HELGOLÄNDER MEERESUNTERSUCHUNGEN
Helgoländer Meeresunters. 37, 139–148 (1984)

X-diseases in the chaetognath *Sagitta crassa*

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ABSTRACT: Two different, hitherto unknown, diseases occurred in two specimens of *Sagitta crassa* which were individually isolated and maintained in the laboratory. One specimen survived for 24 days, producing a total of 343 eggs and suddenly died without showing any prior symptoms, and upon death had a grotesque appearance. The other had ciliary sense organs the hairs of which became stuck to one another. Ciliary sense organs are important for feeding of chaetognaths; once they become abnormal, the chaetognath may die of starvation. Specimens suffering from X-diseases have not been obtained from field samples so far. Chaetognaths which remained transparent at the time of death included specimens whose ciliary sense organs were attacked by bacteria, those slightly infected by bacteria on their body surface and those with abnormally rough body surfaces. Although the reasons for the development of the abnormality of the ciliary sense organs and body surfaces as well as the mechanism of bacterial infection remain obscure, bacterial infection and abnormalities of the body surface are often observed not only in the laboratory but also in the sea.

INTRODUCTION

"No marine organism seems to be completely free of potential disease agents and all systematic animal groups contain members which can act as agent or host" (Kinne, 1980a, p. 3). Although the information at hand on the diseases of marine animals is in many cases fragmentary and often inadequate, commercial interests have directed considerable funds and efforts into analyzing disease phenomena in bivalves, decapod crustaceans and teleost fishes (Sindermann, 1970; Kinne, 1980b, 1983; Lauckner, 1983). In contrast, the ecological significance of biotic diseases in most of the animals in oceans and coastal waters has received little attention from marine scientists. Of no or limited economical importance, most of the animals concerned await thorough investigation (Kinne, 1980a).

Chaetognaths are an abundant component of the plankton community and are usually the most important carnivores in the sea. However, general reviews on chaetognaths (Hyman, 1959; Alvariño, 1965; Ghirardelli, 1968) contain no information on diseases. Nagasawa et al. (1984) have shown that living chaetognaths are attacked by bacteria both under laboratory and field conditions and that bacterial infections are common in chaetognaths maintained in the laboratory; in fact, most of the captive specimens suffer from some decay of body parts. We also describe here abnormalities of ciliary sense organs and abnormalities in specimens still transparent upon death (i.e. a condition possibly not caused by bacterial infection).

MATERIALS AND METHODS

Chaetognaths, *Sagitta crassa* Tokioka, were collected on 12 different days in Shinhamako, a saline lake which is connected with Tokyo Bay and maintained as described by Nagasawa (1984) in the laboratory and provided with copepods such as *Acartia clausi* Giesbrecht, *Tigriopus japonicus* Mori, or *Oithona aruensis* Früchtl (Nishida & Ferrari, 1983), or polychaete larvae. Fecal pellets, uneaten copepods and any eggs produced were removed and counted each day. A group of 100 chaetognaths was thus observed daily until they died. Their condition at the time of death was noted and categorized (Nagasawa et al., 1984). Eight specimens, referred to as S1, S2, S3, S4, S5, S6, S7 and S8, were examined under a scanning electron microscope (JSM-35) after critical point drying (Hitachi HCP-2) and coating with gold (JFC-1100). Individual S1 was included in the category of "tail damage" whereas S2 and S3 in the category "head damage". Another 5 individuals, S4, S5, S6, S7 and S8, were included in the category "body, curved and transparent". Each species of chaetognaths has identical morphological characteristics of its ciliary sense organ (Nagasawa & Marumo, 1982) and body surface. Therefore, as standards for comparison with the abnormal body surfaces and ciliary sense organs of specimens described in this study, healthy specimens of *Sagitta ferox* Doncaster prepared for study of the fine structure of ciliary sense organs (Nagasawa, unpubl.) were used.

