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# Taxonomy of recent and fossil (Holocene) diatoms (Bacillariophyta) from northern Willapa Bay, Washington

by

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ABSTRACT

Diatoms from modern surface samples and Holocene deposits were collected in northern Willapa Bay as part of an investigation into the history of Holocene relative sea-level changes in southwestern Washington. Modern diatoms were collected from lower, middle and upper-intertidal surfaces at eight localities in northern Willapa Bay, and fossil diatoms were collected from four outcrops along the Niawiakum River on the east side of Willapa Bay. This report discusses 192 species and varieties from 56 genera that exceeded 2% of at least one modern or fossil sample. Most species are cosmopolitan and have been reported from other temperate zone estuaries. However, this report represents the first documentation of 141 of these species for Willapa Bay.

## INTRODUCTION

### Background for the Study

Willapa Bay, in southwestern Washington (Figure 1), is a major Pacific Northwest estuary, covering approximately 350 $km^2$ during high tide (Major, 1989). Pleistocene terrace deposits on the eastern shore of Willapa Bay, and Holocene deposits exposed on cut-banks during low tide, provide a history of Late Quaternary sea-level changes in response to global climatic fluctuations and eustacy (Kvenvolden et al., 1979; Clifton and Phillips, 1980) and episodic tectonism and relative sea-level changes during large or great earthquakes along the Cascadia subduction zone (Atwater, 1987; 1988). Diatoms can benefit paleoecological interpretations of coastal and estuarine deposits (Palmer and Abbott , 1986) and have been shown to be useful in paleoecological interpretations in Willapa Bay (Hemphill-Haley, 1992). The purpose of this report is to document the taxonomy of diatom species in northern Willapa Bay that are applicable to paleoecological studies of estuarine deposits in southwestern Washington. Because significant geologic changes in southwestern Washington are associated with relatively young deposits (e.g., possibly 6 episodes of punctuated sea-level change in the past 3000 yr (Atwater, 1988)), diatoms recovered from the fossil deposits are likely to have counterparts that exist in the modern estuary. Willapa Bay was specifically chosen for these studies because, although it has not completely escaped anthropological influence, it has remained one-of the more pristine estuaries of the Pacific Northwest, and thus it is possible to document modern diatoms in undisturbed habitats that should approximate similar ecological settings which existed during the past several thousand years.

Modern diatoms were collected in surface sediments from eight sampling localities in northern Willapa Bay (Figure 1) and the assemblages were evaluated using Q-mode factor analysis (Hemphill-Haley, 1992). Over 250 diatom species and varieties were observed in the surface samples, of which 98 of these exceeded 2% of at least one sample. The modern-distribution data were then applied to a paleoecological analysis of late Holocene relative sea-level

rise related to coastal neotectonics in Willapa Bay (Hemphill-Haley, 1992). A total of 259 different species and varieties were identified at four outcrops along the Niawiakum River, on the east side of Willapa Bay (Figure 2), of which 129 exceeded 2% of at least one fossil sample. Because there are species in common to both studies, the combined modern and fossil analyses identified 192 that exceeded 2% of at least one sample.

## Related Studies

Previous studies of benthic marine and estuarine diatoms from temperate regions worldwide benefited this project. Classic works by Hustedt (1930; 1927-66; 1939; 1955; 1957), Brockmann (1950), Hendey (1964), and Patrick and Reimer (1966; 1975) were essential for ecological and taxonomic descriptions, as were the more recent monographs by Krammer and Lange-Bertalot (1985; 1986: 1987; 1988), Lange-Bertalot and Krammer (1987; 1989), Foged (1978; 1979; 1981), Germain (1981) and John (1983). Round (1971), McIntire and Moore (1977), and Round et al. (1990) provided habitat definitions, as well as an extensive literature compilation.

Various ecological and taxonomic studies from Oregon have contributed to the understanding of Pacific Northwest diatoms. These include a series of studies from Yaquina estuary (McIntire and Overton, 1971; Riznyk and Phinney, 1972; McIntire, 1973; Riznyk, 1973; McIntire and Reimer, 1974; Main and McIntire, 1974; Moore and McIntire, 1977; Amspoker and McIntire, 1978), Netarts Bay (Whiting, 1983; Whiting and McIntire, 1985), the Columbia River estuary (Amspoker and McIntire, 1986), and the Oregon coast (Castenholz, 1962; 1963). Important taxonomic studies from elsewhere along the west coast of the U.S. includes Laws (1988) for San Francisco estuary, and Rao and Lewin (1976) for False Bay, San Juan Island, Washington. Tynni (1986) listed 106 species from a single tidal flat sample collected at Ledbetter Point, near the mouth of Willapa Bay.

This report represents the documentation of 141 species previously undocumented in Willapa Bay. The majority of the diatoms listed are cosmopolitan, suggesting that diatom distributions in Willapa Bay are correlative with other temperate estuaries in the Pacific Northwest, and probably worldwide.

## METHODS

Modern intertidal diatoms from northern Willapa Bay were collected by scraping the uppermost 1-2 millimeters of the surface sediment with a small spatula along four leveled transects, two tidal flats, and two salt marshes (Hemphill-Haley, 1993; Figure 1). Diatoms collected in the field (excluding Toke Point samples that dried out) were stained for evidence of intact cytoplasm and mounted using the Taft Syrup Mount (TSM) method (Stevenson, 1984). The cells were stained by diluting the sample in 20 ml of distilled $H_2O$, and adding approximately 10 mg of Fast Green FCF cytoplasm stain. After 24 hours the sample was cleaned of excess stain by rinsing, centrifuging, and decanting until the supernatant remained relatively clear. The sample was then diluted to 5 ml, and a 0.1 ml aliquot transferred to a glass cover slip with a drop of the TSM medium, and allowed to dry. Cover slips were mounted on slides by inverting the cover slip on a warmed slide, and tapping it down. The edges of the cover slip were sealed with clear fingernail polish. Although samples prepared by this method are not as easy to work with as acid-cleaned samples mounted in a high refractive-index medium such as Hyrax, it does facilitates both taxonomic identification of most species (particularly heavily-silicified taxa with good fossilization potential) and identification of previously live vs. empty diatom frustules in a sample. Live (stained) and dead (unstained) diatoms were tabulated as a means of identifying possible allochthonous (i.e., reworked) valves in surface assemblages.

Holocene samples were collected from measured outcrop surfaces along the Niawiakum River (Hemphill-Haley, 1992). Diatom strewn slides were processed by the following method: 1)

approximately 1 cc of sediment was dried and weighed; 2) organic debris was removed by gentle heating in concentrated nitric acid; 3) acid was removed and the sample was neutralized by repeated rinses in distilled water; 4) the total sample volume was reduced to 5 ml; 5) an 0.05 to 0.10 ml aliquot was transferred to a cover slip and allowed to dry; 6) the cover slip was permanently fixed to a glass slide using Hyrax.

Photomicrographs were produced with an Olympus BH-2 microscope and PM-10AK automatic exposure photomicrographic system using Kodak Tmax 100 film, at magnifications of 600x and 1250x.

## FLORAL LIST

As noted by Laws (1988), the increased use of the electron microscope in recent years has resulted in great modifications to the classic diatom literature. An effort was made to include recent taxonomic revisions that have gained acceptance in the field (e.g., Lange-Bertalot, 1977, 1980a,b; Lange-Bertalot and Simonsen (1978); Simonsen (1979), Krammer and Lange-Bertalot 1986, 1988). Round et al. (1990) have introduced major revisions to many diatom genera, but except for a few taxa these changes are not listed first in this report in favor of the generally accepted species names now in use. However, the Round et al. (1990) revisions are provided as synonyms in anticipation of their potential future usage.

The taxa are listed alphabetically, which is a convenient and widely-used format in diatom biostratigraphy (see also Riznyk (1973), Laws (1988), the numerous volumes by Foged, and the Deep-Sea Drilling Project and Ocean Drilling Program volumes). The listing for each species includes a reference to a detailed taxonomic description and the valve dimensions from that description; auxillary references are also provided. The ecology is based on a consensus from the literature, and my observations in Willapa Bay. Salinity terminology (Table 2) is modified from Hustedt (1957). Distributions in modern surface samples and Holocene fossil deposits in Willapa

Bay are discussed, plus references to other occurrences in the Pacific Northwest, and in temperate areas worldwide. Finally, general observations on taxonomy, ecology, taphonomy, etc. for each species are provided. Designations for intertidal zones are from Hemphill-Haley (1992), and are as follows: upper intertidal = areas between extreme high water (EHW) and mean higher water (MHHW) (i.e., high marshes); middle intertidal = areas between MHHW and mean lower high water (MLHW) (i.e., low marshes); lower intertidal = areas below MLHW, including unvegetated channel banks and tidal flats, and *Zostera* (eel grass) beds. Designations for relative frequencies are as follows: 1) very rare, < 2% relative to the total assemblage; 2) rare, 2-4.99%; 3) frequent, 5-9.99%; 4) common, 10-33%; 5) abundant, > 33%. Abbreviations used for the descriptions and plates are as follows: L= length, W = width, Str = striae, ITM = in 10 µm, RV = raphe valve, RLV = rapheless valve, Diam = diameter, WB = Willapa Bay.

ACHNANTHES Bory 1822

*Achnanthes brevipes* Agardh 1824

Description: John, 1983, p. 68, pl. 29, fig. 1-14.

Hustedt, 1927-66, II, p. 424-426, fig. 877a-c; Hendey, 1964, p. 174-175, pl. 28, fig. 7-8; Riznyk, 1973, p. 3, pl. 1, fig. 1; McIntire and Reimer, 1974, p. 171; Foged 1978, p. 23, pl. 15, fig. 13-13, 18-20, pl. 16, fig. 2, 6-8, 17; Jensen, 1985, p. 368, fig. 877d,e; Laws, 1988, p. 152, pl. 17, fig. 22.

Dimensions: L: 15-125 µm. W: 5-15 µm. Str: 9-11 ITM.

Ecology: Epiphyte; α–mesohalobous/polyhalobous.

Distribution: WB: Observed on only a few occasions in brackish muddy intertidal deposits. Hendey (1964, p. 174): "sessile littoral species common in estuaries and harbours where less than fully saline conditions obtain." John (1983, p. 68): "One of the most common epiphytic diatoms in the Swan River estuary." Cosmopolitan.

Remarks: A strongly polymorphic species with transitional forms that may be difficult to distinguish from its varieties (Foged, 1978; John, 1983).

*Achnanthes brevipes* Agardh var. *intermedia* (Kützing) Cleve 1895

(Plate 1, Figure 1)

Description: McIntire & Reimer, 1974, p. 171, pl. 2, fig. 8a,b; pl. 3, fig. 2a,b.

Hustedt, 1927-66, II, p. 425, fig. 877d,e; Foged 1978, p. 23, pl. 15, fig. 13-14, 18-20; 1979, p. 18, pl. 15, fig. 14; John 1983, p. 68, pl. 29, fig. 10-11; Jensen, 1985, p. 369, fig. 877d,e; Laws, 1988, p. 152, pl. 17, fig. 17-19.

Dimensions: L: 30-125 µm. W: 12-30 µm. Str: 9-10 ITM.

Ecology: Epiphytic; α–mesohalobous/polyhalobous.

