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MARINE FUNGI IN SEA FOAM FROM JAPANESE COAST

AKIRA NAKAGIRI

Summary

From sea foam collected on beaches around the Japanese coast, spores of marine fungi have been observed and isolated. Thirty-six species of marine fungi comprising 27 species of ascomycetes, one species of basidiomycetes, and 8 species of deuteromycetes, were recorded.

In foam and scum formed in rivers or the sea, there are many propagules of aquatic or semi-aquatic organisms as well as debris trapped and accumulated during transportation in water. Spores of aquatic hyphomycetes and other aquatic fungi were found to accumulate in foam in streams (2, 10). Foam has been used for research to learn the mycoflora of the stream system or to isolate fungal spores for culture.

On the sea shore, foam accumulates spores of marine fungi as well as other small marine organisms, e.g., protozoa, phytoplanktons, and bacteria, as well as debris (Fig. 2). Sea foam may be a useful sample for examining the flora of marine fungi and also for isolating fungal spores. In particular, sea foam on sand beaches has been found to contain many spores of marine fungi inhabiting sand (6, 15), whereas the sea foam on a rocky shore rarely accumulates spores of marine fungi (unpublished data).

In the course of studying the higher marine fungi since 1980, 27 species of ascomycetes, one species of basidiomycetes, and 8 species of deuteromycetes have been recorded from sea foam samples from the Japanese coast.

Materials and Methods

Collection of sea foam Sea foam was collected at a sand beach when the window blew onshore and rough waves produced foam at the shoreline. A heavy sea just after a storm produced "good" sea foam abundant in fungal spores; but even with a calm sea, foam or spume at the shore would be sampled if it was gathered repeatedly. Foam collected in bottles was kept cool during transportation to the laboratory to prevent spores from germination.

Collection sites Localities and dates of collection are shown in Figure 1 and Table 1. Collection site numbers on the map (Fig. 1) are referred to in the text to indicate ranges of fungal distribution. Marine fungi whose spores were found and isolated from the foam samples were recorded with reference to the collection sites.

Isolation Bottles of sea foam samples were left to settle in a cool place. Sediment of sea foam was pipetted onto agar plates of SWS medium (1% soluble starch, 0.1% soytone, 1.5% agar in 20‰ salinity artificial seawater [Jamarin S; Jamarin Lab., Japan], pH 8.2), and single spores of marine fungi contained in the foam were isolated under the microscope with Skerman's micromanipulator (14). Germinated hyphae from the isolated spores were transferred to a new medium to obtain isolates.

Culture The isolates were cultured mainly on SWS. In some cases other media, e.g., SWS with soluble starch replaced by cellulose powder or other carbohydrates, were used to induce ascocarp formation of ascomycete strains (7). Besides the agar media, sterilised quartz sand with balsa wood which was soaked in seawater containing 0.1% soytone was also used for incubation. Incubation was carried out at 20-28 C.

Results

Marine fungi recorded in sea foam samples are described briefly in terms of spore morphology and cultural properties. Localities where the species were recorded are also listed as range according to the numbers on the map (Fig. 1, Table 1).

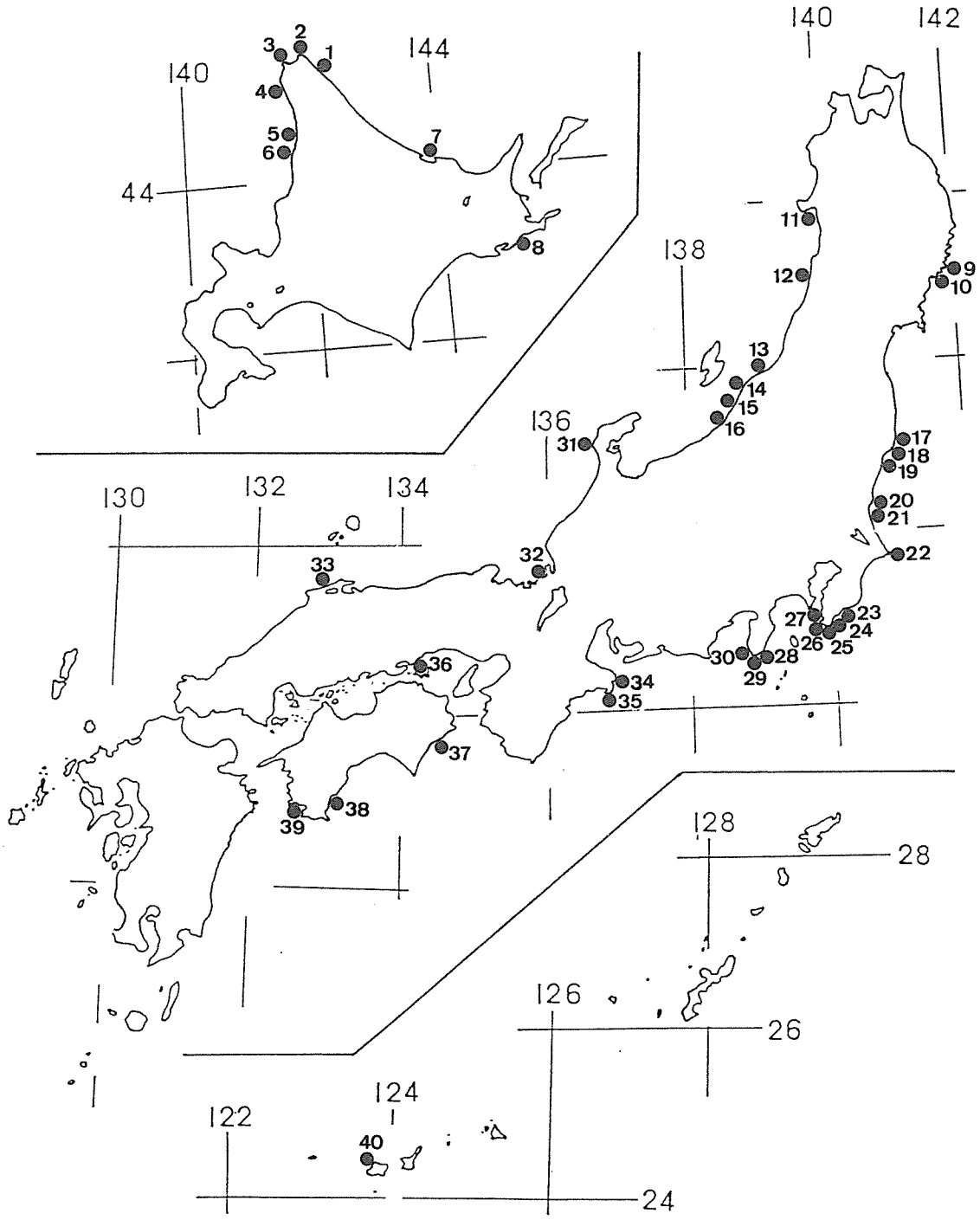


Fig. 1. Collection sites (Refer to Table 1).

Table 1. Collection sites and dates.