RESULTS

X-disease No. 1

Individual S1 (8 mm long) began to lay eggs 8 days after sampling; it survived for 24 days producing a total of 343 eggs. Surprisingly, one of the two ovaries usually did not contain eggs. During maintenance *Acartia clausi* were offered as food; the mean daily ration of S1 was 10.4 copepods (Nagasawa, 1984). The tail of S1 became a little opaque 23 days after sampling, but we never expected S1 to die from this minor tail damage judging from previous observations of other chaetognaths with minor bacterial infections (Nagasawa et al., 1984). However, S1 died the day after the tail damage appeared, and its entire body became opaque and constricted. We believe its death was not caused by bacteria. Uneaten copepods were still alive in the container of S1 although the predator was dead. This suggests that S1 did not die due to the quality of the seawater used. We found fecal pellets, but no eggs in the container of this dead specimen suggesting that it had fed as usual, but died before spawning which usually occurs at dawn (Nagasawa & Marumo, 1984).

Under SEM the whole body of S1 had a grotesque appearance (Fig. 1), apparently due to degeneration of the epithelium. We assume, therefore, that this chaetognath died due to an unknown disease. For lack of other specimens with similar symptoms, no histological observations have been made so far.

Individual S2 (7 mm long) survived for 8 days feeding on *A. clausi.* At first, the tail of S2 was packed full of testicular products, and the ovaries were full of small eggs. When S2 was suddenly decapitated 7 days after sampling, its testicular products decreased remarkably. One day before decapitation S2 did not feed and its ovaries revealed a space in their inner side due to a decrease in egg number. Although S2 had no head damage, its head was evidently severed. This headless chaetognath was still alive and its body