Distribution: WB: Observed live specimens of var. *intermedia* attached to *Zostera marina;* also in intertidal samples near *Zostera* beds. Cosmopolitan.

Remarks: Apparently differs from *A. brevipes* by the more linear valve, absence of constriction at the middle, and smaller overall size.

*Achnanthes delicatula* (Kützing) Grunow in Cleve and Grunow 1880

Description: John, 1983, p. 70, pl. 30, fig. 3-4.

Hustedt, 1927-66, II, p. 389, fig. 836; Foged 1978, p. 24, pl. 15, fig. 11a,b; Germain, 1981, p. 114, pl. 42, fig. 10-15; Jensen, 1985, p. 339, fig. 836.

Dimensions: L: 10-15 µm. W: 6-9 µm. Str: 14-16 ITM (RV); 16-17 ITM (RLV).

Ecology: Epipsammic. Mesohalobous, euryhaline; pH circumneutral (Foged, 1978).

Distribution: WB: Observed most frequently in sandy tidal flat samples. John (1983, p. 70) observed this taxon in "periphytic samples" of the lower Swan River estuary. Cosmopolitan.

Remarks: John (1983, p. 70) noted that the differences between *A. delicatula* and *A. haukiana* var. *rostrata* are subtle, with *A. haukiana* var. *rostrata* being more robust. *A. delicatula* is more common than *A. haukiana* in tidal flat sediments of Willapa Bay.

*Achnanthes haukiana* Grunow in Cleve and Grunow 1880

Syn: *Achnanthes delicatula* spp. *haukiana* Lange-Bertalot and Ruppel 1980.

Description: Patrick & Reimer, 1966, p. 267, pl. 17, fig. 23-24.

Hustedt, 1927-66, II, p. 388, fig. 834; Foged, 1978, p. 25, pl. 15, fig. 9; Lange-Bertalot and Ruppel 1980, p. 6, pl. 1, fig. 1-20; Jensen, 1985, p. 338, fig. 834; Laws, 1988, p. 153, pl. 17, fig. 14; Laws, 1988, p. 153, pl. 17, fig. 14; Lange-Bertalot and Krammer, 1989, p. 45, pl. 87, fig. 14-23 (as *A. delicatula* spp. *haukiana*).

Dimensions: L: 9-31 µm. W: 5-9 µm. Str: 10-15 ITM.

Ecology: Epipsammic; epiphytic. Oligohalobous/mesohalobous. Patrick and Reimer (1966, p. 269): "Found most commonly in slightly to moderately brackish water, also reported from inland freshwater areas with relatively high specific conductivity."

Distribution: WB: Common in oligohalobous/mesohalobous lower and middle intertidal samples of the South Fork Willapa, Willapa and Niawiakum rivers. Not important in open tidal flat samples, nor recorded by Riznyk (1973) for tidal flats in Yaquina estuary. Reported by Laws (1988, p. 153) for San Francisco estuary: "Intertidal mud flats near areas where creeks enter Bay." Cosmopolitan.

Remarks: Patrick and Reimer (1966, p. 268) note that *A. haukiana* is "best distinguished by the coarse striae, at least some of which are usually wedge-shaped or conical..." Lange-Bertalot and Krammer (1989) consider this taxon a subspecies of *A. delicatula*. Similar to *A. delicatula*, but differs in the coarser striae and linear-lanceolate (versus narrow linear) axial area. Also similar to the marine tidal flat species *A. oregonensis* Riznyk. Not observed as frequently as the variety *rostrata*.

*Achnanthes haukiana* var. *rostrata* Schulz 1926

Description: Patrick & Reimer, 1966, p. 269, pl. 17, fig. 33-34. Hustedt, 1927-66, II, p. 388; John, 1983, p. 71, pl. 30, fig. 7-10; Jensen, 1985, p. 338; Laws, 1988, p. 153, pl. 17, fig. 11-13, 15.

Dimensions: L; 10-15 µm. W: 5-6 µm. Str: 12-14 ITM.

Ecology: Same as *A. haukiana*.

Distribution: WB: Common in oligohalobous/mesohalobous lower and middle intertidal samples with *A. haukiana*.

Remarks: Differs from *A. haukiana* by the produced sub-rostrate apices, and the irregular shape of the central area. John (1983): "This taxon resembles *A. delicatula* (Kütz.) Grunow. But (*A. delicatula*) has a higher striae density and the striae appear less coarse than those in the present taxon."

*Achnanthes lanceolata* (Brébisson) Grunow 1880

Description: Patrick & Reimer, 1966, p. 269, pl. 18 fig. 1-10.

Hustedt, 1927-66, II, p. 408, fig. 863a-d; ; Riznyk, 1973, p. 115, pl. 1, fig. 4-5; Foged, 1978, p. 26, pl. 15, fig. 4,5; Germain, 1981, p. 115, pl. 44, fig. 1-18; Foged 1981, p. 49, pl. 12, fig. 11-12, 23-24; John, 1983, p. 73, pl. 31, fig. 13-16; Jensen, 1985, p. 354, fig. 863a-d; Laws, 1988, p. 153, pl. 17, fig. 20; pl. 25, fig. 8,9; Lange-Bertalot and Krammer, 1989, p. 83, pl. 84, fig. 1-16.

Dimensions: L: 12-31 µm. W: 4.5-8 µm. Str: 11-14 ITM.

Ecology: Epipsammic; epiphytic. Oligohalobous (indifferent); alkaliphilous; cosmopolitan (Foged, 1978).

Distribution: WB: Most commonly observed attached to mineral grains and plant fragments in sandy, oligohalobous and β–mesohalobous channel bank and marsh samples from the South Fork Willapa and Willapa Rivers. Cosmopolitan.

Remarks: The horseshoe-shaped hyaline marking on the pseudoraphe valve is a distinguishing feature of the species. Morphologically variable (John, 1983).

*Achnanthes lanceolata* var. *dubia* Grunow 1880

Syn: *Achnanthes lanceolata* var. *rostrata* (Østrup) Hustedt 1911

Description: Patrick and Reimer, 1966, p. 271, pl. 18, fig. 11-15.

Lange-Bertalot and Krammer, 1989, p. 86, pl. 84, fig. 26-40; pl. 87, fig. 1-4.

(As *A. lanceolata* var. *rostrata* ): Hustedt, 1927-66, II, p. 410, fig. 863i-m; Jensen, 1985, p. 356, fig. 863i-m; Foged (1978, p. 27, pl. 15, fig. 7.

Dimensions: L: 8-16 µm. W: 3.6-5 µm. Str: 10-14 ITM.

Ecology: Same as *A. lanceolata.*

Distribution: WB: Found with *A. lanceolata.* Also observed in pure clusters attached to plant debris in freshwater samples from the South Fork Willapa River. This agrees with Hustedt (1927-66 in Jensen, 1985, p. 356) who noted that "var. [*dubia*] is frequently found in "pure" blooms and in many areas, as the only form..."

Remarks: Differs from *A. lanceolata* by having produced subrostrate apices; also shows the distinctive horseshoe-shaped hyaline area on one margin.

*Achnanthes minutissima* Kützing 1833

Description: Patrick and Reimer, 1966, p. 253, pl. 16, fig. 9-10.

Hustedt, 1927-66, II, p. 376, fig. 820a-c; Germain, 1981, p. 109, pl. 41, fig. 12-19; John, 1983, p. 74, pl. 32, fig. 3-4; Jensen, 1985, p. 329, fig. 820a-c; Lange-Bertalot and Krammer, 1989, p. 103, pl. 51, fig. 1-20.

Dimensions: L: 5-40 µm. W: 2-4 µm. Str: 30-38 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous. (Foged, 1981).

Distribution: WB: Widely distributed in marsh and intertidal channel bank samples where salinities ranged between 5-25‰. Cosmopolitan.

Remarks: Patrick and Reimer (1966, p. 252) noted that: "There are several small *Achnanthes* species (especially *A. linearis*, *A. affinis*, *A. microcephala*, and *A. minutissima*) which all appear very similar upon casual observation. Rather great care must be taken to keep them separate when they appear as a mixed population. There is a need for continued taxonomic and morphological work in this area to determine the accuracy of the present separation." Lange-Bertalot and Krammer (1989) later provided morphological analysis of a variety of small *Achnanthes*, and defined a series of new combinations in the "*Achnanthes minutissima* Complex." It is generally difficult to separate the varieties of *A. minutissima* , and for biostratigraphic purposes may not be informative as the varieties occur together.

*Achnanthes minutissima* var. *affinis* (Grunow) Lange-Bertalot 1989

Syn: *Achnanthes affinis* Grunow 1880

Description: Patrick & Reimer, 1966, p. 254, pl. 16, fig. 11-12 (as *A. affinis*). Hustedt, 1927-66, II, p. 376, fig. 826; Germain, 1981, p. 110, pl. 41, fig. 22-34; Jensen, 1985, p. 332, fig. 826; Lange-Bertalot and Krammer, 1989, p. 104, pl. 53, fig. 22-37; pl. 56, fig. 5-7.

Dimensions: L: 14-23 µm. W: 3-4 µm. Str: 27-30 ITM.

Ecology: Same as *A. minutissima.*

Distribution: WB: Same as *A. minutissima.* Hustedt (*in* Jensen, 1985, p. 333): "Distributed throughout all of Europe in fresh water and in weakly saline waters of the interior."

Remarks: Lange-Bertalot and Krammer (1989) included this taxon in their "*Achnanthes minutissima* complex." Hustedt (*in* Jensen, 1985, p. 333) noted that for *A. affinis* "especially the rapheless valve may easily be confused with *A. minutissima.*" Differs from the nominate variety in that the striae are more parallel on the rapheless valve, and striae are interrupted by a transverse central area on the raphe valve.

*Achnanthes petersenii* Hustedt 1937

Syn: *Achnanthes linearis* (W. Smith) Grunow 1880

Description: Patrick & Reimer, 1966, p. 251, pl. 16, fig. 3-4 (as *A. linearis*). Hustedt, 1927-66, II, p. 378, fig. 821a,b; Germain, 1981, p. 110, fig. 35-37; Jensen, 1985, p. 329, fig. 821a,b; Lange-Bertalot and Krammer, 1989, p. 117, pl. 65, fig. 18-44; pls. 66, fig. 4-7.

Dimensions: L: 10-20 µm. W: 2.5-3.5 µm. Str: 24-29 ITM (RV); 23-29 ITM (RLV).

Ecology: Epipelic. Oligohalobous (indifferent) (Foged, 1981).

Distribution: WB: Observed in oligohalobous/β–mesohalobous lower and middle intertidal samples.

Remarks: May or may not show a transverse central area (Lange-Bertalot and Krammer, 1989).

*Achnanthes pusilla* (Grunow) De Toni 1891

Syn: *Achnanthes linearis* var. *pusilla* Grunow 1880

Description: Patrick & Reimer, 1966, p. 252, p. 16, fig. 5-6 (as *A. linearis* var. *pusilla*). Hustedt, 1927-66, II, p. 379, fig. 821c,d; Jensen, 1985, p. 330, fig. 821c,d; Lange-Bertalot and Krammer, 1989, p. 127, pl. 64, fig. 31-43; pl. 65, fig. 1.