*1.	Higashiura, Soya mura, Wakkanai C., Hokkaido; Aug. 22, 1981
2.	Cape Soya, Soya mura, Wakkanai C., Hokkaido; Aug. 22, 1981
3.	Cape Noshyappu, Noshyappu, Wakkanai C., Hokkaido; Aug. 22, 1981
4.	Wakkasanai, Toyotomi cho, Teshio gun, Hokkaido; Aug. 27, 1984
5.	Kitasarakishi, Teshio cho, Teshio gun, Hokkaido; Sept. 24, 1981; Mar. 17, June 12, Nov. 17, 1982
6.	Cape Konpira, Shyosanbetsu mura, Tomamae gun, Hokkaido; Aug. 21, 1981; Mar. 17, June 13, 1982
7.	Wakka, Tokoro cho, Tokoro gun, Hokkaido; Aug. 29, 1984
8.	Hamanaka, Hamanaka cho, Akkeshi gun, Hokkaido; Aug. 30, 1984
9.	Ofunato Bay, Ofunato C., Iwate Pref.; Oct. 5, 1980
10.	Oya, Motoyoshi cho, Motoyoshi gun, Miyagi Pref.; Oct. 5, 1980; June 17, Oct. 29, 1981
11.	Funakoshi, Oga C., Akita Pref.; June 20, 1981
12.	Fukura, Uza machi, Akumi gun, Yamagata Pref.; June 20, 1981
13.	Fujitsukahama, Shiunji machi, Kitakanbara gun, Niigata Pref.; June 17, 1981
14.	Gokahama, Maki machi, Nishikanbara gun, Niigata Pref.; May 29; 1981
15.	Teradomari machi, Santo gun, Niigata Pref.; May 29, 1981
16.	Kujiranami, Kashiwazaki C., Niigata Pref.; Feb. 1, 1982
17.	Cape Shioya, Iwaki C., Fukushima Pref.; June 8, 1982; Mar. 18, 1983
18.	Izura, Kitaibaraki C., Ibaraki Pref.; Mar. 23, 1982
19.	Isohara, Isohara cho, Kitaibaraki C., Ibaraki Pref.; Mar. 23, 1982
20.	Ajigaura, Ajigaura cho, Nakaminato C., Ibaraki Pref.; Apr. 18, Dec. 17, 1980; Dec. 11, 1981; May 27, 1982
21.	Oarai, Oarai machi, Higashiibaraki gun, Ibaraki Pref.; Dec. 17, 1980; Dec. 11, 1981
22.	Kimigahama, Inubozaki; Choshi C., Chiba Pref.; Sept. 15, 1981; Apr. 27, July 10, Dec. 1, 1982; Mar. 24, 1983
23.	Maehara, Kamogawa C., Chiba Pref.; Dec. 21, 1982
24.	Shirahama, Shirahama machi, Awa gun, Chiba Pref.; Feb. 27, 1981
25.	Heisaura, Tateyama C., Chiba Pref.; Mar. 6, 1985
26.	Cape Suno, Sunosaki, Tateyama C., Chiba Pref.; July 10, 1982
27.	Kenbutsu, Tateyama C., Chiba Pref.; Feb. 27, 1981
28.	Shirahama, Shimoda C., Shizuoka Pref.; Apr. 4, 1980; Mar. 24, Apr. 6, May 13, June 15, July 11, Aug. 13, Sept. 16, 1981; Nov. 1, 1982; Feb. 6, Apr. 3, 1983
29.	Nabetahama, Shimoda C., Shizuoka Pref.; July 11, Aug. 14, 1981
30.	Iwachi, Matsuzaki cho, Kamo gun, Shizuoka Pref.; Apr. 11, Nov. 1, 1982
31.	Notokongo, Togi machi, Hakui gun, Ishikawa Pref.; Feb. 2, 1982
32.	Hayase, Mihama cho, Mikata gun, Fukui Pref.; Oct. 1, 1980
33.	Konami, Shimane cho, Yatsuka gun, Shimane Pref.; Sept. 27, 1981
34.	Chidorigahama, Osatsu, Toba C., Mie Pref.; Oct. 9, 1988
35.	Hirohama, Fuseda, Shima cho, Shima gun, Mie Pref.; Oct. 9, 1988
36.	Kashino, Ushimado cho, Oku gun, Okayama Pref.; Sept. 24, 1981
37.	Uchizuma, Mugi cho, Kaifu gun, Tokushima Pref.; July 21, 1982
38.	Ukibuchi, Ogata cho, Hata gun, Kochi Pref.; July 24, 1982
39.	Mukuzu, Sukumo C., Kochi Pref.; July 25, 1982
40.	Hoshizunanohama, Iriomote Is., Taketomi cho, Yaeyama gun, Okinawa Pref.; Apr. 22, June 20, 1982

* The figures refer to the locality numbers in Fig. 1.

Ascomycotina
Pyrenomycetes
Sphaeriales
Halosphaeriaceae

Arenariomyces trifurcatus Höhnk Fig. 3

Veroeff. Inst. Meeresforsch. Bremerhaven 3: 30, 1954

= Halosphaeria trifurcata (Höhnk) Cribb & Cribb, Univ. Queensl. Pap. Dep. Bot. 3: 99, 1956

≡ Peritrichospora trifurcata (Höhnk) Kohlm., Nova Hedwigia 3: 89, 1961

≡ Corollospora trifurcata (Höhnk) Kohlm., Ber. Dtsch. Bot. Ges. 75: 126, 1962

Ascospores: 22-35 x 7.5-10.5 μm (excluding appendages), elliptic-fusiform to ellipsoidal or oblong, one-septate, with or without slight constriction at the septum, hyaline.

Appendages: at both ends of the spore with (2-)3(-4) terminal appendages, 22.5-30 μm long, 1.5-2 μm in diam at base, attenuate, developed by outgrowth of spore wall, with a bulbous base, slender, rigid, round shaft, terminating in an apical hook which corresponds to the space between two bulbous bases of the opposite terminal appendages.

Culture: brown to dark brown colony on SWS. A few strains produced ascocarps in culture on the agar media. IFO 32095, 32096.

Range: 1, 4, 5, 6, 7, 8, 10, 11, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 33, 34, 35, 36, 37, 38, 39.

Carbosphaerella leptosphaerioides I. Schmidt Fig. 4

Nat. Naturschutz Mecklenburg 7: 9, 1969 (publ. 1971)

Ascospores: 31-46 x 17-23 μm (excluding sheath), ellipsoidal, triseptate, not or slightly constricted at the septa; central large cells, dark brown; apical small cells, hyaline or light brown; septa with central porus.

Appendages: reticulate or net-like sheath surrounding ascospore, becoming fibrillar by the loss of the cross-connections in the reticula,

flexuous, gelatinous, persistent, irregular shaped.

Culture: gray to black colony on SWS. Ascocarp was not produced in culture on the agar media. IFO 32097.

Range: 1, 5, 6, 10, 13, 14, 15, 16, 17, 20, 25, 28, 38.

Corollospora angusta Nakagiri & Tokura Fig. 5

Trans. mycol. Soc. Japan 28: 417, 1987

Ascospores: 35-57 x 3-7.5 μm (excluding polar appendages), fusiform, slender, 3(-5)-septate, hyaline.

Appendages of two kinds: (i) a single terminal appendage at each end of the spore, 3-8 μm long, spine- or thorn-like, attenuate; (ii) fibrous and peritrichous appendages on the terminal appendages, 5.8-12.5 μm long, and around the central septum, 18-24.5 μm long, developed by fragmentation and peeling of the exospore.

Culture: white colony on SWS. Single-spore isolates produced ascocarps on the agar media and on the glass of slant tubes. IFO 32100, 32101, 32102.

Range: 1, 5, 6, 8, 10, 14, 15, 16, 17, 19, 20, 23, 25, 27, 28, 30, 31, 33, 34, 38.

Corollospora colossa Nakagiri & Tokura Fig. 6

Trans. mycol. Soc. Japan 28: 418, 1987

Ascospores: 60-108 x 13-26 μm, fusiform to ellipsoidal, (6-)7(-8)-septate, hyaline.

Appendages: fibrous, peritrichous, at both ends of the spore, 20-27 μm long and around the central septum, 20-28 μm long, developed by fragmentation and peeling of the exospore.

Culture: dark green to black colony on SWS. Single-spore isolates produced ascocarps on sand grains by the "quartz sand method", but not on the agar media. IFO 32103, 32104.

Range: 1, 5, 6, 7, 10, 13, 14, 15, 16, 20, 21, 22, 23, 27, 28, 34, 37, 38, 39.

Corollospora filiformis Nakagiri in Nakagiri and Tokura Fig. 7
Trans. mycol. Soc. Japan 28: 422, 1987

Ascospores: (73-)87-120 x 5-8(-10) μm, filiform, (9-)13(-17)-septate, hyaline.