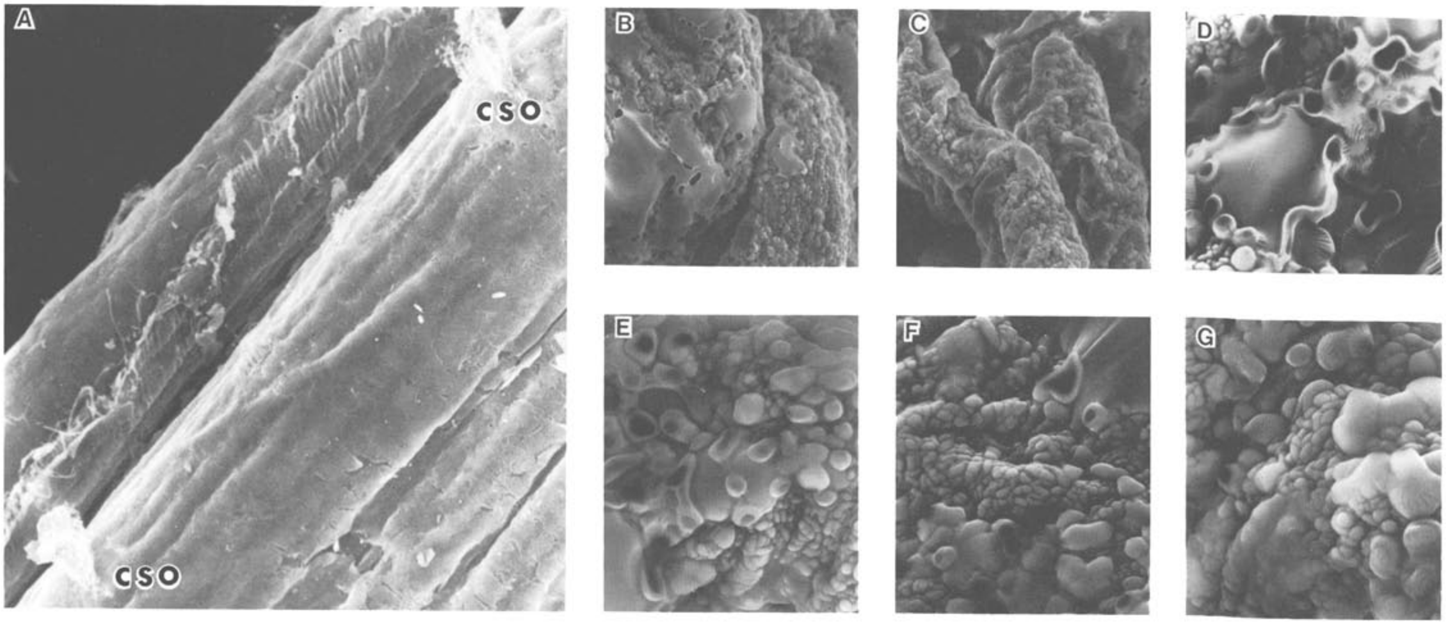


Fig. 1. Scanning electron micrographs of the body of chaetognaths which are normal (A) and abnormal (B–G). The body of the healthy specimen (A) looks smooth and has ciliary sense organs (cso), whereas the body of individual S1, which suddenly died of an unknown disease, has a rough and grotesque appearance (B–G). (A) *Sagitta ferox*. × 308. (B–G) *Sagitta crassa*. (B) × 288. (C) × 264. (D) × 1200. (E) × 1200. (F) × 1200. (G) × 1800

was neither curved nor opaque. Decapitation usually occurs when chaetognaths exhibit head damage and decay gradually develops. Decapitation usually takes time to occur after head damage first appears. However, S2 was suddenly decapitated without any head damage.

Under SEM the body of S2 had a slightly grotesque appearance (Fig. 2) similar to that of S1. Grotesque parts of S2 are considered to be premonitory symptoms of the X-disease of S1.