Dimensions: L: 13-17 µm. W: 3-4 µm. Str: 20-27 ITM (RV); 18-27 ITM (RLV).

Ecology: Epipelic; oligohalobous (indifferent).

Distribution: WB: Observed in oligohalobous and β–mesohalobous lower and middle intertidal samples. Cosmopolitan.

Remarks: The valve shape, parallel striae, and orbicular central area are distinctive. Hustedt (*in* Jensen, 1985, p. 330) reported that in northern Europe this taxon "is found generally as the most common form of the genus *Achnanthes*."

ACTINOCYCLUS Ehrenberg 1837

*Actinocyclus curvatulus* Janisch in Schmidt 1878

Syn: *Coscinodiscus curvatulus* Grunow in Schmidt 1878

Description: Hustedt, 1927-66, I, p. 538, fig. 307.

Schrader, 1973, pl. 19, fig. 2; Sancetta, 1982, p. 222, pl. 1, fig. 1-3.

As *C. curvatulus*: Hustedt, 1930, p. 406, fig. 214; Hendey, 1964, p. 81; Riznyk, 1973, p. 120, pl. 6, fig. 1; Laws, 1988, p. 157, pl. 9, fig. 3,4.

Dimensions: Diam: 96-160 µm. Areolae: 5-6 ITM near the center, 8-9 (12) ITM near the margin.

Ecology: Planktonic; polyhalobous. A common pelagic species north of the Subarctic Front (Sancetta, 1982).

Distribution: WB: Rare in Holocene sediments. Hendey (1964, p. 81): "A common neritic species on all European coasts, North Sea coasts, English Channel; widespread."

Remarks: Identified by the large flat valve with areolae in curved fascicles. Presumably allochthonous from the open ocean.

*Actinocyclus kützingii* (Schmidt) Simonsen 1975

Syn: *Coscinodiscus kützingii* Schmidt 1878

Description: John, 1983, p. 27, pl. 9, fig. 5.

Simonsen, 1975, p. 92.

(As *C. kützingii*): Hustedt, 1930, p. 398, fig. 209; Hendey, 1964, p. 81; Rao and Lewin, 1976, p. 177, fig. 45.

Dimensions: Diam: 35-45 µm. Areolae: 6-7 ITM near the center, 7-10 near the margin.

Ecology: Planktonic. Polyhalobous. Rao and Lewin (1976, p. 177): "Probably planktonic and left as deposit in the epipelic community."

Distribution: WB: Rare in Holocene sediments; modern distribution not recorded. Hendey (1964, p. 81): "A common neritic species on all European coasts, North Sea coasts, English Channel; widespread." Cosmopolitan.

Remarks: Distinguished by areolae in radiate fascicles that decrease in size toward the margins, and smaller marginal areolae in decussate patterns, concave toward the margin.

*Actinocyclus normanii* (Gregory) Hustedt 1957

Syn: *Coscinodiscus normanii* Gregory in Greville 1859

Description: John, 1983, p. 28, pl. 9, fig. 6-9.

Hustedt, 1957, p. 218, fig. 5,6; Laws, 1988, p. 153, pl. 8, fig. 1-3, 7, 9 11, 12.

(As *C. normanii*): Hendey, 1964, p. 80

Dimensions: Diam: 25-45 µm. Areolae: 14-16 near the center; 18-20 at the margin.

Ecology: Planktonic, mesohalobous (Schrader, 1978).

Distribution: WB: rare in modern lower intertidal sediments; rare in Holocene deposits. Abundant in fossil deposits and present in modern deposits of San Francisco estuary (Laws, 1988). Hendey (1964, p. 80): "Common in plankton of the North Sea."

Remarks: Distinguished by the concentrically undulate valve face. Also, the areolae are arranged into alternating larger and smaller fascicles that give the areolation a somewhat erratic appearance. Marginal processes are associated only with large fascicles.

ACTINOPTYCHUS Ehrenberg 1841

*Actinoptychus adriaticus Grunow 1863*

Syn: *Actinoptychus vulgaris* Schmidt 1888

Description: Hustedt, 1927-66, I, p. 480, fig. 267.

Foged, 1978, p. 30, pl. 4, fig. 4.

(As *A. vulgaris*): Sancetta, 1982, p. 225, pl. 1, fig. 8; John, 1983, p. 29, pl. 10, fig. 10,11.

Dimensions: Diam: 20-60 µm.

Ecology: Tychoplanktonic. Polyhalobous. (Foged, 1981).

Distribution: WB: A few valves observed in subtidal samples from the Niawiakum River channel; also in late Holocene deposits in the Niawiakum River valley. John (1983, p. 29): "Rare, collected from [brackish to marine] station in planktonic and benthic forms." Cosmopolitan.

Remarks: Distinguished by narrow-triangular sectors without a bifurcating hyaline line, a hyaline space on the margin of the lowered sectors.

*Actinoptychus marmoreus* Brun 1891

Description: Schmidt et al., pl. 153, fig. 14.

Riznyk, 1973, p. 116, pl. 1, fig. 11; Tynni, 1986, p. 15, pl. 9, fig. 38.

Dimensions: Diam: 45-75 µm.

Ecology: Tychoplanktonic. Polyhalobous. (Foged, 1981).

Distribution: WB: Observed thus far from late Holocene deposits; modern distribution not recorded. Riznyk (1973, p. 116) recorded it as very rare from a tidal flat in Yaquina estuary, and Tynni (1986) recorded it in his tidal flat sample from Ledbetter Point. Cosmopolitan.

Remarks: Distinguished by a robust valve with 8 to 12 alternating raised and lowered sectors, raised sectors bisected by a hyaline line extending from the hyaline central area. Tynni (1986, p. 15): "A spotted surface is typical of the species. This feature is not well developed in the eroded 10-sector form encountered in the sediment of Long Beach."

*Actinoptychus senarius* Ehrenberg 1843

(Plate 1, Figure 2,3)

Syn: *Actinoptychus undulatus* (Bailey) Ralfs in Pritchard 1861

Description: Hendey, 1964, p. 95, pl. 23, fig. 1-2.

Rao and Lewin, 1976, p. 179, fig. 42; Laws, 1988, p. 153, pl. 13, fig. 1-4,7.

(As *A. undulatus*): Hustedt, 1927-66, I, p. 475, fig. 264.

Dimensions: 20-86 µm.

Ecology: Tychoplanktonic. Polyhalobous (Foged, 1981).

Distribution: WB: Observed most commonly in tideflat samples, but also observed in brackish muddy intertidal samples (due to planktonic transport?). Hendey (1964, p. 95): "...widely spread throughout north temperate seas and common in the neritic plankton... never abundant but hardly ever absent from littoral gatherings taken at almost any time of the year." Cosmopolitan.

Remarks: *A. senarius* is a tychoplanktonic species common in the plankton or the benthos (Schuette and Schrader, 1979). Therefore it is not evident if its occurrence in tideflat samples documents a benthic habitat, or if it is simply filtered out of the phytoplankton. It is probably best used as an indication of elevated salinity, and possibly of evidence of planktonic transport. Riznyk (1973, p. 116) recorded it as common in tideflat samples from Yaquina estuary; Whiting (1983, p. 129) noted its occurrence only in planktonic samples in Netarts Bay. John (1983, p. 29) reported it as common in both planktonic and benthic brackish to marine samples. Hendey (1964, p. 95) considered this species as common, but never abundant, member of the neritic plankton, and Pankow (1976) reported it as "Planktonic, polyhalobous, meioeuryhaline." Laws (1988, p. 153) recorded it as the dominant species in some samples (Yerba Buena mud) from San Francisco Bay. Rao and Lewin (1976, p. 179) noted it "Occurred in the epipelon. Very rare."

*Actinoptychus splendens* (Shadbolt) Ralfs in Pritchard 1861

Description: John, 1983, p. 29, pl. 10, fig. 5-9.

Hustedt, 1927-66, I, p. 478, fig. 265; Cupp, 1943, p. 67, fig. 30, pl. 5, fig. 2; Hendey, 1964, p. 95, pl. 22, fig. 1; Foged 1978, p. 30, pl. 4, fig. 1; Laws, 1988, p. 154, pl. 13, fig. 5-6.

Dimensions: Diam: 50-140 µm.

Ecology: Tychoplanktonic. Polyhalobous (Foged, 1978).

Distribution: Observed in late Holocene deposits in Niawiakum River valley, associated with *A. senarius*. Not identified in modern WB surface samples. According to Laws (1988, p. 154), its distribution is "Same as *A. senarius*."

Remarks: This is a large tychoplanktonic species, distinguished by the high number of sectors (can be up to 20), the difference in the structure between the raised and lowered sectors, the stellate hyaline central area, and the sharp hyaline invagination from the central area into the depressed sectors.

AMPHORA Ehrenberg *ex* Kützing 1844

*Amphora coffeiformis* (Agardh) Kützing 1844

Description: Patrick & Reimer, 1975, p. 78, pl. 14, fig. 11-12.

Hustedt, 1930, p. 345, fig. 634; Hendey, 1964, p. 264; John, 1983, p. 149, pl. 61, fig. 8-11; Jensen, 1985, p. 797, fig. 634; Krammer & Lange-Bertalot, 1986, p. 347, pl. 151, fig. 1-6.

Dimensions: L: 13-60 µm. W: 3.5-7 µm. Str: 20-25 ITM.

Ecology: Epiphytic, periphytic; mesohalobous. (John, 1983). Patrick and Reimer (1975, p. 79): "Found only in habitats with rather high conductivity such as estuaries, springs, soil. Mesohalobe; alkalibiont." Cosmopolitan coastal brackish water form and in saline water of the interior with high electrolyte content (Krammer and Lange-Bertalot, 1986).

Distribution: WB: Rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the protracted subcapitate to capitate apices, arched dorsal margin and nearly straight ventral margin, and the gently-radiating striae.

*Amphora libyca* Ehrenberg 1840

(Plate 1, Figure 4)

Syn: *Amphora ovalis* var. *affinis* (Kützing) Van Heurck 1880; *Amphora ovalis* var. *libyca* (Ehrenberg) Cleve 1895

Description: Krammer and Lange-Bertalot, 1986, p. 345, pl. 149, fig. 3-11.

(As *Amphora ovalis* var. *affinis*): Hustedt, 1930, p. 342, fig. 628; Patrick and Reimer, 1975, p. 69, pl. 13, fig. 3-4; Foged, 1978, p. 33, pl. 36, fig. 11; John, 1983, p. 152, pl. 62, fig. 11,12.

(As *Amphora ovalis* var. *libyca*): Foged, 1981, p. 54, pl. 45, fig. 3; Krammer, 1980, p. 209, fig. 4, 12-20.

Dimensions: L: 20-80 µm. W: 14-35 µm. Str: 11-15 ITM.

Ecology: Epiphytic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: WB: Rare in Holocene samples from the lower Niawiakum River. Cosmopolitan.

Remarks: Distinguished by the shape of the frustule, the filiform raphe with central and apical fissures turned dorsally, and the dorsal striae interrupted at the middle by a hyaline space.

*Amphora mexicana* A. Schmidt 1874

Description: John, 1983, p. 154, pl. 53, fig. 4-12.

Dimensions: L: 60-140 µm. W: 17-30 µm. Str: 8-9 ITM.