Appendages: fibrous, peritrichous, at both ends of the spores, 18-25 μm long and around the central septum, 13-22 μm long, developed by fragmentation and peeling of the exospore.

Culture: brownish gray to black colony on SWS. Single-spore isolates produced ascocarps on sand grains by the "quartz sand method", but not on the agar media. IFO 32106.

Range: 39.

Corollospora fusca Nakagiri & Tokura Fig. 8
Trans. mycol. Soc. Japan 28: 424, 1987

Ascospores: 63-220 x 20-38 μm (excluding polar appendages), fusiform, muriform with transverse and longitudinal septa, (5-)12-21 transversally septate, dark brown, longitudinally finely striated on the spore surface. Ridges of striation run in parallel and sometimes dichotomize.

Appendages of two kinds: (i) a single terminal appendage at each end of the spore, 28.5-65 μm long, thorn-like, hyaline; (ii) fibrous and peritrichous appendages on the terminal appendages, 28-54 μm long, and around the central septum, 25-75 μm long, developed by fragmentation and peeling of the exospore.

Culture: grayish yellow to dark green colony on SWS. Single-spore isolates produced ascocarps on sand grains by the "quartz sand method", but not on the agar media. IFO 32107, 32108, 32109.

Range: 4, 5, 6, 10, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 25, 27, 28, 34, 38, 39, 40.

Corollospora gracilis Nakagiri & Tokura Fig. 9
Trans. mycol. Soc. Japan 28: 426, 1987

Ascospores: 26-45 x 3-5.5(-7) μm (excluding polar appendages), fusiform, slender, one-septate, hyaline.

Appendages of two kinds: (i) a single terminal appendage at each end of the spore, 6.5-12 μm long, spine- or thorn-like, attenuate; (ii) fibrous and peritrichous appendages on the terminal appendages, 4-8 um long, and around the central septum, 12-20 μm long, developed by fragmentation and peeling of the exospore.

Culture: white colony on SWS. Single-spore isolates produced ascocarps abundantly on the agar media as well as on the glass of slant tubes. IFO 32110, 32111.

Range: 4, 5, 8, 10, 13, 14, 15, 16, 18, 20, 22, 23, 28, 29, 30, 34, 35, 37, 38.

Corollospora intermedia I. Schmidt Fig. 10

Nat. Naturschutz Mecklenburg 7: 6, 1969 (publ. 1971)

Anamorph: Varicosporina prolifera Nakagiri, Trans. mycol. Soc. Japan 27: 198, 1986

Ascospores: 25-40 x 8-11 μm (excluding polar appendages), ellipsoidal, three-septate, constricted at the septa, hyaline.

Appendages of two kinds: (i) a single terminal appendage at each end of the spore, 5-9 μm long, spine- or thorn-like, attenuate; (ii) fibrous and peritrichous appendages on the terminal appendages, 5-10 μm long, and around the central septum, 10-18 μm long, developed by fragmentaion and peeling of the exospore.

Culture: white colony on SWS, turning to dark olive to black in age. Conidia were produced abundantly. Single-spore isolates produced ascocarps on SWS, which, however, did not mature inside. IFO 32119, 32120.

Range: 1, 28, 30, 35.

Corollospora lacera (Linder) Kohlm. Fig. 11

Ber. Dtsch. Bot. Ges. 75: 126, 1962

≡ Peritrichospora lacera Linder in Barghoorn and Linder, Farlowia 1: 415, 1944

Ascospores: 39-58 x 10-15 μm (excluding polar appendages), fusiform, straight or slightly curved, (4-)5-septate, constricted at the septa, hyaline.

Appendages of two kinds: (i) a single terminal appendages at each end of the spore, (11-)17-40 μm long, thorn-like, attenuate; (ii) fibrous and peritrichous appendages on the terminal appendages, 23-45 μm long and around the central septum, 12-20 μm long, developed by fragmentation and peeling of the exospore.

Culture: dark green to black colony on SWS. Single-spore isolates produced ascocarps on sand grains by the "quartz sand method", but not on the agar media. IFO 32121, 32122.

Range: 1, 4, 5, 6, 8, 10, 16, 18, 19, 20, 22, 27, 28.

Corollospora luteola Nakagiri & Tubaki Fig. 12

Trans. mycol. Soc. Japan 23: 102, 1982

Anamorph: Sigmoidea luteola Nakagiri & Tubaki, ibid. 23: 102, 1982

Ascospores: 50-85 x 4.8-7.5 μm, fusiform, straight or slightly curved, (4-)5(-6)-septate, hyaline.

Appendages: fibrous, peritrichous, at both ends of the spore, 12-17.5 μm long, and around the central septum, 16-28 μm long, developed by fragmentation and peeling of the exospore.

Culture: pale yellow to yellow colony on SWS. Single-spore isolates produced ascocarps and conidia on the agar media. IFO 31315, 31316.

Range: 1, 8, 10, 27, 28.

Corollospora maritima Werdermann Fig. 13

Notizbl. Bot. Gart. Berlin 8: 248, 1922

= Arenariomyces cinctus Höhnk, Veroeff. Inst. Meeresforsch Bremerhaven 3: 28, 1954

= Peritrichospora integra Linder in Barghoorn and Linder, Farlowia 1: 414, 1944

Ascospores: 27.5-37.5 x 7-11.5 μm (excluding polar appendages), elliptic-fusiform to ellispoidal, one-septate, hyaline.

Appendages of two kinds: (i) a single terminal appendage at each end of the spore, 10-20.5 μm long, spine- or thorn-like, slender attenuate; (ii) fibrous and peritrichous appendages on the terminal appendages, 3-12

μm long, and around the central septum, 8-15 μm long, developed by fragmentation and peeling of the exospore.

Culture: olive gray to black colony on SWS. Single-spore isolates produced ascocarps on the glass of slant tubes. Catenulate chlamydospores of globose to oval or oblong, brown cells were produced on the agar media. IFO 32117, 32118.

Range: 1, 2, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 27, 28, 29, 30, 33, 35, 36, 37, 38, 39.

Corollospora pseudopulchella Nakagiri & Tokura Fig. 14

Trans. mycol. Soc. Japan 28: 428, 1987

Ascospores: 65-97.5 x 7.5-11.5 μm, fusiform, slender, 7-11 septate, hyaline.

Appendages: fibrous, peritrichous, at both ends of the spore, 7.5-12.5 μm long, and around the central septum, 18-31 μm long, developed by fragmentation and peeling of the exospore.

Culture: olive to olive gray colony on SWS. Single-spore isolates produced ascocarps on sand grains by the "quartz sand method". Catenulate or bulbil-like chlamydospores of globose to subglobose, brown cells were produced on the agar media. IFO 32112, 32113.

Range: 1, 4, 6, 10, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 26, 28, 30, 33, 34.

Corollospora pulchella Kohlm., Schmidt & Nair Fig. 15

Ber. Dtsch. Bot. Ges. 80: 98, 1967

Anamorph: Clavatospora bulbosa (Anastasiou) Nakagiri & Tubaki, Bot. Mar. 28: 489, 1985

Ascospores: 60-97 x 8-12.5 um, fusiform, straight or slightly curved, (5-)7-9(-10)-septate, constricted at the septa, hyaline.

Appendages: fibrous, peritrichous at both ends of the spore, 7.5-13 um long and around the central septum, 13-28 μm long, developed by fragmentation and peeling of the exospore.

Culture: olive to olive gray colony on SWS. Single-spore islolates produced ascocarps on sand grains by the "quartz sand method", but not on

agar media. Conidia and catenulate chlamydospores of subglobose to oblong, olive brown cells were produced on the agar media. IFO 32123, 32124.

Range: 37, 38, 39.

Corollospora quinqueseptata Nakagiri in Nakagiri and Tokura Fig. 16
Trans. mycol. Soc. Japan 28: 430, 1987

Ascospores: (37.5-)41.3-58.8 x 7.5-9.8 μm (excluding polar appendages), fusiform, (3-)5(-8)-septate, hyaline.

