps, less than 5% of the total number.

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