Ecology: Epipelic. Mesohalobous.

Distribution: WB: Rare in fossil samples from the lower Niawiakum River. Rare in mesohalobous samples from the Swan River estuary (John, 1983).

Remarks: Distinguished by the large valve with a strongly biarcuate raphe, the prominent semi-elliptical central nodule and the coarse striae interrupted by undulate longitudinal lines.

*Amphora pediculus* (Kützing) Grunow 1880

Syn: *Amphora ovalis* var. *pediculus* (Kützing) Van Heurck 1885

Description: Krammer and Lange-Bertalot, 1986, p. 346, pl. 150, fig. 8-13.

As *Amphora ovalis* var. *pediculus*: Hustedt, 1930, p. 343, fig. 629; Patrick & Reimer, 1975, p. 69, pl. 13, fig. 5a-6b; Foged, 1981, p. 54, pl. 45, fig. 10; John, 1983, p. 153, pl. 42, fig. 13, 14; Jensen, 1985, p. 795, fig. 629.

Dimensions: L: 5-18 µm. W: 2-4 µm. Str: 18-25 ITM.

Ecology: Epiphyte. Oligohalobous (indifferent); alkaliphil (Foged, 1981).

Distribution: WB: Observed in channel bank samples Cosmopolitan.

Remarks: Differs from *A. libyca* by the smaller size, more linear raphe, and more rectangular dorsal hyaline area.

*Amphora proteus* Gregory 1857

(Plate 1, Figure 5)

Description: John, 1983, p. 153, pl. 63, fig. 1-3.

Hendey, 1964, p. 262; Riznyk, 1973, p. 117, pl. 2, fig. 8; Foged, 1978, p. 34, pl. 36, fig. 12.

Dimensions: L: 27-48 µm. W: 5-7.5 µm. Dorsal Str: 16-18 ITM. Ventral Str: 14-16 ITM.

Ecology: Epipelic; epiphytic. Polyhalobous (Foged, 1978).

Distribution: WB: Common in sandy tidal-flat and marsh-edge samples of the open bay; rare in Holocene samples. John (1983, p. 153): Common epiphyte at the lower stations of Swan River..." Whiting (1983, p. 130): Common in benthic samples, but absent from epiphyte (*Zostera*) samples in Netarts Bay. Very common in tidal flat samples from Yaquina estuary (Riznyk, 1973). Cosmopolitan.

Remarks: Similar in some respects to the oligohalobous species *Amphora libyca* , but the ventral margin is more concave and striae on the dorsal margin are not interrupted by a hyaline area.

*Amphora ventricosa* (Gregory) Hendey 1951

Syn: *Amphora angustata* (Gregory) Cleve

Description: John, 1983, p. 156, pl. 64, fig. 7,8; pl. 65, fig. 1-10; pl. 66, fig. 1,2.

Hendey, 1951, p. 70, pl. 9, fig. 6; Hendey, 1964, p. 269, pl. 38, fig. 12; Foged, 1978, p. 34, pl. 38, fig. 9, 10; Laws, 1988, p. 154, pl. 27, fig. 9.

(As *Amphora angustata* (Gregory) Cleve): Brockmann, 1950, p. 23, pl. 4, fig. 18.

Dimensions: L: 25-80 µm. W: 6-14 µm. Str: 12-18 ITM.

Ecology: Epipsammic; epipelic; α–mesohalobous/polyhalobous. Polyhalobous; cosmopolitan." (Foged, 1978). Marine water, euryhaline (Brockmann, 1950).

Distribution: WB: Common in sandy lower intertidal samples of the open bay; rare in Holocene samples. (1988, p. 154): "Frequent and widespread in Recent sediments, especially from intertidal mud flats and salt marshes in central and southern San Francisco Bay." Cosmopolitan.

Remarks: Distinguished by the valve shape, straight ventral margin, axial area narrowing towards the apices, and the straight raphe branches. John (1983) reported variability in the shape of the valve and striae density in populations from different salinities. More saline forms, similar to the Willapa Bay specimens, tended to be more narrowly lanceolate in shape, with broad axial areas, and denser, more parallel striae.

AULACOSEIRA Thwaites 1848

*Aulacoseira ambigua* (Grunow) Simonsen 1979

Syn: *Melosira ambigua* (Grunow) Müller 1903

Description: Hustedt, 1927-66, I, p. 256, fig. 108 (as *Melosira ambigua*).

Foged 1981, p. 104, pl. 1, fig. 12; Laws, 1988, p. 154, pl. 1, fig. 8.

Dimensions: Diam: 4-15 µm. Pervalvar axis: 3.5-13 µm.

Ecology: Planktonic. Oligohalobous (indifferent); alkaliphilous (Foged, 1978).

Distribution: WB: The *A. granulata* group includes the combined occurrences of the cosmopolitan oligohalobous (indifferent) species *A. ambigua*, *A. granulata*, *A. islandica*, and *A. italica* in Willapa Bay sediments. The group is rare in modern oligohalobous and mesohalobous

channel-bank deposits, but can be concentrated in Holocene deposits because of the robust valves (especially *A. granulata*).

Remarks: Cells are separated by a distinctive sulcus.

*Aulacoseira granulata* (Ralfs) Simonsen 1979

Syn: *Melosira granulata* (Ehrenberg) Ralfs in Pritchard 1861

Description: Hustedt, 1927-66, I, p. 248, fig. 104 (as *Melosira granulata*)

Schrader, 1974, p. 862, pl. 2, fig. 8; Foged 1981, p. 104, pl. 1, fig. 3,4,7; Laws, 1988, p. 154, pl. 1, fig. 11-15.

Dimensions: Diam: 5-21 µm. Pervalvar axis: 5-18 µm

Ecology: Planktonic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: See *A. ambigua*.

Remarks: Striae often coarse, in parallel lines; valve joined with strong interlocking spines, several as long as the apical axis of the valve.

*Aulacoseira islandica* (Müller) Simonsen 1979

(Plate 1, Figure 6)

Syn: *Melosira islandica* Müller 1906

Description: Hustedt, 1927-66, I, p. 252, fig. 106 (as *Melosira islandica*)

Foged 1981, p. 105, pl. 1, fig. 11.

Dimensions: Diam: 7-27 µm. Pervalvar axis: 4-21 µm.

Ecology: Planktonic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: See *A. ambigua*.

Remarks: Striae delicate, in parallel lines.

*Aulacoseira italica* (Kützing) Simonsen 1979

Syn: *Melosira italica* (Ehrenberg) Kützing 1844

Description: Hustedt, 1927-66, I, p. 257, fig. 109 (as *Melosira italica*).

Foged 1981, p. 105, pl. 1, fig. 8.

Dimensions: Diam: 5-28 µm. Pervalvar axis: 8-21 µm.

Ecology: Planktonic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: See *A. ambigua.*

Remarks: Distinguished by striae that bend around the valve, and short interlocking spines between the valves.

BACILLARIA Gmelin 1791

*Bacillaria paxillifer* (O.F. Müller) Hendey 1951

Syn: *Bacillaria paradoxa* Gmelin 1791

Description: Hendey, 1964, p. 274, pl. 21, fig. 5.

Hustedt, 1930, p. 396, fig. 755; Germain, 1981, p. 326, pl. 123, fig. 1-2; John, 1983, p. 163, pl. 68, fig. 4-5; Jensen, 1985, p. 849, fig. 755.

Dimensions: L: 70-100 µm. W: 4-5 µm. Str: 20-24 ITM.

Ecology: Epiphyte; epipelic. Mesohalobous to Polyhalobous. Strongly euryhaline (Hendey, 1964).

Distribution: WB: Common in mesohalobous channel-bank deposits and low-marsh samples; rarely observed in fossil samples. Hendey (1964, p. 274): "Common on all coasts bordering the North Sea and English Channel. Sometimes in the plankton." Cosmopolitan.

Remarks: The valve is distinctive with its produced apices, centered keel, and strong squarish keel puncta (7-9 in 10 µm). Common in modern sediments in Willapa Bay, but fractures easily (like *Synedra fasciculata*) and thus is rare in fossil deposits.

BERKELEYA Greville 1827

*Berkeleya rutilans* (Trentepohl) Grunow 1880

Syn: *Amphipleura rutilans* (Trentepohl) Cleve 1894

Description: (As *Amphipleura rutilans*): Patrick and Reimer, 1966, p. 304, pl. 21, fig. 3 (As *A. rutilans*): Hustedt, 1927-66, II, p. 720, fig. 1093; Brockmannnn, 1950, p. 14, pl. 2, fig. 4,5; Rao and Lewin, 1976, p. 193, fig. 204,205; John, 1983, p. 105, pl. 44, fig. 1,2; Jensen, 1985, p. 602, fig. 1093; Krammer and Lange-Bertalot, 1986, p. 264, pl. 98, fig. 9-11; Laws, 1988, p. 154, pl. 19, fig. 4,7.

Dimensions: L: 15-35 µm. W: 4-6 µm. Str: 24-28 ITM at the middle, 30 ITM at the ends.

Ecology: Epiphytic; epilithic. Mesohalobous; euryhaline (Brockmannnn, 1950). Hendey (1964, p. 240): "Common and widespread on the coasts of all North Sea countries and English Channel. The colonies attach themselves to any solid substratum such as rocks or marine installations, or the larger algae. Seldom found in deep water, as the cells require plenty of light."

Distribution: WB: Observed in only a few Holocene samples; modern distribution not recorded. Not reported from Ledbetter Point by Tynni (1986). Common in benthic and epiphytic samples in Netarts Bay (Whiting, 1983), and benthic samples in San Francisco Bay (Laws, 1988). Cosmopolitan.

Remarks: Distinguished by the short raphe branches, and the parallel striae. Cannot be included in *Amphipleura* because of the asymmetrical raphe sternum, and the morphology of the striae poroids (Cox, 1975a,b; Round et al., 1990).

BIDDULPHIA Gray 1821

*Biddulphia dubia* (Brightwell) Cleve 1883

Syn: *Triceratium dubia* Brightwell 1859

Description: Cupp, 1943, p. 164, fig. 114.

(As Triceratium dubia): Hustedt, 1927-66, I, p. 806, fig. 469; Riznyk, 1973, p. 135, pl. 4, fig. 1; Laws, 1988, p. 177, pl. 14, fig. 8.

(As *Biddulphia reticulata* var. *rhombica* ): Tynni, 1986, p. 16, pl. 11, fig. 48,49.

Dimensions: L: 42-65 µm. W: 30-44 µm. Areolae: 2-2.5 ITM.

Ecology: Benthic; tychopelagic(?). Mesohalobous/polyhalobous.

Distribution: WB: Rare valves observed at Toke Point, near the mouth of Willapa Bay; rare in sandy Holocene samples. Recorded at Ledbetter Point by Tynni (1986).

Remarks: Reported by Cupp (1943, p. 165) - and later referenced by Tynni (1986) and Laws (1988) - as a "warm-water species, subtropical to tropical." It's occurrence in Washington and Oregon do not agree with this ecological designation.

BIREMIS Mann and Cox in Round et al. 1990

*Biremis ambiqua* (Cleve) Mann in Round et al. 1990

Syn: Pinnularia *ambigua* Cleve 1895

Description: Hendey, 1964, p. 233, pl. 34, fig. 5-8.