Appendages of two kinds: (i) a single terminal appendage at each end of the spore, 5.3-12 μm long, spine- or thorn-like, attenuate; (ii) fibrous and peritrichous appendages on the terminal appendages, 7.5-11.3 μm long, and around the central septum, 16.8-24.5 μm long, developed by fragmentation and peeling of the exospore.

Culture: white to brownish gray colony on SWS. Single-spore isolates produced ascocarps on the agar media and on the glass of slant tubes. IFO 32115, 32116.

Range: 2, 10, 20, 23, 28, 34, 35.

Halosphaeria appendiculata Linder in Barghoorn and Linder Fig. 17
Farlowia 1: 412, 1944
= Remispora ornata Johnson & Cavaliere, Nova Hedwigia 6: 188, 1963

Ascospores: 18.8-25 x 7.5-10 μm, ellipsoid, one-septate, not or slightly constricted at the septum, hyaline.

Appendages: a single terminal appendage at each end of the spore, 7.5-12.5 μm long, membranous, obclavate, attenuate, curved, spoon-shaped at the base; (3-)4 similar radiating appendages around the septum; developed by outgrowth of the spore.

Culture: dark brown colony with white aerial hyphae on SWS. Single-spore isolates produced ascocarps on SWS. IFO 32147, 32148.

Range: 6, 10, 12, 22, 29.

Halosphaeria torquata Kohlm. Fig. 18

Nova Hedwigia 2: 311, 1960

Ascospores: 22-28 x 10-15 μm, broadly ellipsoidal, one-septate, not or slightly constricted at the septum, hyaline.

Appendages: a single terminal appendage at each end of the spore, 5-11 μm long, 2-3 μm in diam at the base, subcylindrical, attenuate; a tubular annulus around the septum, 2-4 μm thick.

Culture: brown to dark brown colony on SWS. Catenuate chlamydospores of globose to subglobose, brown cells were produced on SWS. AN-627, 628, 687.

Range: 1, 6, 15, 16, 18, 28, 31, 33.

Halosphaeriopsis mediosetigera (Cribb & Cribb) Johnson Fig. 19

J. Elisha Mitchell Sci. Soc. 74: 44, 1958

≡ Halosphaeria mediosetigera Cribb & Cribb, Univ. Queensl. Pap., Dep. Bot. 3: 100, 1956

= Halosphaeria mediosetigera var. grandispora Kohlm., Nova Hedwigia 2: 310, 1960

Anamorph: Trichocladium achrasporum (Meyers & Moore) Dixon in Sheare & Crane, Mycologia 63: 244, 1971

Ascospores: 24.5-36.3 x 6.5-10 μm, ellipsoid to fusiform, one-septate, not constricted at the septum, hyaline.

Appendages: a single terminal appendages at each end of the spore, inverted cap-shaped; 3(-4) crescent-shaped appendages around the septum, 12.5-17.5 μm long, rigid, attenuate, obliquely attatched to the septum; developed by spiral fragmentation and peeling of the exospore.

Culture: dark brown to dark gray colony on SWS. Single-spore isolates produced ascocarps on SWS. Japanese strains have never produced Trichocladium conidia in culture; but catenulate and brown colored chlamydospores, which were similar in shape to the conidia, were produced. IFO 32127, 32128.

Range: 1, 14, 15, 17, 18, 22, 27, 28, 30, 32, 38, 39.

Kohlmeyeriella tubulata (Kohlm.) Jones, R. G. Johnson & Moss Fig. 20
Bot. J. Linn. Soc. 87: 210, 1983
≡ Corollospora tubulata Kohlm., Ber. Dtsch. Bot. Ges. 81: 53, 1968

Ascospores: 130-165 x 16-25 μm (including polar appendages), fusiform, curved, frequently C-shaped, repand on outer side, smooth on inner side, one-celled, thick-walled, hyaline.

Appendages: polar, tube-like, (20-)32-47 X 3-6 μm, curved, rigid, slightly tapering, mucus-filled; mucus released from an apical pore, forming a persistent gelatinous globule at the mouth of the tube.

Culture: grayish brown colony on SWS. Single-spore isolates did not produce ascocarps on the agar media. Catenulate chlamydospores of globose to subglobose or oblong, brown to dark brown cells were formed in culture. IFO 32149, 32150.

Range: 1, 5, 19.

Lindra obtusa Nakagiri & Tubaki Fig. 21
Mycologia 75: 488, 1983
Anamorph: Anguillospora marina Nakagiri & Tubaki, ibid. 75: 488, 1983

Ascospores: 182.5-250(-313) x 2.3-3.2(-3.8) μm, filiform, rounded at the ends (not inflated or tapering), curved or crooked (S, U, α-shaped), 9-16(-21)-septate, not or barely constricted at the septa, hyaline.

Appendages: absent.

Culture: white to pale yellow colony on SWS. Single-spore isolates produced ascocarps and conidia on the agar media. IFO 31317, 31318.

Range: 6, 8, 9, 10, 30, 33, 34.

Lindra thalassiae Orpurt, Meyers, Boral & Simms Fig. 22
Bull. Mar. Sci. Gulf. Caribb. 14: 406, 1964

Ascospores: 275-438 x 5-6 μm, filiform, tapering toward both apices, curved (S, U, α-shaped), 18-24-septate, not or barely constricted at the septa, hyaline; tips slightly inflated.

Appendages: absent.

Culture: white colony on SWS. Single-spore isolates freely produced ascocarps in culture on the surface of the agar media, on the mycelia and on the glass wall. IFO 32131, 32132.

Range: 1, 4, 5, 10, 20, 33, 34, 35, 40.

Lulworthia crassa Nakagiri Fig. 23

Trans. mycol. Soc. Japan 25: 378, 1984

Ascospores: 140-205 x 5-8 μm (including appendages), allantoid, curved, non-septate, hyaline.

Appendages: mucus filling chamber at each end of spore, conical or tubular, 20-33 μm long; a drop of mucilage is released through an apical pore.

Culture: dark brown to dark gray or black colony on SWS. Single-spore isolates produced ascocarps on sand grains by the "quartz sand method", but not on the agar media. IFO 32133, 32134.

Range: 5, 6, 10, 16, 18, 19, 20, 21, 28, 39.

Lulworthia lignoarenaria Koch & Jones Fig. 24

Mycotaxon 20: 389, 1984

Ascospores: 350-450 x 4-5.5 μm (including appendages), filiform, curved, 25-31-septate, hyaline.

Appendages: mucus filling chamber at each end of spore, conical or tubular, 33-53 μm long, ; a drop of mucilage is released through an apical pore.

Culture: dark brown or dark green to black colony on SWS. Ascocarp was not produced in culture. IFO 32135, 32136.

Range: 4, 5, 6, 8, 16, 17, 19, 28.

Marinospora calyptrata (Kohlm.) Cavaliere Fig. 25

Nova Hedwigia 11: 548, 1966

≡ Ceriosporopsis calyptrata Kohlm., Nova Hedwigia 2: 301, 1960

≡ Ceriosporella calyptrata (Kohlm.) Cavaliere, ibid. 10: 394, 1966

Ascospores: 23-32 x 8-13 μm (excluding appendages), ellipsoid, one-septate, constricted at the septum, hyaline.

Appendages: a single terminal appendage at each end of spore, obclavate or subcylindrical, tapering, 5-17.5 x 2.5-5 μm; around the septum, 3-4 similar, radiating appendages; small, 1-2 μm high, cupuliform, thin caps, which may invert, cover the apices of appendages.

Culture: brown to dark brown colony on SWS. Ascocarp was not produced in culture. IFO 32151.

Range: 1, 5, 6, 18, 28.

Nereiospora cristata (Kohlm.) Jones, R. G. Johnson & Moss Fig. 26
Bot. J. Linn. Soc. 87:206, 1983
≡ Peritrichospora cristata Kohlm., Nova Hedwigia 2: 324, 1960
≡ Corollospora cristata (Kohlm.) Kohlm., Ber. Dtsch. Bot. Ges. 75: 126, 1972

Ascospores: 29-37 x 14-19 μm (excluding appendages), ellipsoid, 2-3-septate, constricted at the septa, central cells brown, apical cells hyaline.