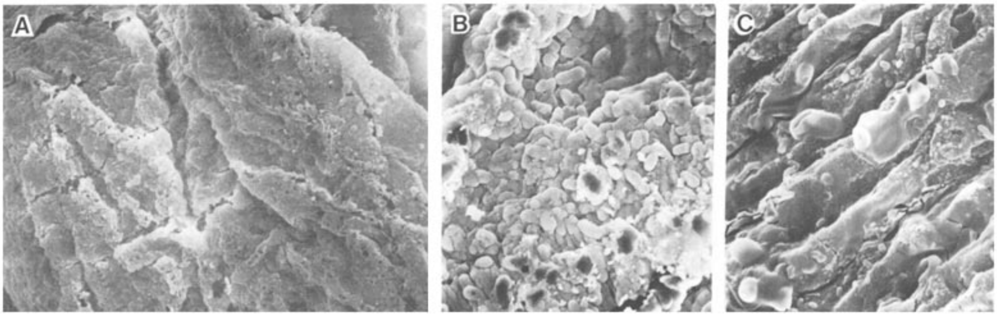
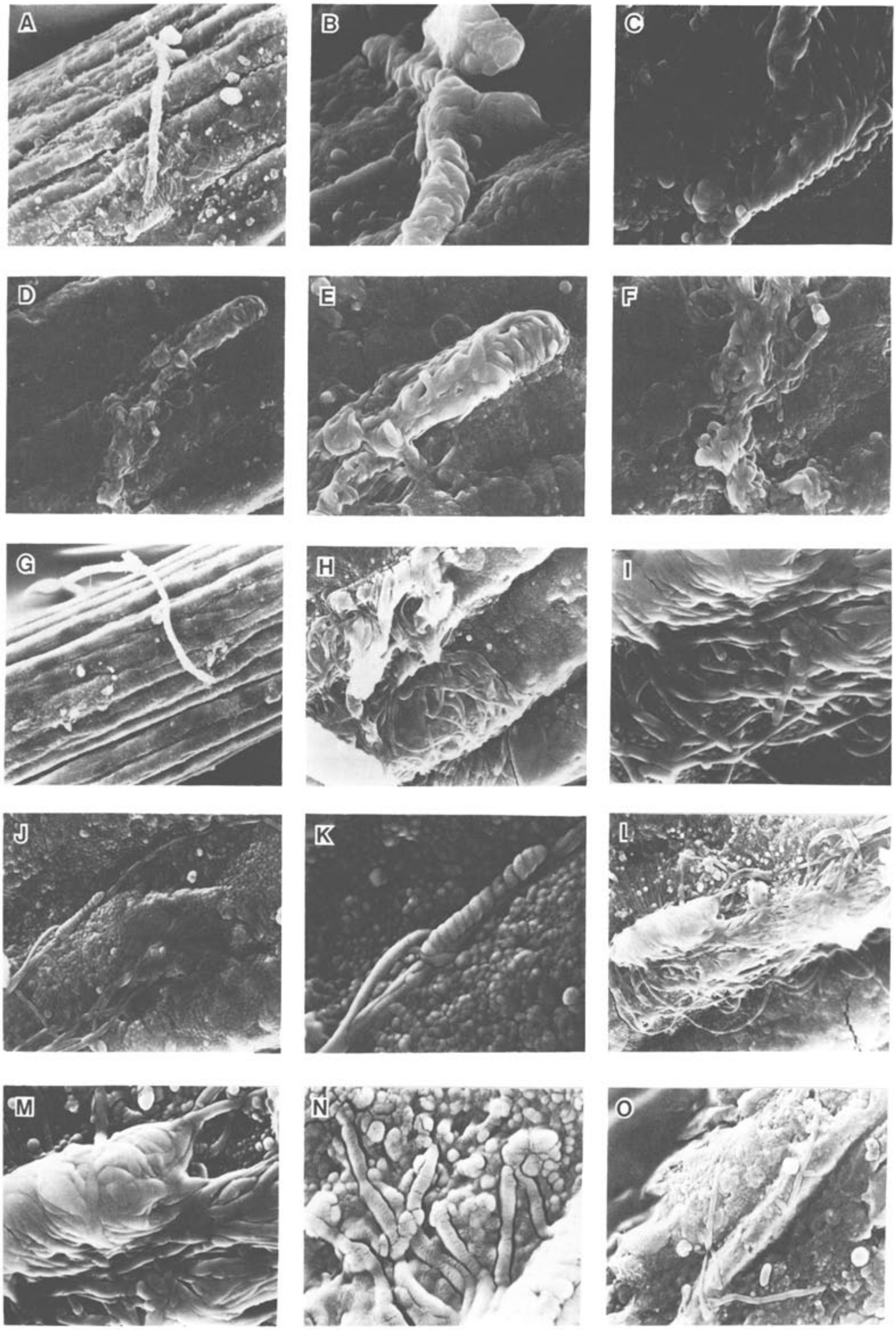


Fig. 2. Scanning electron micrographs of individual S2 which was suddenly decapitated. (A) Anterior part of body that has a rough appearance similar to that of S1. × 384. (B) Higher magnification showing the grotesque appearance of the tubercular processes. × 2400. (C) Some tubercular processes with holes. × 1200

X-disease No. 2

S3 (7 mm long) began to lay eggs 11 days after sampling and survived for 21 days, producing a total of 10 eggs. Egg-laying of S3 lasted for only 2 days and then stopped. First *A. clausi* and then *Tigriopus japonicus, Oithona aruensis* and polychaete larvae were offered as food. Testicular products of S3 increased and decreased at intervals of several days. The head of S3 became opaque and damaged 21 days after sampling. We found many bacteria in the head. In addition to the presence of bacteria, the ciliary sense organs on the body were especially abnormal due to the adhesion of hair (Fig. 3). Once these organs become abnormal, the chaetognath may die of starvation because these organs are important for feeding (Feigenbaum, 1978; Nagasawa & Marumo, 1978, 1982). While the reason for the development of this abnormality in the ciliary sense organs remains obscure, we attribute it also to an unknown disease and not to bacterial infection.