Brockmann, 1950, p. 20, pl. 1, fig. 7, pl. 3, fig. 21, pl. 4, fig. 19; John, 1983, p. 123, pl. 53, fig. 1; Round et al., 1990, p. 548 (typification of the genus).

Dimensions: L: 35-75. W: 8-10 µm. Str: 13-14 ITM.

Ecology: Epipelic. Euryhaline (Hendey, 1964)

Distribution: WB: Observed on the marsh-edge tidal flat at Stony Point. Hendey (1964, p. 233): "Littoral and euryhaline... on sandy foreshores." Cosmopolitan.

Remarks: Both Brockmann 91950) and Hendey (1964) remarked that "*Pinnularia ambigua*" was in need of revision because of it's asymmetrical valve form and affinities for some species of *Amphora*. It is the type species of the genus *Biremis* Mann and Cox 1990.

CALONEIS Cleve 1894

*Caloneis bacillum* (Grunow) Cleve 1894

Description: Patrick & Reimer, 1966, p. 586, pl. 54, fig. 7.

Germain, 1981, p. 238, pl. 87, fig. 1-28; John, 1983, p. 107, pl. 45, fig. 1-2; Krammer & Lange-Bertalot, 1986, p. 390, pl. 173, fig. 9-20; Laws, 1988, p. 155, pl. 22, fig. 6,11.

As *Pinnularia fasciata*: Hustedt, 1930, p. 316, fig. 569; Jensen, 1985, p. 722, fig. 569.

As *Stauroneis amphioxys* var. *obtusa*: Hendey, 1964, p. 220, pl. 43, fig. 7-9.

Dimensions: L: 15-45 µm. W: 4-9 µm. Str: (22) 24-30 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Patrick and Reimer (1966, p. 586): "Soft, hard, or slightly brackish water; lakes, rivers, bogs. Often found in standing alkaline waters." Pankow (1976): "Oligohalobous, mesoeuryhaline, benthic, widely distributed in fresh waters."

Distribution: WB: Common in oligohalobous and mesohalobous middle and upper intertidal samples. Often observed associated with *Frustulia vulgaris*. Hendey (1964, p. 220): "Common in the Spartina zone around Poole Harbour." Hustedt (1930, in Jensen, 1985, p. 774): "Widely distributed and not rare in waters of all kinds in the entire area, yet, as a rule, always occurring isolated." Cosmopolitan.

Remarks: Hendey 's (1964, p. 220) description for *Stauroneis amphioxys* var. *obtusa* is equivalent, in terms of valve form and dimensions, to descriptions for *C. bacillum*. Although Hendey did not mention longitudinal lines crossing the valves, these are clearly figured (pl. 43, fig. 7-9). He records the habitat as "Common in the Spartina zone around Poole Harbour," which is comparable to some of the habitats that I have observed for *C. bacillum* along Willapa Bay. Therefore, *C. bacillum* may be more strongly euryhaline than previously reported. Further, Patrick and Reimer (1966, p. 586) noted that in some specimens the striae are more robust, with as few as 22 in 10 µm, but striae densities of 24-30 in 10 µm are more common for the species. I have

observed a general relationship between elevated salinities and specimens with fewer striae and more robust valves as compared to specimens from freshwater settings.

The linear-lanceolate valve shape, parallel to slightly radiate striae, and the straight-edged transverse fascia are distinguishing features.

*Caloneis liber* (W. Smith) Cleve 1894

Description: John, 1983, p. 107, pl. 35, fig. 3.

Hendey, 1951, p. 57, pl. 9, fig. 8; Hendey, 1964, p. 229, pl. 29, fig. 2; Patrick and Reimer, 1966, p. 582, p. 53, fig. 9.

Dimensions: L: 60-70 µm. B: 15-16 µm. Str: 20-24 in 10 µm.

Ecology: Epipelic. Mesohalobous/polyhalobous.

Distribution: WB: Observed in Holocene sediments with common *C. westii*; modern distribution not recorded. Hendey (1964, p. 229): "Frequent on sandy shores. Common on most British coasts."

Remarks: Distinguished by the asymmetric central area and the two longitudinal lines for each half of the valve. Resembles the oligohalobous species *C. alpestris*.

*Caloneis westii* (Wm. Smith) Hendey 1964

(Plate 1, Figure 7)

Syn: *Navicula westii* W. Smith 1853; *Navicula formosa* Gregory 1856; *Caloneis formosa* (Gregory) Cleve 1894; *Caloneis liburnica* Grunow in Van Heurck 1880; *Caloneis oregonica* (Ehrenberg) Patrick 1966

Description: Hendey, 1964, p. 230, pl. 44, fig. 5-10; pl. 45, fig. 1-13.

Riznyk, 1973, p. 118, pl. 4, fig. 6; Krammer & Lange-Bertalot, 1986, p. 386, pl. 170, fig. 1-2; Laws, 1988, p. 155, pl. 22, fig. 4-5, 9.

(As *Caloneis formosa* (Gregory) Cleve 1894): Hustedt, 1930, *in* Jensen, 1985, p. 770, fig. 350; Hendey, 1951, p. 57, pl. 17, fig. 13.

(As *Caloneis oregonica* (Ehrenberg) Patrick 1966): Patrick and Reimer, 1966, p. 581, pl. 53, fig. 6.

Dimensions: L: 60-130 µm. W: 20-28 µm. Str: 12-14 ITM.

Ecology: Epipelic. Mesohalobous, euryhaline (Pankow, 1976). Hendey (1964, p. 231): "A brackish water form frequently found in the littoral zone; common on all coasts of the North Sea, English Channel."

Distribution: WB: Live cells common in *Triglochin /Salicornia* low-marsh sites along the edge of Willapa Bay; observed less frequently on marsh-edge tidal flats of the open bay and on the barren channel bank of the lower Niawiakum River (salinity range 10-28‰). Common in Holocene samples. Very rare in tidal flat sediments Yaquina estuary (Riznyk, 1973) and Netarts Bay (Whiting, 1983). Laws (1988, p. 155): "Common in Sangamon sediments and intertidal mud flats and salt marshes of the present (San Francisco) bay." Cosmopolitan.

Remarks: *C. westii* is a common estuarine species, epipelic on fine-grained sediment. I did not record it from sandy open tidal flat samples of Willapa Bay, and both Riznyk (1973) and Whiting (1983) observed only a few valves in their studies of tidal flat samples in Yaquina Bay and Netarts Bay, respectively. Its preference for fine-grained substrate is implied by Foged (1981, p. 29) who observed *C. westii* in only one sample with this description: "Small inlet in the east side of the southern part of Wainwright Inlet. Clay everywhere. No. 396: Scrapings from clayey ground." Its distribution in low salt marsh samples from the margin of Willapa Bay may be a response to the accumulation of fine silt inbetween marsh plants. It was also observed in low (*Spartina*) salt marshes habitats in Delaware and Mississippi (Sullivan, 1975; 1978), and in a low (*Salicornia*) marsh in Cheshire, England (Round, 1960). Round (1960. p. 113) suggests that *C. westii* may also be one of the group of diatoms "unexpected in the epiphytic habitat." In Holocene deposits around Willapa Bay, *C. westii* often occurs with *Scolipleura tumida* and *Nitzschia granulata.* Laws

(1988, p. 155) reported that in San Francisco Bay *C. westii* "is commonly found in association with *Nitzschia granulata* in Recent and Sangamon sediments."

CAMPLYODISCUS Ehrenberg 1840

*Camplyodiscus echeneis* Ehrenberg 1840

Description: Krammer and Lange-Bertalot, 1988, p. 213, pl. 175, fig. 1,2; pl. 176, fig. 1-3. Hustedt, 1930, p. 449, fig. 875; Hendey, 1951, p. 78, pl. 17, fig. 1-6; Hendey, 1964, p. 291, pl. 40, fig. 14; Riznyk, 1973, p. 118, pl. 4, fig. 5; Jensen, 1985, p. 900, fig. 875; Laws, 1988, p. 155, pl. 35, fig. 1,2.

Dimensions: Diam: 80-200 µm. Puncta: 2-4 ITM.

Ecology: Epipelic. Foged (1978, p. 40): "Mesohalobous, euryhaline. The northern temperate zone."

Distribution: WB: Rare in modern mesohalobous lower intertidal samples; common in Holocene samples. Hendey (1964, p. 291): "A marine and brackish-water species common in all European countries. Frequent on all British shores, but seldom abundant."

Remarks: Distinguished by the large, saddle-shaped valve lines of coarse puncta, irregular in length, that more or less radiate from the center of the valve.

CATENULA Mereschkowsky 1903

*Catenula adhaerens* Mereschkowsky 1903

Description: Hendey, 1964, p. 157.

Brockmann, 1950, p. 22, pl. 1, fig. 9; Tynni, 1986, p. 17, pl. 27, fig. 163.

Dimensions: L: 13-16 µm. W: 2.8-3.3 µm.

Ecology: Epipsammic. α–mesohalobous/polyhalobous.

Distribution: WB: Distributed on tidal flats of the open bay; rare in Holocene samples.

Remarks: Distinguished by the small asymmetrical valve, slightly indented on the dorsal margin, and the thickened central and polar raphe endings which stand out in LM.

CERATAULUS Ehrenberg 1843

*Cerataulus turgidus* (Ehrenberg) Ehrenberg 1843

Description: John, 1983, p. 31, pl. 11, fig. 6,7.

Hustedt, 1927-66, I, p. 860, fig. 512; Hendey, 1964, p. 106, pl. 20, fig. 4; Riznyk, 1973, p. 118, pl. 5, fig. 1; Laws, 1988, p. 156, pl. 14, fig. 10.

Dimensions: Diam: 45-77 µm. Pervalvar axis: 52-100 µm. Areolae: 9-11 ITM.

Ecology: Epipsammic; tychoplanktonic. α–mesohalobous/polyhalobous. Attaches to sand grains by means of mucilage extruded through the ocelli (Round et al., 1990). Hendey (1964, p. 106): "A common littoral species, on all coasts of North Sea, English Channel."

Distribution: WB: Rare to common in Holocene samples. Common in Yaquina estuary (Riznyk, 1973), rare in Netarts Bay (Whiting, 1983).

Remarks: Distinguished by the radiating areolae and scattered spines on the valve surface, and especially by the conspicuous rounded ocelli on opposite sides of the valve.

COCCONEIS Ehrenberg 1837

*Cocconeis diminuta* Pantocksek 1902

(Plate 1, Figure 8)

Description: Hustedt, 1927-1966, II, p. 346, fig. 800.

Foged, 1981, p. 61, pl. 13, fig. 11; Jensen, 1985, p. 306, fig. 800; Laws, 1988, p. 156, pl. 18, fig. 10-12; Pankow, 1990, p. 166, pl. 34, fig. 20-21.

Dimensions: L: 7-15 µm. W: 5-9 µm. Str: 32 ITM (RV; 13 ITM (RLV).

Ecology: Epipsammic. Oligohalobous (indifferent); alkaliphilous (Foged 1981, p. 61). Whiting (1983, p. 131, Appendix table 1): present in mesohalobous benthic samples from Netarts Bay, absent from epiphyte (*Zostera*) samples.