Appendages: seta-like, flexible, attached in a tuft to each apex and in several tufts around the central septum; apical setae, 7-10 μm long; lateral setae, 9-13 μm long developed by outgrowth of the spore.

Culture: brownish gray to black colony on SWS. Catenulate and branched chlamydospores of globose to subglobose or ellipsoidal to oblong, light brown cells were formed in culture. AN-671, 672, 673, 891, 892, 893.

Range: 1.

Trailia ascophylli Sutherland Fig. 27
Trans. Br. mycol. Soc. 5: 149, 1915

Ascospores: 85-110 x 3-4 μm, filamentous, tapering, curved, 1-4-septated, not constricted at the septa, hyaline.

Appendages: absent.

Culture: white to cream colored colony on SWS. Ascocarp primordium-like structure was observed in culture. AN-509.

Range: 1, 2, 8, 9, 18, 20, 22, 27, 28, 29, 38.

Sphaeriaceae

Chaetosphaeria sp. Fig. 28

Ascospores: (33-)40-66 x 6-9 μm, ellipsoid or cylindrical, 3(-6)-septate, hyaline.

Appendages: peritrichous appendages around the central septum, 13-25 μm long, developed by fragmentation and peeling of the exospore.

Culture: white colony on SWS. Single-spore isolates produced ascocarps on the agar media.

Range: 1, 8.

Note: this fungus is similar to Ch. chaetosa Kohlm. except that the latter has smaller ascospores (24-36.5 x 6-11.5 μm) and produces coriaceous ascocarps. Further reseach on the taxonomic position of this fungus is necessary.

incertae sedis

Torpedospora radiata Meyers Fig. 29

Mycologia 49: 496, 1957

Ascospores: 20-47 x 3.5-5 μm, cylindrical or clavate, broader at the apex, (2-)3-septate, not or slightly constricted at the septa, hyaline.

Appendages: 3(-4) radiating appendages on the lower end, 10-26 x 1.0-2.5 μm, semirigid, straight or slightly curved, with a thick base, tapering toward the apex.

Culture: hyaline to light brown colony on SWS. Single-spore isolates produced ascocarps in culture. IFO 32145, 32146.

Range: 20, 27, 28, 29, 30, 32, 33, 34, 36, 38.

Basidiomycotina

Gasteromycetes

Melanogastrales
Melanogastraceae

Nia vibrissa Moore & Meyers Fig. 30
Mycologia 51: 874, 1959

Basidiospores: 10-16 x 4-8 μm (excluding appendages), ovoid to pyriform, one-celled, hyaline, at the point of attachment to the basidium with a short cylindrical projection.

Appendages: a single appendage at the apex, slender, flexible, attenuate, hyaline, 20-33 μm long, less than 1.5 μm in diam, terminally slightly inflated; 3-4 similar, subterminal radiating appendages around the base, 15-27 μm long.

Culture: hyaline to cream colored colony on SWS. Some strains of single-spore isolates produced basidiocarps on the agar media. IFO 32088, 32089, 32090.

Range: 1, 5, 6, 8, 10, 17, 18, 20, 22, 26, 27, 28, 30, 38.

Deuteromycotina
Hyphomycetes
Hyphomycetales
Moniliaceae

Anguillospora marina Nakagiri & Tubaki Fig. 31
Mycologia 75: 488, 1983
Teleomorph: Lindra obtusa Nakagiri & Tubaki, ibid. 75: 488, 1983

Conidia: 150-255(-312.5) x 2.5-4 μm, filiform, straight or curved, 9-13(-19)-septate, swollen at both ends, hyaline.

Culture: white to yellow colony on SWS. Single-spore isolates produced conidia and ascocarps on the agar media.

Conidiogenous cells: hyaline, holoblastic, terminal, percurrent, without a separating cell.

Range: 3, 6, 7, 8, 9, 10, 30, 33.

Sigmoidea luteola Nakagiri & Tubaki Fig. 32

Trans. mycol. Soc. Japan 23: 102, 1982

Teleomorph: Corollospora luteola Nakagiri & Tubaki, ibid. 23: 102, 1982

Conidia: 106-222.5 μm long, 1.3-2.5 μm in diam at the base, 4.5-7.5 μm in diam at the central cell, filiform, curved, 7-13(-18) septate, constricted at the septa, hyaline; terminal and basal cells of mature conidia are devoid of contents.

Culture: pale yellow to yellow colony on SWS. Single-spore isolates produced conidia and ascocarps on the agar media.

Conidiogenous cells: hyaline, holoblastic, terminal, irregularly sympodial and denticulate.

Range: 1, 4, 5, 6, 8, 14, 15, 16, 24, 27.

Sigmoidea marina Haythorn & Jones in Haythorn, Jones and Harrison Fig. 33

Trans. Br. mycol. Soc. 74: 620, 1980

Conidia: (88-)103-153 μm long, 1.5-2.5 μm in diam at the base, 2.8-5 μm in diam at the central cell, filiform, curved, 6-10-septate, constricted at the septa, hyaline; terminal and basal cells of mature conidia are devoid of contents.

Culture: hyaline to white colony on SWS. Isolates produced conidia on the agar media. IFO 32159, 32160.

Conidiogenous cells: hyaline, holoblastic, terminal, sympodial and denticulate.

Range: 1, 3, 7, 8, 10, 22, 28.

Varicosporina prolifera Nakagiri Fig. 34

Trans. mycol. Soc. Japan 27: 198, 1986

Teleomorph: Corollospora intermedia I. Schmidt, Nat. Naturschutz Mecklenburg 7: 6, 1969 (publ. 1971)

Conidia: three-dimensionally branched, septate, hyaline; main axis,

25-57 μm long, 2.5-5 μm in diam at the apex, 1-2(-4)-septate; first side branch, 18-38.8 μm long, 2.5-4(-5) μm in diam at the apex, 1-2(-3)-septate, arising perpendicularly from the apical or central cell of the main axis; second side branch, 15-32.5 μm long, 2,7-5 μm in diam at the apex, 1-2(-3)-septate, arising perpendicularly from the apical or central cell of the first side branch; third side branch, rare in some strains, 8-21.3 μm long, 3-4.5 μm in diam at the apex, 1-2-septate, arising perpendicularly from the apical or central cell of the second side branch. Very often, conidia are released before the third side branch grows out. The basal cell of the main axis, which is attached to the conidiogenous cell, is often devoid of content when conidia are released.

Culture: white colony on SWS, turning dark olive to black in age. Isolates produced conidia and immature ascocarps on the agar media.

Conidiogenous cells: hyaline, holoblastic, terminal, sympodial and flat-topped denticulated, sometimes producing conidia in a manner intermediate between the sympodial-type and percurrent proliferation.

Range: 28, 34.

Varicosporina ramulosa Meyers & Kohlmeyer Fig. 35

Can. J. Bot. 43: 916, 1965

Conidia: three-dimensionally branched, septate, hyaline; main axis, 27.5-62.5 μm long, 1.5-2.5 μm in diam at the apex, 1-3-septate; first side branch, 30-58 μm long, 2.7-5 μm in diam at the apex, 3-5-septate, arising perpendicularly from the central cell of the main axis; second side branch, 27.5-46.5 μm long, 3.3-5 μm in diam at the apex, 2-4-septate, arising perpendicularly from the central cell of the first side branch; third side branch, 22.5-37.5 μm long, 4-5 μm in diam at the apex, 2(-4)-septate, arising perpendicularly from the central cell of the second side branch. Very often, conidia are released before the third side branch grows out.

Culture: white colony on SWS and turned to dark olive to black in age. Isolates produced conidia and "sclerocarps", degenerate ascocarps, which was considered to have lost the ability to produce ascospores (3). IFO 32163.