Fig. 3. Scanning electron micrographs of individual S3. (A) Two ciliary sense organs are connected by their hair which became stuck together. × 600. (B) Enlarged view of the base of an abnormal ciliary sense organ, upper part of (A), × 2880. (C) Higher magnification of part of the ciliary sense organ, lower part of (A), × 2880. (D) Another abnormal ciliary sense organ, × 780. (E) Enlarged view of the base of (D), × 1800. (F) Higher magnification of part of (D), × 1800. (G) An unknown rope-like structure between two ciliary sense organs. × 240. (H) Enlarged view of the base of a ciliary sense organ on the right of the rope-like structure. × 1440. (I) Enlarged view of another part of (H). × 3600. (J) A spiral string stemming from the ciliary sense organ near the rope in (G). × 2400. (K) Enlarged view of (J). × 6000. (L) Enlarged view of a ciliary sense organ to the left of the rope-like structure. × 1440. (M) Enlarged view of a part of (L). × 3600. (N) Anterior part of the trunk of the chaetognath. × 6000. (O) Another part of the anterior trunk of the chaetognath. × 2400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Bacterial infection of ciliary sense organs

S4 (7 mm long) laid 4 eggs 2 days after sampling and survived for 13 days. Testicular products of S4 decreased 6 days after sampling and then they disappeared. Thus, its tail remained empty until it died. Progressive atrophy occurred in S4. The hair of the ciliary sense organs was not visible one day before death. The body of S4 became curved but did not become opaque when it died. *O. aruensis* were offered, but this chaetognath only fed on a small number of these copepods.

Scanning electron micrographs showed that the ciliary sense organs of S4 were attacked by bacteria (Fig. 4). Because of bacterial attack, the hair of these organs disappeared before death.