Distribution: WB: Observed most frequently in sandy intertidal sediments; often observed attached to sand grains with *Achnanthes delicatula*. Less frequent on silty tidal flats and channel banks. Cosmopolitan.

Remarks: As noted by Patrick and Reimer (1966, p. 239), *C. diminuta* may be confused with *C. disculus*, but differs from its smaller size, and 12-14 striae in 10 µm on the rapheless valve as compared with nine or fewer for *C. disculus*. Maximum length observed in WB samples was 11 µm. *C. diminuta*, as reported by Hustedt (1927-66), is a freshwater species found in lakes. The diatoms reported here is clearly associated with sandy mesohalobous deposits, but also matches descriptions of *C. diminuta* (Hustedt, 1927-66; Pankow, 1990).

*Cocconeis disculus* (Schumann) Cleve 1895

Description: Patrick and Reimer, 1966, p. 239, pl. 15, fig. 1-2.

Hustedt, 1930-59, II, p.346, fig. 799; Germain, 1981, p. 104, pl. 39, fig. 11-13; Jensen, 1985, p. 305, fig. 799; Hendey, 1964, p. 178, pl. 28, fig. 19; John, 1983, p. 77, pl. 33, fig. 10-11.

Dimensions: L: 20-25 µm. W: 11-16. Str: 22 ITM (RV); 7-9 ITM (RLV).

Ecology: Epipsammic; epipelic. Mesohalobous; benthic. Hendey (1964, p. 178): "Frequent in brackish waters on all European coasts..." Whiting (1983, p. 131, Appendix table 1): present in mesohalobous benthic samples, absent from epiphyte (*Zostera*) samples.

Distribution: WB: A few empty valves observed in tidal flat samples; rare in Holocene sediments.

Remarks: Striae are robust, 7-9 in 10 µm. Size range usually 20-30 µm, though John (1983, p. 77) reports 9-32 µm.

*Cocconeis placentula* Ehrenberg 1838

Description: Patrick and Reimer, 1966, p. 240, pl. 15, fig. 5,6.

Hustedt, 1927-66, II, p. 347, fig. 802a,b; Foged, 1978, p. 42, pl. 13, fig. 7-9; Foged, 1981, p. 61, pl. 13, fig. 13,14; John, 1983, p. 79, pl. 34, fig. 11,12; pl. 35, fig. 1; Jensen, 1985, p. 306, fig. 802a,b; Laws, 1988, p. 157, pl. 18, fig. 5,6.

Dimensions: L: 8-28 µm. W: 4.5-15 µm. Str: 16-18 in 10 µm (RV); 19-20 in 10 µm (RLV).

Ecology: Epiphytic; epipsammic. Oligohalobous (indifferent), alkaliphilous, (Foged, 1981). John (1983, p. 80): "A common epiphytic diatom..." Cosmopolitan.

Distribution: WB: Rare in oligohalobous and mesohalobous lower and middle intertidal samples.

Remarks: Striae on the rapheless valve about 25 in 10 µm, interrupted by many delicate wavy longitudinal hyaline lines.

*Cocconeis placentula* var. *euglypta* (Ehrenberg) Cleve 1895

Description: Patrick & Reimer, 1966, p. 241, pl. 15, fig. 8.

Hustedt, 1927-66, II, p. 347, fig. 802c; Foged, 1978, p. 42, pl. 13, fig. 9; John, 1983, p. 79, pl. 35, fig. 2-3; Jensen, 1985, p. 306, fig. 802c.

Dimensions: L: 10-50 µM. W: 8-30 µM. STR: 19-23 ITM (RV); 19-20 ITM (RLV).

Ecology: Epiphytic; epipsammic. Oligohalobous (indifferent), alkaliphilous (Foged, 1981).

Distribution: WB: Observed in sandy oligohalobous and β–mesohalobous intertidal deposits; more frequent in channel bank than low-marsh samples. Cosmopolitan.

Remarks: The raphe valve is virtually indistinguishable from *C. placentula* ; the rapheless valve differs in the striae interrupted by four or five strong longitudinal hyaline lines.

*Cocconeis scutellum* Ehrenberg 1838

(Plate 2, Figure 1,2)

Description: John, 1983, p. 82, pl. 36, fig. 2-4.

Hustedt, 1927-66, II, p. 337, fig. 790; Hendey, 1964, p. 180, pl. 27, fig. 8; Foged, 1978, p. 42, pl. 13, fig. 4; pl. 14, fig. 10; Jensen, 1985, p. 298, fig. 790.

Dimensions: L: 10-40 µm. W: 7-29 µm. Str: 12-14 in 10 µm (RV); 11-12 in 10 µm (RLV).

Ecology: Epiphyte; α–mesohalobous/polyhalobous. Polyhalobous (Foged, 1981). Main and McIntire, 1974, p. 94: "...*Cocconeis scutellum* was primarily associated with *Zostera*, a host that is exposed to little or no desiccation." Common in intertidal benthic samples in Netarts Bay, a dominant epiphyte on *Zostera marina* (Whiting 1983, p. 131, Appendix table 1).

Distribution: WB: Common in silty intertidal sediments with salinities > 10‰, particularly where *Zostera* is present. Hendey (1964, p. 180): "Ubiquitous, common on coasts all over the world."

Remarks: Raphe valve distinguished by a small orbicular central area, and a loculiferous rim and hyaline area at the margin. May be confused with smaller valves of *C. maxima*. Striae on rapheless valve are composed on single rows of puncta that give rise to 3 rows of smaller puncta near the margin.

*Cocconeis scutellum* var. *parva* Grunow ex Cleve 1895

(Plate 2, Figure 3,4)

Description: John, 1983, p. 82, pl. 36, fig. 5,6.

Hustedt, 1927-66, II, p. 338, fig. 791; Foged, 1978, p. 42, pl. 14, fig. 11; Jensen, 1985, p. 300, fig. 791.

Dimensions: L: 10-30 µm. W: 7-10 µm. Str: 11-14 ITM (RLV).

Ecology: Epiphyte; α–mesohalobous/polyhalobous; . Whiting (1983, p. 131, Appendix table 1): Common epiphyte on *Zostera*, present in intertidal benthic samples. Main and McIntire (1974, p. 94): Observed attached to macrophytes throughout the intertidal zone.

Distribution: WB: Equally frequent as *C scutellum* in silty intertidal samples, but more frequent in sand flat samples. Hendey (1964, p. 180): "Common on all coasts of the British Isles; often found with the type."

Remarks: Differs from the nominate variety by the smaller overall size: Length less than 20 µm, breadth less than 7 µm.

COSCINODISCUS Ehrenberg 1838

*Coscinodiscus radiatus* Ehrenberg 1841

Syn: *Coscinodiscus devius* Schmidt

Description: Cupp, 1943, p. 56, fig. 20, pl. 1, fig. 4.

Hustedt, 1927-66, I, p. 420, fig. 225; Hendey, 1964, p. 76, pl. 22, fig. 7; Riznyk, 1973, p. 17, pl. 7, fig. 1; Rao and Lewing, 1976, p. 177, fig. 37; Sancetta, 1987, p. 234, pl. 2, fig. 1-10; Laws, 1988, p. 158, pl. 5, fig. 7, pl. 6, fig. 2-4.

(As *C. devius*): John, 1983, p. 25, pl. 8, fig. 1-6.

Dimensions: Diam: 35-60 µm. Areolae: 3-4 ITM across most of the valve; 6-7 ITM at the margin.

Ecology: Planktonic (tychoplanktonic?). Euryhalobous (Pankow, 1976).

Distribution: WB: Very rare in modern mesohalobous channel bank deposits; rare in Holocene sediments. Riznyk (1973, p. 17): "Found infrequently in the sediment filtered out of phytoplankton." Cosmopolitan.

Remarks: Sancetta (1987, p. 235) reported that *C. radiatus* is variable in the overall shape of the areolae, occurrence of a hyaline central area, and the number and orientation pores (external openings of labiate processes) on the valve face. The most common form of *C. radiatus* observed in Willapa Bay samples matches the description for "*C. obscurus* Schmidt 1878".

*Coscinodiscus radiatus* Ehrenberg f. *obscurus*

(Plate 2, Figure 5)

Description (As *Coscinodiscus obscurus*): Hustedt, 1931-66, II, p. 418, fig. 224.

Laws, 1988, p. 157, pl. 5, fig. 6, 8-9; pl. 6, fig. 1.

Dimensions: Diam: 40-80 µm.

Ecology: Planktonic (tychoplanktonic?); polyhalobous. Cosmopolitan.

Distribution: WB: Very rare in modern mesohalobous channel bank deposits; rare to common in Holocene sediments.

Remarks: Sancetta (1987, p. 235) showed that Schmidt's (1878) definition of "*C. obscurus*", based on the distributions of small pores (external openings of labiate processes) at the ends of shorter rows of areolae on the valve face, was not a valid reason for separating the taxon from *C. radiatus*. I separate a form of *C. radiatus* from the species *sensu stricto* because of its common occurrence in Holocene deposits, and its apparent association with silty sediments of open tidal flats in the bay. The form *obscurus* is heavily silicified, with a hyaline central area and isolated pores at the ends of shorter rows of areolae. Willapa Bay specimens are very similar to those figured by John (1983, pl. 8, fig. 1 and 6) as *C. devius* Schmidt. The robust valve may be the reason for its concentration in some Holocene samples.

CYCLOTELLA Kützing 1833

*Cyclotella compta* (Ehrenberg) Kützing 1849

Description: Hustedt, 1927-66, I, p. 354, fig. 183.

Schrader, 1974, p. 860, pl. 4, fig. 10; pl. 14, fig. 5; Germain, 1981, p. 32, pl. 8, fig. 1-7; Laws, 1988, p. 158, pl. 3, fig. 3; pl. 7, fig. 7.

Dimensions: Diam: 15-50 µm.

Ecology: Planktonic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Schrader (1974, p. 860): "Planktonic, common in European lakes and rivers, oligohalobous meioeuryhaline (Pankow, 1976), common in oligotrophic to mesotrophic lakes (Stoermer and Yang, 1970)."

Distribution: WB: Rare in Recent and Holocene samples. Cosmopolitan.

Remarks: Distinguished by the more or less coarse puncta in radiating rows in the center, and the concentrically-undulate valve.

*Cyclotella ocellata* Pantocksek 1912

(Plate 2, Figure 6)

Description: Hustedt, 1927-66, I, p. 340, fig. 173.

Schrader, 1974, p. 861, pl. 14, fig. 7; Germain, 1981, p. 34, pl. 8, fig. 8-13; Foged, 1981, p. 64, pl. 2, fig. 9.

Dimensions: Diam: 6-20 µm.

Ecology: Planktonic; meroplanktonic(?). Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Schrader (1974, p. 861): "Freshwater benthic and planktonic, oligo- to mesotrophic (in Great Lakes it appears to occupy the extreme oligotrophic end of the spectrum, Stoermer and Yang, 1970)."

Distribution: WB: Rare in Recent and Holocene samples.

Remarks: Distinguished by the hyaline central area, approximately one-half the diameter of the valve, furnished with several large puncta nearly evenly spaced from one another.

*Cyclotella striata* (Kütz.) Grunow 1880

(Plate 2, Figure 7)

Description: Hustedt, 1927-66, p. 344, fig. 176a,b.