Conidiogenous cells: hyaline, holoblastic, terminal, sympodial and denticulate or monoblastic on lateral or terminal determinate conidiophore.

Range: 7, 14, 15, 28, 29, 35, 38, 39.

Dematiaceae

Asteromyces cruciatus Moreau & Moreau ex Hennebert Fig. 36
Can. J. Bot. 40: 1213, 1962

Conidia: 7.5-13 x 4.8-6 μm, ovoid to pyriform, one-celled, thin-walled, brown, originating successively on denticles on the conidiogenous cell; the first conidium is apical, the following ones are in one or more lateral whorls of usually eight conidia. Conidia are usually released in aggregates attached to the conidiogenous cell.

Culture: brown to greenish gray colony on SWS. Greenish grey conidial masses concentrically scatter on the surface of the agar media. Reddish brown pigment diffuses into the media. IFO 32141, 32142.

Conidiogenous cells: hyaline to brown, holoblastic, 7.5-20 μm long (including stalk), 3-5.5 μm in diam, subglobose with stalk, hyaline or light brown, bearing up to 15 conidia on the denticles.

Range: 1, 4, 5, 8, 10, 14, 20, 24, 25, 27, 28, 33.

Clavatospora bulbosa (Anastasiou) Nakagiri & Tubaki Fig. 37
Bot. Mar. 28: 489, 1985
≡ Clavariopsis bulbosa Anastasiou, Mycologia 53: 11, 1961
Teleomorph: Corollospora pulchella Kohlm., Schmidt & Nair, Ber. Dtsch. Bot. Ges. 80: 98, 1967

Conidia: tetraradiate, with (1-)2-3 arms, septate, slightly constricted at the septa, light brown; main axis, one-septate; proximal cell, 9-17 μm high, 5.5-9.5 μm in diam, ellipsoidal to ovoid, truncate at the base; distal cell, 5.5-13 μm high, 7.5-12 μm in diam, arising simultaneously from the inflated distal cell; arms, 7-45 x 4.5-7 μm, cylindrical, 1-4-septate.

Culture: olive to olive gray colony on SWS. Isolates produced conidia on the aerial hyphae on the agar media.

Conidiogenous cells: olive, holoblastic, terminal, proliferating

simpodially or rarely percurrently at the apex.

Range: 28, 29, 34, 36, 38, 39.

Orbimyces spectabilis Linder in Barghoorn & Linder Fig. 38

Farlowia 1: 404, 1944

Conidia: consisting of a large dark cell with one or two crowns of septate, light colored appendages at the distal end; basal cell, 15.5-27.5 x 15-27.5 μm, globose to subglobose, thick-walled, shining black, smooth, with a scar of detachment from conidiophore at the base; radiating appendages, septate, consisting of a central cell and (1-)3-6(-7) arms; arms, 11-37 x 3-4 μm, cylindrical, (0-)1-4(-5)-septate, slightly constricted at the septa, light brown at the base, subhyaline at the apex.

Culture: dark green to black colony on SWS. Isolates produced conidia abundantly on the agar media. IFO 32157, 32158.

Conidiogenous cells: hyaline, holoblastic, terminal, determinate.

Range: 1, 5, 8, 16.

Of the marine fungi whose spores were accumulated in sea foam, the halosphaeriaceous ascomycetes are dominant as shown in the above list. Ascospores of the species of Arenariomyces, Carbosphaerella, Corollospora, Kohlmeyeriella and some species of Lindra and Lulworthia, which are so-called arenicolous fungi (4), were frequently found in sea foam. They live among or on grains of sand and produce hard, carbonaceous ascocarps on sand grains or shells of marine animals. Spores of the lignicolous fungi., e.g., Halolsphaeria appendiculata, H. torquata, Halosphaeriopsis mediosetigera, which live in wood and produce thin-walled ascocarps in the wood, were barely found in sea foam. Basidiospores of Nia vibrissa were also observed in sea foam around the Japanese coast. In hyphomycetes, conidia of Asteromycetes cruciatus, Sigmoidea spp. and Varicosporina ramulosa were common in sea foam.

Isolation of fungal spores from sea foam samples was useful for correct identification and life historical study (7, 8). Most of the arenicolous ascomycetes produced ascocarps on the glass wall of a slant tube or on sand grains by the "quartz sand method". Single spore isolates

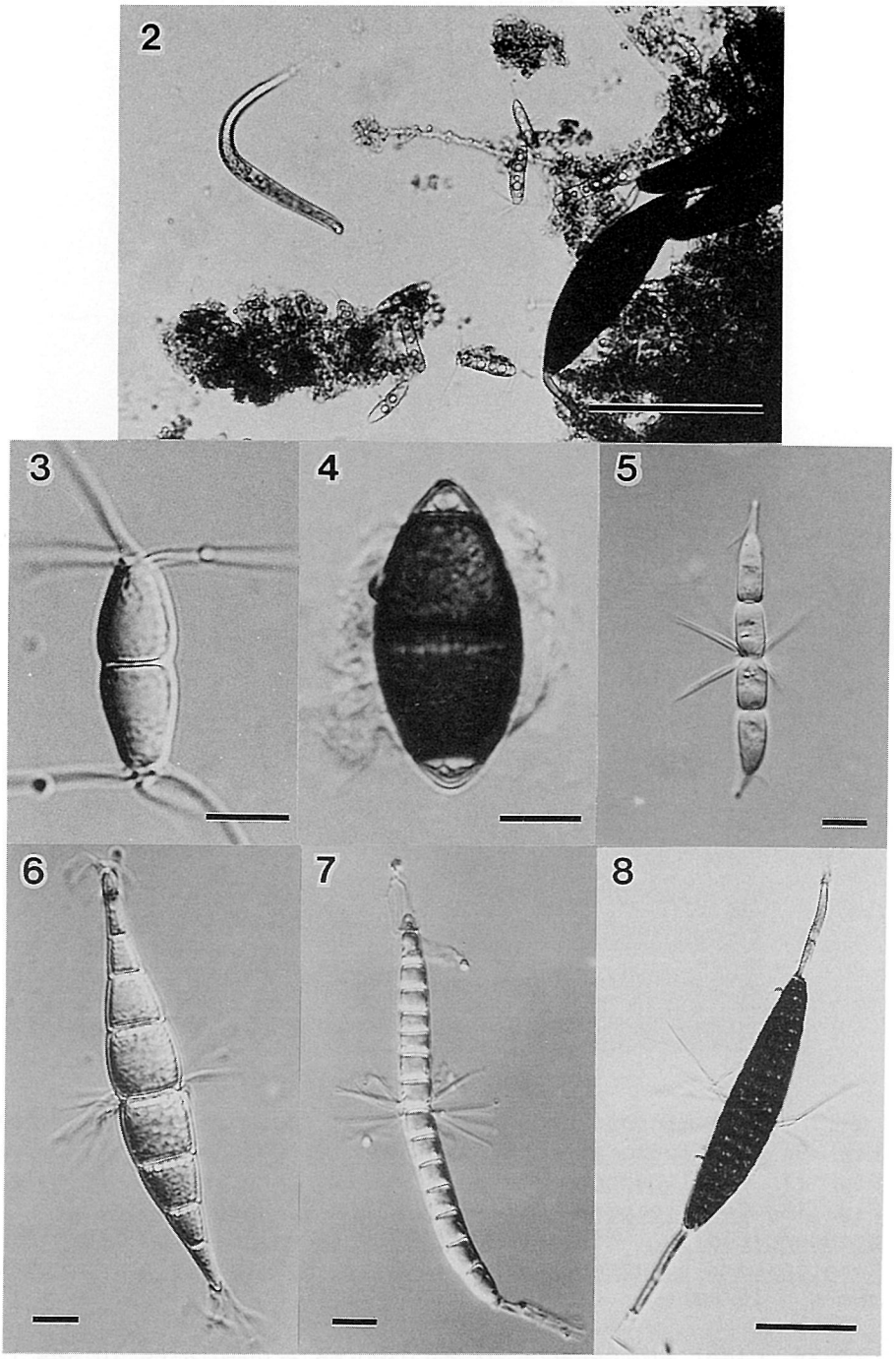
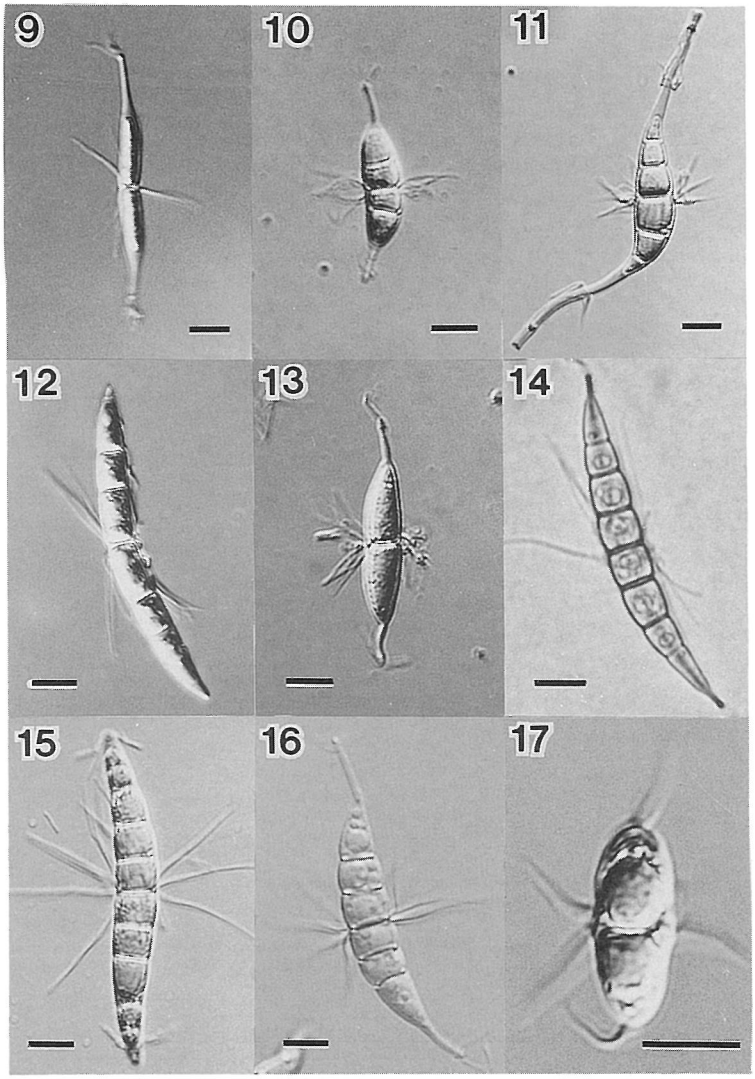