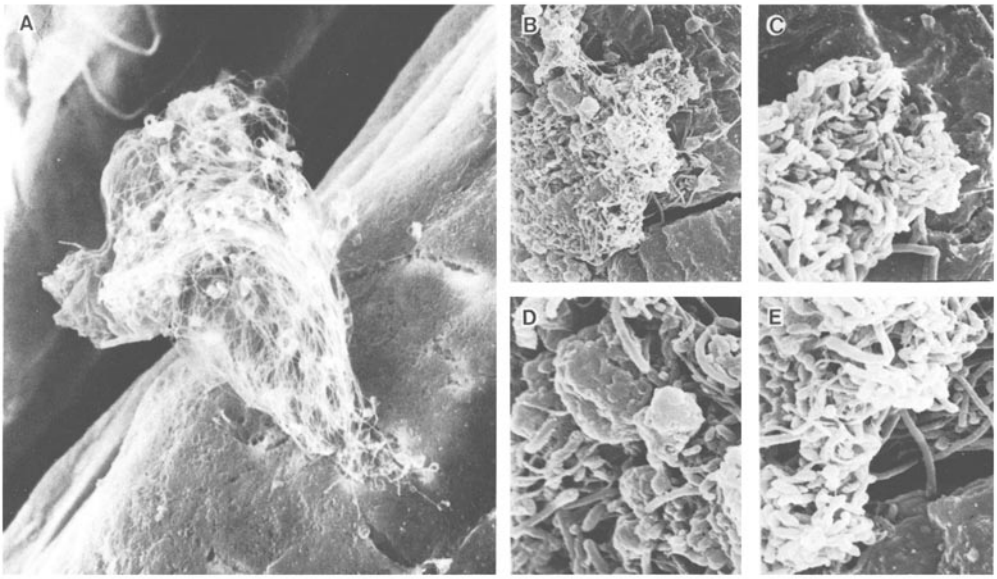
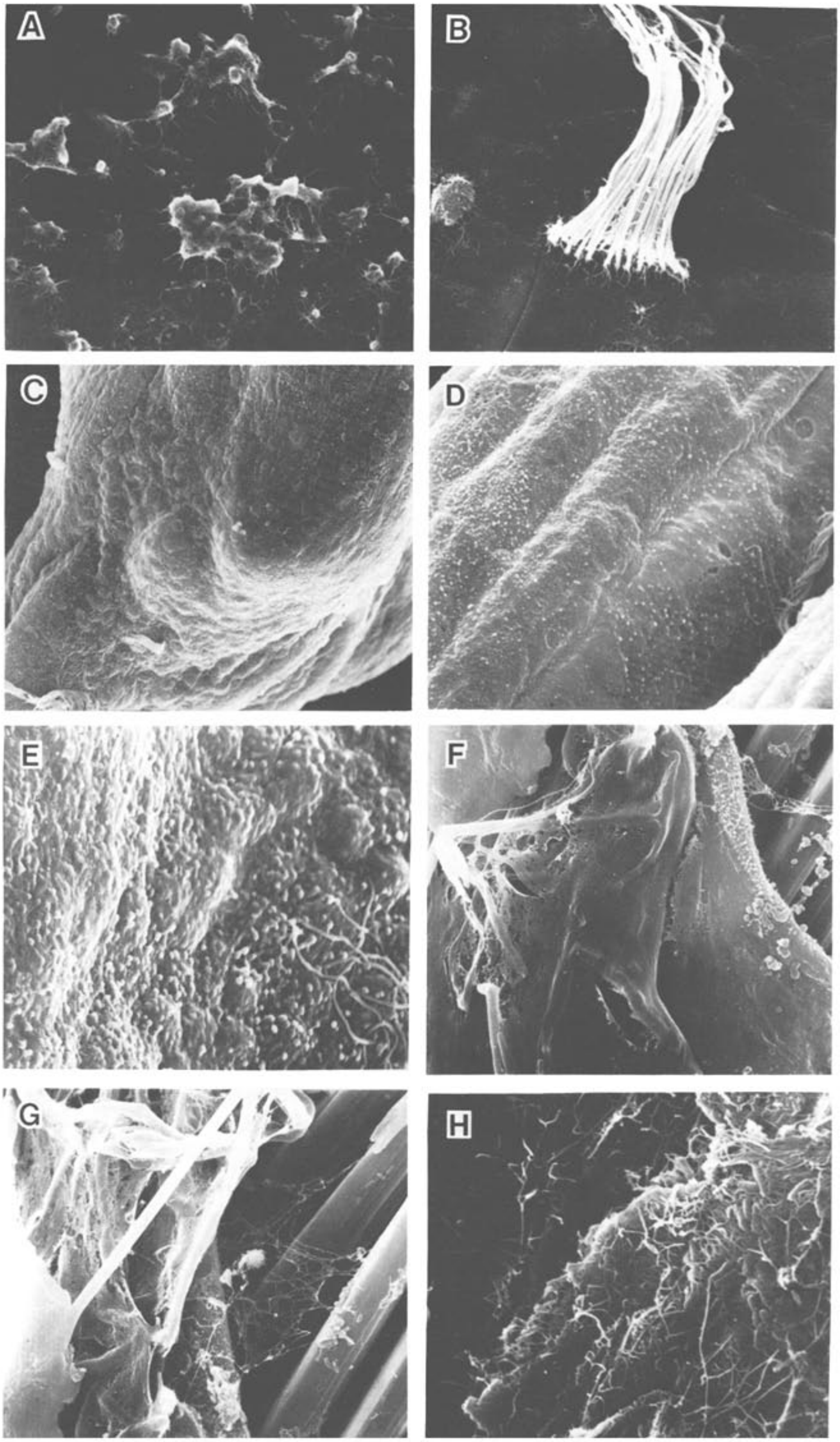


Fig. 4. Scanning electron micrographs of ciliary sense organs which are normal (A) and attacked by bacteria (B–E). (A) A ciliary sense organ of a healthy specimen of *Sagitta ferox*. × 1400. (B–E) Bacterial infection of a ciliary sense organ of individual S4. (B) × 1200. (C) × 3600. (D) × 3600. (E) × 3600