Foged, 1978, p. 45, pl. 2, fig. 6-8; 1979, p. 36, pl. 3, fig. 7; John, 1983, p. 21, pl. 5, fig. 10-12; Laws, 1988, p. 158, pl. 3, fig. 4,6; pl. 7, fig. 5,6.

Dimensions: Diam: 10-50 µm.

Ecology: Planktonic. Meroplanktonic (Laws, 1988). Mesohalobous, alkaliphilous (Foged, 1979). Hendey (1964, p. 74): "A common marine and brackish-water species, often abundant in estuaries in the spring plankton."

Distribution: WB: Rare to common in Holocene samples. Cosmopolitan.

Remarks: The valve is strongly undulate, and divided at about half-radius into a coarsely punctate central area and a strongly striate marginal zone.

CYMATOSIRA Grunow 1862

*Cymatosira belgica* Grunow *ex* Van Heurck 1862

Description: Hendey, 1964, p. 160.

Hustedt, 1927-66, II, p. 127, fig. 649; Jensen, 1985, p. 121, fig. 649; Laws, 1988, p. 158, pl. 15, fig. 7-9, 13.

Dimensions: L: 12-30 µm. W: 3-5 µm.

Ecology: Epipsammic; tychopelagic. Polyhalobous.

Distribution: WB: Rare; only observed in sand flat samples. Hendey (1964, p. 160) :"Common littoral species on all North European coasts, British Isles, mostly on clean sandy beaches."

Remarks: Best distinguished in girdle view by the inflated middle and apices, and the distinct marginal spines. In valve view the irregularly-arranged puncta and the irregularly-shaped central area are distinctive.

CYMBELLA Agardh 1830

*Cymbella aspera* (Ehrenberg) H. Peragallo in Pelletan 1889

Description: Patrick & Reimer, 1975, p. 53, pl. 10, fig. 8.

Hustedt, 1930, p. 365, fig. 680; Foged, 1978, p. 46, pl. 38, fig. 8; 1979, p. 37, pl. 35, fig. 14; 1981, p. 65, pl. 47, fig. 4; John, 1983, p. 145, pl. 60, fig. 7; Jensen, 1985, p. 818, fig. 680; Krammer and Lange-Bertalot, 1986, p. 319, pl. 131, fig. 1.

Dimensions: L: 70-200 µm. W: 20-30 µm. Str: 7-10 ITM near the middle, 11-12 ITM near the ends. Puncta: 11-15 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Patrick and Reimer (1975, p. 54): "Not usually found in large numbers. Often reported from seeps and springs, but also found in streams and lakes in shallower water. Oligohalobe; alkaliphil."

Distribution: WB: Rare in oligohalobous/β–mesohalobous lower intertidal samples; usually rare but sometimes common in Holocene samples, presumably because of the robust valve.

Remarks: Reworked valves are often broken, with the thickened central nodule remaining intact.

*Cymbella minuta* Hilse in Rabenhorst 1862

Syn: *Cymbella ventricosa* Kützing 1844; *Encyonema minutum* (Hilse in Rabenhorst) Mann *in* Round et al., 1990

Description: Patrick and Reimer, 1975, p. 47, pl. 8, fig. 1a-4b.

John , 1983, p. 145, pl. 60, fig. 8-9; Krammer and Lange-Bertalot, 1986, p. 305, pl. 119, fig. 1-13; Laws, 1988, p. 159, pl. 27, fig. 14.

(As *Cymbella ventricosa*): Hustedt, 1930, p. 359, fig. 661; Riznyk, 1973, p. 121, pl. 7, fig. 3; Foged, 1978, p. 50, pl. 37, fig. 6-8; 1979, p. 42, pl. 34, fig. 11,12; Germain, 1981, p. 292, pl. 107, fig. 11-22; Jensen, 1985, p. 811, fig. 661.

Dimensions: L: 9-28 µm. W: 4.5-6µm. Str: 14-16 ITM near the center, 18-19 ITM near the apices.

Ecology: Epipelic. Periphytic (Lowe, 1974). Oligohalobous (indifferent); circumneutral pH (Foged, 1979).

Distribution: WB: Common in β–mesohalobous and oligohalobous samples from the Willapa and South Fork Willapa rivers; rare in Holocene samples. Cosmopolitan.

Remarks: Best distinguished by the small, strongly dorsi-ventral valve, with the raphe and narrow axial area lying near and parallel to the straight ventral margin.

*Cymbella tumida* (Brébisson) Van Heurck 1880

(Plate 2, Figure 8)

Description: Patrick and Reimer, 1975, p. 58, pl. 10, fig. 8.

Hustedt, 1930, p. 366, fig. 677; Foged, 1978, p. 49, pl. 37, fig. 2,3; Germain, 1981, p. 288, pl. 106, fig. 1-2; Jensen, 1985, p. 818, fig. 677; Krammer & Lange-Bertalot, 1986, p. 318, pl. 130, fig. 4-6.

Dimensions: L: 35-80µm W: 12-18 µm Str: 8-10 ITM near the center, 12-13 ITM near the ends. Puncta: 16-20 ITM.

Ecology: Epipelic. Periphytic (*in* Lowe, 1974). Oligohalobous (indifferent); circumneutral pH (Foged, 1978). Alkaliphilous (Patrick and Reimer, 1975).

Distribution: WB: Common in β–mesohalobous channel-bank and marsh samples from the Willapa River; rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the arched dorsi-ventral valve, usually with large rostrate apices. The central area is orbicular, distinctive, with a single stigma opening on its ventral side.

DELPHINEIS Andrews 1977

*Delphineis surirella* (Ehrenberg) Andrews 1981

Syn: *Rhaphoneis surirella* (Ehrenberg) Grunow ex Van Heurck 1880

Description: Andrews, 1981, p. 83, pl. 1-2.

(As *Rhaphoneis surirella*): Hustedt, 1927-66, II, p. 174, fig. 679d; Hendey, 1964, p. 155, pl. 26, fig. 11-13; John, 1983, p. 54, pl. 21, fig. 8,9; Jensen, 1985, p. 162, fig. 679d.

Dimensions: L: 17-53 µm. W: 12-17 µm. Str: 7-10 ITM. Areolae: 7-8 ITM.

Ecology: Epipsammic; epiphytic. Mesohalobous/polyhalobous. Andrews (1981, p. 85): "...*D. surirella* has a common growth habit of short chains of frustules attached to the substrate in a shallow-marine environment." Hendey (1964, p. 155): "Common on sandy shores and mud and

sand flats; brackish and marine." Common in benthic samples and rare in epiphyte (*Zostera*) samples in Netarts Bay (Whiting, 1983). Epiphytic and epipelic in the lower Swan River estuary (John, 1983). Hustedt (1927-66, p. 174): "Distributed on all European coasts, also in harbors and river mouths with brackish water."

Distribution: WB: Common in mesohalobous lower intertidal samples; rare to common in Holocene samples. Cosmopolitan.

Remarks: The species as defined by Andrews (1981, p. 84) has a narrower stemum (axial area) that differs from "*Delphineis* cf. *surirella*" (discussed below) observed in Willapa Bay specimens: "The type variety has in the past been defined to include only specimens having a narrow axial area, whereas specimens having a relatively wide axial area have been assigned to *D. surirella* var. *australis* Petit. Although this distinction does not seem useful in this population, it may be valid elsewhere; hence I have not placed the variety *australis* into synonomy... however, *D. surirella* is broadly construed to include individuals that might be assigned to the variety."

*Delphineis* cf. *surirella*

(Plate 2, Figure 9)

Syn: *Rhaphoneis angustata* : Riznyk, 1973, p. 131, pl. 7, fig. 8,9.

Description: Valve elliptical, tapering toward the rounded apices. Striae normal to the margin along most of the length of the valve, and curved around the apices. The striae are composed of 3 areolae near the middle of the valve, but are reduced to 2 areolae near the apices. The central area is elliptical, about 1.6-2 µm wide. There is a small pore at each apex, located on opposite sides of the apical axis from the other.

Dimensions: L: 20-35 µm. W: 5-7 µm. Str: 10 ITM.

Ecology: Epipsammic (?); epiphytic (?). Mesohalobous/polyhalobous.

Distribution: WB: Usually observed with *D. surirella* in modern and fossil samples.

Remarks: Similar in some respects to the planktonic species *Delphineis karstenii*, as described by Fryxell and Miller (1978), but differs in the distinctive tapering of the valve at the apices. Differs from the Miocene species *Delphineis angustata* ((Andrews, 1977) by the finer striae and the consistent occurrence of 3 puncta per stria near the middle of the valve. Reported by Akiba (1985, p. 447, pl. 20, fig. 4-11) as "*Delphineis* cf. *angustata*."

DENTICULA Kützing 1844

*Denticula subtilis* Grunow 1862

(Plate 2, Figure 10)

Description: Patrick & Reimer, 1975, p. 172, pl. 22, fig. 10-11;

John, 1983, p. 159, pl. 67, fig. 1; Laws, 1988, p. 159, pl. 30, fig. 12, 13; Lange-Bertalot and Krammer, 1987, p. 66, pl. 42, fig. 12; Krammer and Lange-Bertalot, 1988, p. 140, pl. 96, fig. 1-9.

Dimensions: L: 8-20 µm. W: 2-3 µm. Str: 28-30 ITM. Costae: 6-9 ITM.

Ecology: Epipelic; aerophilous. Mesohalobous. Patrick and Reimer (1975, p. 172): "Brackish water of estuaries."

Distribution: WB: Common upper intertidal species, also at the upland-marsh transition along the Niawiakum River. Cosmopolitan.

Remarks: Distinguished by the small valve with distinct costae and tapered apices. Indicative of high brackish marshes.

DIATOMA Bory de St.-Vincent 1824

*Diatoma hiemale* var. *mesodon* (Ehrenberg) Grunow 1881

Description: Patrick & Reimer, 1966, p. 108, pl. 2, fig. 8.

Hustedt, 1927-66, II, p. 103, fig. 631e-h; Foged, 1977, p. 48, pl. 5, fig. 13; Foged, 1979, p. 43, pl. 7, fig. 3-6; Germain, 1981, p. 54, pl. 15, fig. 1-8; Jensen, 1985, p. 100, fig. 631e-h.

Dimensions: L: 12-40 µm. W: 6-15 µm. Str: 18-24 ITM. Costae: 2-4 ITM.

Ecology: Periphytic; epiphytic (?). Oligohalobous (indifferent); alkaliphilous (Foged, 1979). Prefers flowing water with high nutrient content (Patrick and Reimer, 1966, p. 108).

Distribution: WB: Rare in channel bank and marsh samples from the Willapa and South Fork Willapa Rivers. Cosmopolitan.

Remarks: Differs from the *Diatoma hiemale* by the wider, elliptical valves, and fewer costae.

DIMEREGRAMMA Ralfs in Pritchard 1861

*Dimeregramma minor* (Gregory) Ralfs in Pritchard 1861

(Plate 2, Figure 11,12)

Description: Hustedt, 1927-66, II, p. 118, fig. 640.

Hendey, 1964, p. 156, pl. 27, fig. 12; Riznyk, 1973, p. 17, pl. 7, fig. 6,7; Rao and Lewin, 1976, p. 183, fig. 66-70; John, 1983, p. 46, pl. 17, fig. 4,5 Jensen, 1985, p. 113, fig. 640; Laws, 1988, p. 160, pl. 15, fig. 15,16.