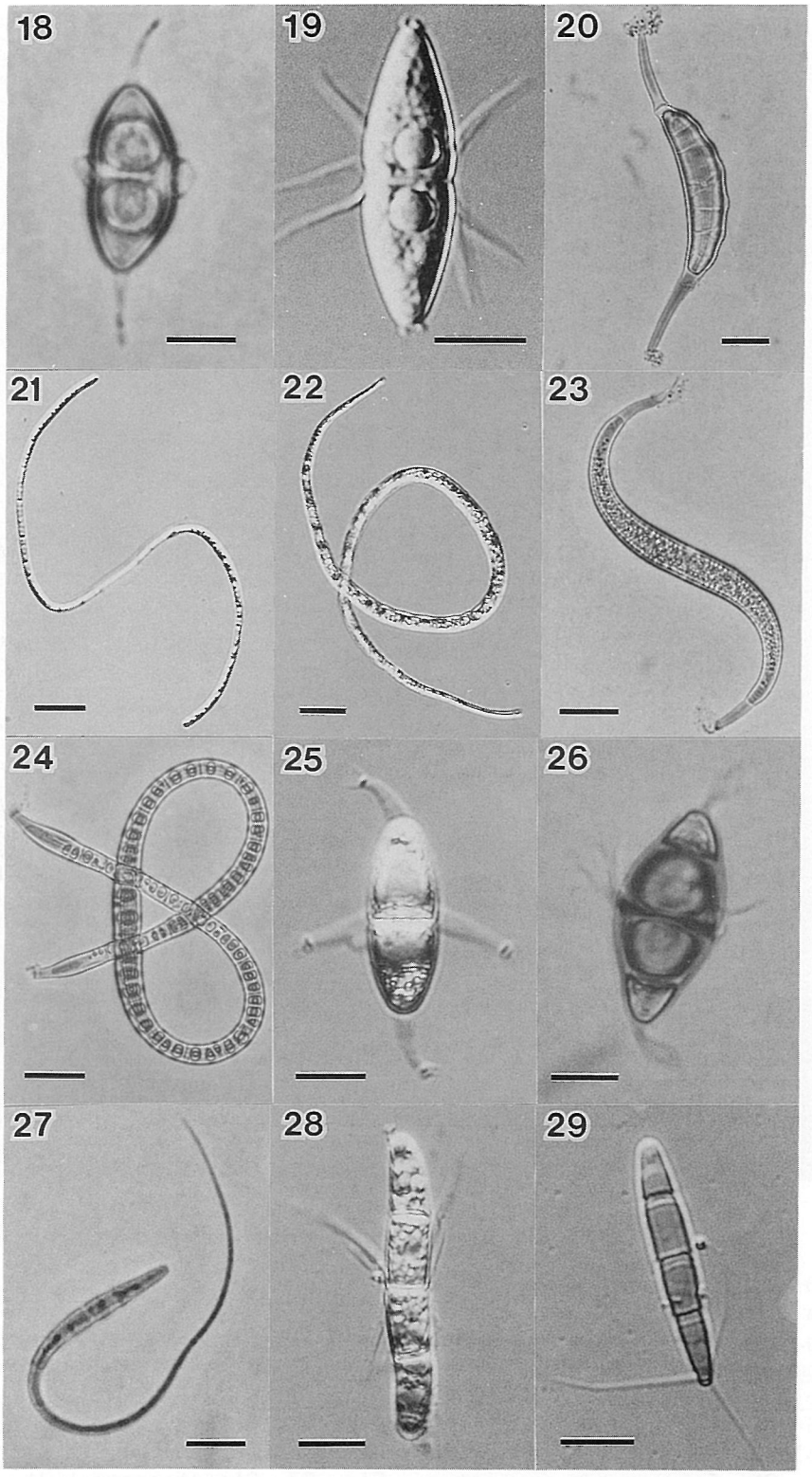
Fig. 2. Light micrograph of sea foam with accumulated marine fungal spores and debris. (Bar = 100 μm)

Figs. 3-8. Light micrographs of ascospores accumulated in sea foam. Fig. 3. Arenariomyces trifurcatus. Fig. 4. Carbosphaerella leptosphaerioides. Fig. 5. Corollospora angusta. Fig. 6. Corollospora colossa. Fig. 7. Corollospora filiformis. Fig. 8. Corollospora fusca. (Bars = 10 μm)



Figs. 9-17. Light micrographs of ascospores accumulated in sea foam.
Fig. 9. Corollospora gracilis. Fig. 10. Corollospora intermedia.
Fig. 11. Corollospora lacera. Fig. 12. Corollospora luteola.
Fig. 13. Corollospora maritima. Fig. 14. Corollospora pseudopulchella. Fig. 15. Corollospora pulchella. Fig. 16. Corollospora quinqueseptata. Fig. 17. Halosphaeria appendiculata.
(Bars = 10 μm)