Abnormal epidermis and bacterial infection

Individuals S5, S6, S7 and S8 were still transparent at the time of death unlike the condition when death is caused by heavy bacterial infection (Nagasawa et al., 1984). S5 (6 mm long) survived in the laboratory for 9 days. Testicular products of S5 disappeared

Fig. 5. Scanning electron micrographs of individuals S5 (A, B), S6 (C, D, E), S7 (F, G) and S8 (H) which remained transparent when they died. (A) Protuberances are found here and there on the body of S5. × 3600. (B) A protuberance and a ciliary sense organ of S5. × 3600. (C) Posterior part of the head of S6 where many granular processes are found. × 360. (D) Granular processes are also found on the body of S6. × 1200. (E) Higher magnification of the head of S6. × 1800. (F) A part of the head of S7 is covered with some branch-like growth. × 1200. (G) Hooks of S7 infected with a small number of bacteria. × 1200. (H) Many filaments and a small number of bacteria on the body of S8. × 3600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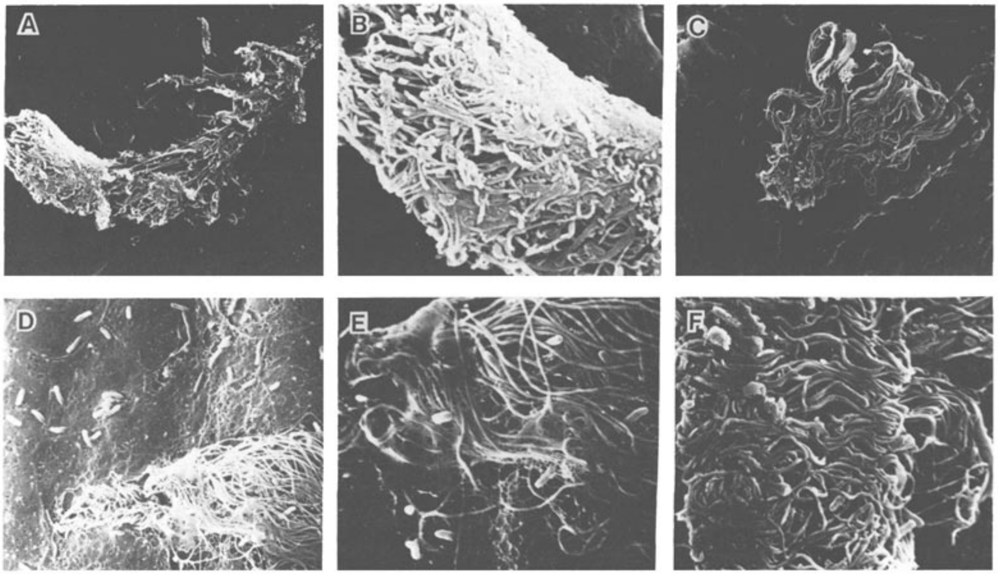

Fig. 6. Scanning electron micrographs showing bacterial infection of ciliary sense organs. (A–C) *Sagitta helenae* kept in the laboratory for feeding experiments. (D–F) *Sagitta crassa* obtained from Tokyo Bay on 25 June 1982. (A) Top of a ciliary sense organ attacked by bacteria. × 960. (B) Enlarged view of the part most infected by bacteria. × 3600. (C) A ciliary sense organ of another specimen also infected by a small number of bacteria. × 1200. (D) A ciliary sense organ slightly infected by bacteria. Bacteria are also found on the body. × 1800. (E) Enlarged view of a part of (D). Hair is covered by slime. × 3600. (F) A part of another ciliary sense organ slightly infected by bacteria. × 3600

7 days after sampling and then its tail remained empty. Polychaete larvae were offered. S6 (7 mm long) laid 9 eggs 2 days after sampling and survived in the laboratory for 9 days. At first, it was packed full of testicular products but they began to decrease 5 days after sampling and then the tail became empty. *O. aruensis* individuals were offered, but S6, like S4, only fed on a small number of these copepods. S7 and S8 (both were 5 mm long) survived for 4 days. Testicular products of these two specimens were few at first and then disappeared completely. *A. clausi* were offered but no feeding occurred. This suggests that S7 and S8 died of starvation despite ample food.