Figs. 18-29. Light micrographs of ascospores accumulated in sea foam.
Fig. 18. Halosphaeria torquata. Fig. 19. Halosphaeriopsis mediosetigera. Fig. 20. Kohlmeyeriella tubulata. Fig. 21. Lindra obtusa. Fig. 22. Lindra thalassiae. Fig. 23. Lulworthia crassa.
Fig. 24. Lulworthia lignoarenaria. Fig. 25. Marinospora calyptrata.
Fig. 26. Nereiospora cristata. Fig. 27. Trailia ascophylli.
Fig. 28. Chaetosphaeria sp. Fig. 29. Torpedospora radiata.
(Bars: 18-19, 25-29 = 10 μm; 20-24 = 20 μm)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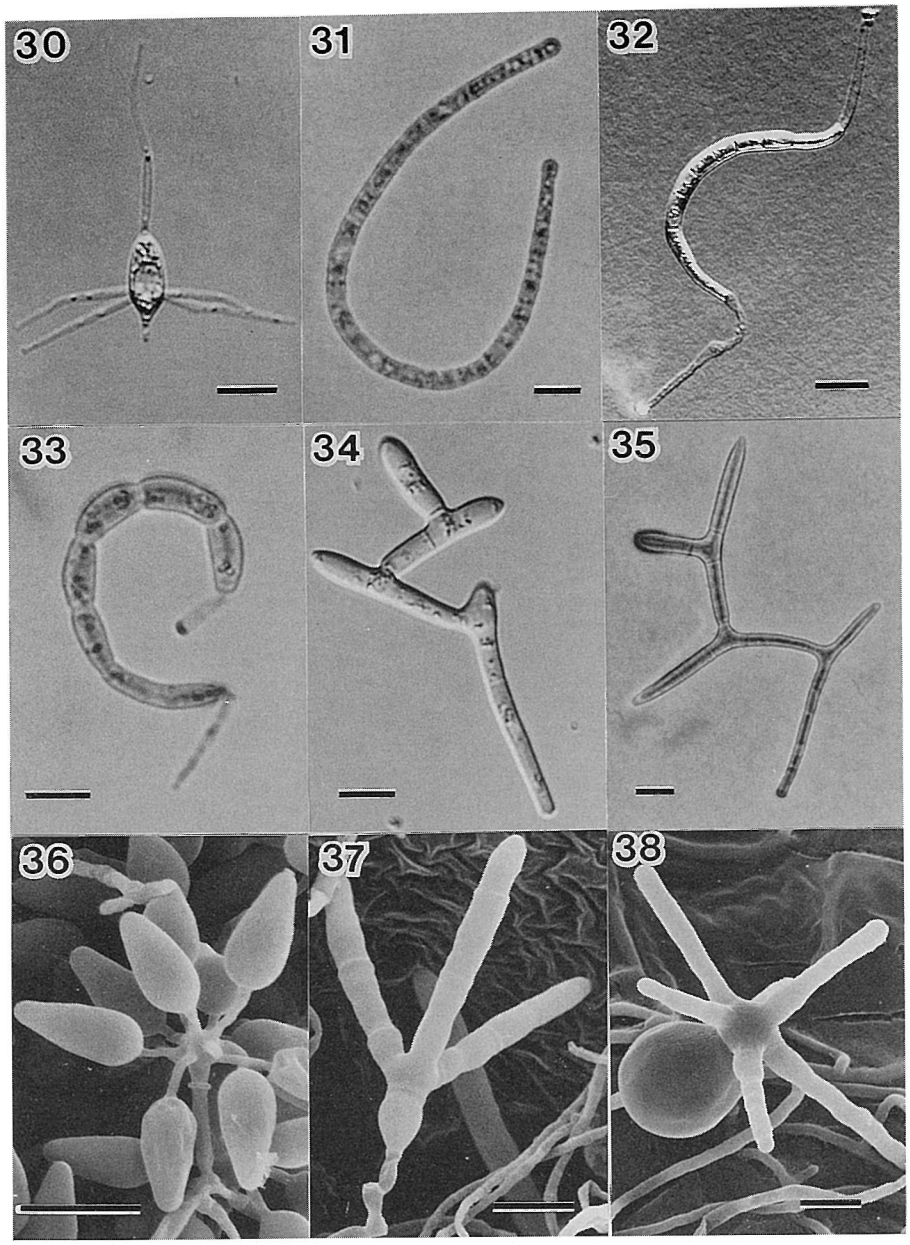

Figs. 30-35. Light micrographs of basidiospore and conidia accumulated in sea foam.
Fig. 30. Nia vibrissa. Fig. 31. Anguillospora marina. Fig. 32. Sigmoidea luteola. Fig. 33. Sigmoidea marina. Fig. 34. Varicosporina prolifera. Fig. 35. Varicosporina ramulosa. (Bars = 10 um)
Figs. 36-38. Scanning electron micrographs of conidia produced in culture. Isolates were obtained from sea foam.
Fig. 36. Asteromyces cruciatus. Fig. 37. Clavatospora bulbosa.
Fig. 38. Orbimyces spectabilis. (Bars = 10 um)

succeeded in producing ascocarps and ascospores, so they are homothalic in sexual reproduction. Some single-spore isolates of Nia vibrissa reproduced basidiospores in culture. All of the marine hyphomycetes easily produced conidia on the agar media.

Discussion

Spores of marine fungi were often contained abundantly in sea foam; and some samples yielded more than 20 species. Although sea foam contains phytoplanktons, protozoa, nematodes, blue-green algae, bacteria, other marine organisms and fungal spores with debris, spores of marine fungi are easily detectable under the microscope because of their peculiar morphology. Besides the marine fungi, plenty of spores of freshwater aquatic hyphomycetes, which are tetraradiate, sigmoid or helicoid in shape, and terrestrial fungi, e.g., Pestalotiopsis, Camposporium, Fusarium, were often accumulated in sea foam on shores close to the mouths of rivers. These fungal spores that had flowed from the river into the sea were considered unable to germinate and grow in a marine environment (1). Sea foam on beaches contained abundant spores of the arenicolous fungi. Arenicolous fungi attaching to sand grains were observed and 11 species were reported from the Japanese coast by Tokura (13). These species from sand samples were mostly included in the species found in foam samples. However, lignicolous or algicolous species were rarely contained in sea foam. So, other methods of collecting samples, e.g., drift wood and living or washed-up algal thallus, are necessary to investigate the total marine fungal flora of a location.

The spores of marine fungi accumulated in sea foam are mostly appendaged or sigmoid or branched and contain conspicuous oil globules in the cells. These characteristics were considered to be advantageous for arenicolous fungi in floating in seawater, becoming trapped between air bubbles and attaching to new substrates (4). These hyphotheses were investigated experimentally (5, 11, 12), and the roles of the spore appendages and sigmoid or branched shapes of marine fungal spores were found to be to reduce the rate sinking in seawater and to anchor the spore on the substrate.

The frequency of marine fungal species in sea foam was found to depend

on locality and region. The sea foam collected on rocky shores, even those which adjoined a sand beach, barely contained arenicolous marine fungal spores, whereas the foam on sand beaches accumulated many spores. So, the fungal spores may not be dispersible over a long distance. This, however, should be examined carefully in further research, with consideration of the spore survival through transportation. With respect to geographical distribution, three types of arenicolous fungi were observed, that is, (i) species distributed widely throughout Japan, e.g., A. trifurcatus, C. marintima, N. vibrissa; (ii) species distributed in the northern part of Japan, e.g., K. tubulata, N. cristata, Chaetosphaeria sp.; (iii) species distributed in the southern part of Japan, e.g., C. filiformis, C. pulchella, V. prolifera and Clav. bulbosa. In addition to the geographical distribution, a seasonal change in reproduction was observed in some species. In winter in the northern part of Japan, conidia of marine hyphomycetes were rarely contained in sea foam whereas a small number of ascospores were still observed. In warmer seasons, there were abundant conidia accumulated in sea foam. Alternation of morphs according to seasons were detected in a holomorphic species, C. intermedia - V. prolifera by collecting sea foam throughout a year (9).

Sea foam is a useful source for research on marine fungi, especially to know the fungal flora of a beach. Coastal sea foam is expected to be examined by marine mycologists world-wide to accumulate distribution data on marine fungi.

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