No bacteria were found on the body surface of individuals S5 and S6, whereas a small number of bacteria occurred on S7 and S8. Some parts of the body of S5 were protuberant (Fig. 5) whereas large numbers of granular processes covered almost the entire body of S6 (Fig. 5). On the body of S7 bacterial infection was not detected but some branch-like growth covered some parts of the body (Fig. 5). Bacteria attacked only the hooks of S7 (Fig. 5). Some parts of the body of S8 were covered by a large number of filaments and a small number of bacteria were found together with these filaments (Fig. 5).

On the whole, the above-mentioned transparent chaetognaths (S4, S5, S6, S7 and S8) showed a decrease in testicular products during culture. Apparently, they fed much less than S1, S2 and S3. Due to low ingestion the testicular products of these animals are considered to have been consumed as energy resource, and thus finally disappeared. Opaque parts of the chaetognaths are usually infected by bacteria (Nagasawa et al., 1984). In contrast, transparent chaetognaths have various types of condition. Although most of them had no bacteria on the body, the body surface was unusual and rough and it was sometimes covered with some abnormal growth. Transparent chaetognaths have no or few bacteria compared with opaque ones.

DISCUSSION

Head or tail damage of chaetognaths caused by bacterial infection occurred in 60 % of chaetognaths kept in the laboratory, whereas about 10 % of the chaetognath population in the sea showed bacterial infection (Nagasawa et al., 1984). Each type of X-diseases reported here was observed in 1 % of the individuals kept in the laboratory. However, X-disease No. 1 may account for 2 % of the specimens in the laboratory, since S2 showed a slightly grotesque appearance similar to S1. Chaetognaths with X-disease as in S1 and abnormality of ciliary sense organs (X-disease in S3) have not been found in field samples. However, taking into account the lower frequency of bacterial infection in the sea compared to that in the laboratory, the frequency of X-diseases may be very low in the sea, and unhealthy chaetognaths are unlikely to be caught because of rapid death, sinking and decay.

Chaetognaths which remained transparent at the time of death accounted for 9 % of the dead chaetognaths recorded in the laboratory (Nagasawa et al., 1984). Bacterial infection of ciliary sense organs occurred in cultivated *Sagitta crassa* at the rate of 1 %; such bacterial infection with tail damage was observed also in *S. helenae* Ritter-Záhony, obtained from the Atlantic Ocean and kept in the laboratory (Fig. 6). We found that ciliary sense organs of field samples *(S. crassa)* were slightly infected by bacteria (Fig. 6). No bacteria or few bacteria were related to the death of chaetognaths that remained transparent but some abnormal structures were found on their bodies unlike any found in healthy specimens. These abnormal structures are frequently observed in field samples from Tokyo Bay (Nagasawa, unpubl.).

Observations and examinations of diseases and abnormalities of chaetognaths have rarely been made. It is necessary to investigate the nature of chaetognath diseases in order to understand their causes and to estimate their contribution to chaetognath mortality in the sea. Basic research on marine animal diseases including X-diseases of chaetognaths requires more attention both in regard to the relations between disease agent and host, and the capacity of these diseases to affect, direct or even control the flow of energy and matter in marine ecosystems.

Acknowledgements: We are grateful to Dr. D. Feigenbaum, Department of Oceanography, Old Dominion University, for reading the manuscript and for his interest and advice. We also thank Professor R. Marumo, Tokyo University of Agriculture, for his suggestions and encouragement. Special thanks are due to Mr. and Mrs. Y. Hasuo who made sampling in Shinhamako possible.

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