Dimensions: (Includes var. *nana*): L: 10-40 µm. W: 6-10 µm. Str: 9-14 ITM.

Ecology: Epiphytic, epipsammic. α–mesohalobous/polyhalobous. Rao and Lewin (1976, p. 183): "Occurred as epipsammon." Hendey (1964, p. 156): "This species is usually found epiphytic upon small red seaweeds during the summer months... A widely distributed littoral species, common on sandy beaches."

Distribution: WB: Common on sandy tidal flats, especially where *Zostera* is present. Rare in Holocene samples. Abundant in tidal flat samples of Yaquina estuary (Riznyk, 1973), rare in Netarts Bay (Whiting, 1983) and San Francisco estuary (Laws, 1988). Cosmopolitan.

Remarks: For this study, combined with var. *nana* (Gregory) Van Heurck, because of the coexistence of the different forms in the same environment, and the differentiation solely on size (note discussion by Hustedt, 1927-66, II, p. 119).

DIPLONEIS Ehrenberg ex Cleve 1894

*Diploneis didyma* (Ehrenberg) Ehrenberg 1854

(Plate 3, Figure 1)

Description: Patrick & Reimer, 1966, p. 417, pl. 38, fig. 14.

Hustedt, 1927-66, II, p. 685, fig. 1075a,b; Brockmann, 1950, p. 14, pl. 3, fig. 7, 9, 24; Hendey, 1964, p. 226, pl. 32, fig. 12; Foged, 1979, p. 44, pl. 21, fig. 7; John, 1983, p. 109, pl. 45, fig. 9; Jensen, 1985, p. 573, fig. 1075a,b; Krammer and Lange-Bertalot, 1986, p. 292, pl. 112, fig. 7.

Dimensions: L: 30-90 µm. W: 15-36 µm. Costae: 8-10 ITM.

Ecology: Epipelic. Mesohalobous; euryhaline (Foged, 1979).

Distribution: WB: Rare in mesohalobous lower intertidal samples, but also rare in mesohalobous upper intertidal marsh samples; very rare to rare in Holocene samples. Hendey (1964, p. 226): "Common and widespread on all British coasts and on all coasts of North Sea countries." Cosmopolitan.

Remarks: Distinguished by the blunt, panduriform valve, coarse costae crossed by several longitudinal lines.

*Diploneis interrupta* (Kützing) Cleve 1894

(Plate 3, Figure 2)

Description: Patrick and Reimer, 1966, p. 416, pl. 38, fig. 12.

Hustedt, 1927-66, II, p. 602, fig. 1019; Riznyk, 1973, p. 122, pl. 7, fig. 13; Foged, 1979, p. 44, pl. 21, fig. 3; Jensen, 1985, p. 508, fig. 1019; Krammer and Lange-Bertalot, 1986, p. 292, pl. 112, fig. 5,6; Laws, 1988, p. 160, pl. 23, fig. 1,2.

Dimensions: L: 29-80 μm. W: 7-15 μm at the center; 12-27 μm at the widest part. Costae: 8-12 ITM.

Ecology: Epipelic; aerophilous. Mesohalobous; alkaliphilous (Foged, 1979). Probably euryhaline.

Distribution: WB: Rare in middle intertidal mesohalobous samples from the Niawiakum River; associated with *Navicula pusilla* var. *lanceolate* in low-marsh and marsh drainage-channel samples. Common also in Holocene deposits. Reported by Brockmann as sometimes frequent in salt marshes and drainage channels. Not a true tidal flat species, but reported as rare in benthic samples in Netarts Bay (Whiting, 1983), and frequent in tidal flat samples from Yaquina estuary (Riznyk, 1973). Hendey (1964, p. 223): "Common on the sandy beaches of all countries bordering the North Sea, English Channel and Irish Sea."

Remarks: Distinguished by the indented middle, the strongly radiating costae that are absent from the center to produce a hyaline area along the margin at mid-valve. Superficially similar to *D. stroemi* in but with more lanceolate longitudinal canals, more strongly radiate costae, and better developed hyaline area along the central margin. Occurs with *D. stroemi* in some Holocene Willapa Bay samples.

The robust valves of *D. interrupta* are resistant to dissolution, and thus may dominate assemblages that are poorly preserved.

*Diploneis oblongella* (Naegeli in Kützing) Ross 1947

Syn: *Diploneis ovalis* var. *oblongella*

Description: Patrick and Reimer, 1966, p. 413, pl. 38, fig. 8.

Krammer & Lange-Bertalot, 1986, p. 287, pl. 108, fig. 7-10; Laws, 1988, p. 160, pl. 22, fig. 15, 16.

(As *D. ovalis* var. *oblongella*): Hustedt, 1957, p. 253; Hustedt, 1927-66, II, p. 672, fig. 1065f-k; Jensen, 1985, p. 563, fig. 1065f-k.

Dimensions: L: 10-100 µm. W: 6-35 µm. Costae, 10-19 ITM.

Ecology: Epipelic; aerophilous. Oligohalobous (indifferent), alkaliphilous (Foged, 1978). Patrick and Reimer (1966, p. 413): "Fresh to slightly brackish water; sometimes in damp places (aerophil)."

Distribution: WB: Rare in fossil deposits from the lower Niawiakum River. Observed in marsh samples from Ledbetter Point State Park (Hemphill-Haley, unpub. data). Cosmopolitan.

Remarks: Patrick and Reimer (1966, p. 413) warn that *D. oblongella* only differs from *D. ovalis* by its size. However, Hustedt (1927-66, II, p. 673) notes that *D. oblongella* is "distinguished by a specific range of variation, characterized by a smaller size in average cross-section, linear shape and closer structure," with costae number fairly constant at 18 in 10 µm.

Distinguishing features include the linear-elliptical shape with nearly parallel sides, and fairly delicate transverse costae with a single row of areolae between the costae.

*Diploneis ovalis* (Hilse) Cleve 1891

Description: Hustedt, 1927-66, II, p. 671, fig. 1065a-e.

Foged, 1978, p. 52, pl. 25, fig. 4; 1981, p. 80, pl. 14, fig. 5; Germain, 1981, p. 142, pl. 55, fig. 1-8; John, 1983, p. 110, pl. 45, fig. 10,11; pl. 46, fig. 1; Jensen, 1985, p. 562, fig. 1065a-e; Krammer and Lange-Bertalot, 1986, p. 286, pl. 108, fig. 14-16.

Dimensions: L: 20-100 µm. W: 10-35 µm. Costae: 10-19 (usually 13-16) ITM.

Ecology: Epipelic; aerophilous. Hustedt (1927-66, II, p. 672): "Widely distributed in fresh water and in slightly brackish waters of the interior. With predilection for places with springs as well as mossy marshes, it appears frequently, therefore, as an aerophil form." Brockmann (1950) reported it as euryhaline, common on mud flats, but I did not observe it on tidal flats in Willapa Bay, nor was it reported by Riznyk (1973) for Yaquina estuary or by Whiting (1983) for Netarts Bay.

Distribution: WB: Only a few valves observed in both modern and fossil samples. Cosmopolitan.

Remarks: Distinguished by a well-formed oval central area, and a single row of puncta between the transapical ribs.

*Diploneis pseudovalis* Hustedt 1930

(Plate 3, Figure 3)

Description: Patrick & Reimer, 1966, p. 412, pl. 38, fig. 5.

Hustedt, 1927-66, II, p. 668, fig. 1063c; Foged, 1981, p. 81, pl. 14, fig. 11; Jensen, 1985, p. 560, fig. 1063c; Krammer & Lange-Bertalot, 1986, p. 287, pl. 108, fig. 11-13.

Dimensions: L: 16-31 μm. W: 9-14 μm. Costae: 8-12 ITM.

Ecology: Epipelic; aerophilous. Mesohalobous, alkaliphilous (Foged, 1981). Patrick and Reimer (1966, p. 412): "In slightly to definitely brackish water."

Distribution: WB: Common to abundant in oligohalobous and mesohalobous marsh deposits above MHW; particularly frequent at transect T4 on the upper Niawiakum River (Figure 1). Very rare in Holocene samples.

Remarks: According to Patrick and Reimer (1966, p. 412), *D. pseudovalis* is similar to *D. subovalis*, which is generally larger, and also to *D. smithii* var. *pumilla*. Hustedt (1927-66, p. 669) notes that it is more delicate than varieties of *D. smithii*. Similar to both *D. subovalis* and *D. smithii*, there is a double row of areolae between the costae.

*Diploneis smithii* (Brébisson in Wm. Smith 1856) Cleve 1894

(Plate 3, Figure 4)

Description: Patrick and Reimer, 1966, p. 410, pl. 38, fig. 2

Hustedt, 1927-66, Kieselalg. II, p. 647, fig. 1051; Hendey, 1964, p. 225, pl. 32, fig. 10; Germain, 1981, p. 146, pl. 56, fig. 1-3; Jensen, 1985, p. 543, fig. 1051; Krammer and Lange-Bertalot, 1986, p. 291, pl. 112, fig. 2-4; Pankow, 1990, p. 186, pl. 41, fig. 8;

Dimensions: L: 25-200 µm. W: 15-75 µm. Costae: 5-12 ITM.

Ecology: Epipelic. Pankow (1990, p. 186): "Polyhalob, pleioeuryh" (i.e., salinities ~ 5- 35 ppt). Foged (1981, p. 81): "Polyhalobe. Cosmopolite." Patrick and Reimer (1966, p. 410): "In slightly brackish to brackish water."

Distribution: WB: Very rare in Holocene samples. Reported by Brockmann (1950, p. 14) as frequent on sand and mud flats; observed by Tynni (1986) on the tidal flat off Ledbetter Point. Reported from tidal flats in Yaquina estuary (Riznyk, 1973).

*Diploneis smithii* var. *rhombica* Mereschkowsky 1902

Description: John, 1983, p. 110, pl. 46, fig. 2,3.

Krammer and Lange-Bertalot, 1986, p. 291, pl. 112, fig. 3.

As *Diploneis smithii* forma *rhombica*: Hustedt, 1927-66, II, p. 647, fig. 1052a; Jensen, 1985, p. 544, fig. 1052a.

Dimensions: L: 25-63 µm. W: 17-32 µm. Costae: 6-7 ITM.

Ecology: Epipelic. Euryhaline. Foged (1978, p. 53): "Polyhalobous. Presumably cosmopolitan."

Distribution: WB: Rare in marsh samples from the β–mesohalobous Willapa River site (Figure 1); very rare to rare in Holocene samples. Brockmann (1950) reports it as frequent on sand and mud flats; however, it was not reported from tidal flats in Yaquina estuary (Riznyk, 1973) or Netarts Bay (Whiting, 1983). I have observed it as occurring frequently with *C. westii* in samples from Carex marshes of the Copper River Delta in the Gulf of Alaska (Hemphill-Haley, unpublished data). John

(1983) reports it as the most common species of *Diploneis* in β–mesohalobous salinities of the upper reaches of the Swan River estuary.

Remarks: Distinguished by robust valve, rhombic shape, and double row of coarse areolae between costae.

ENDICTYA Ehrenberg 1845

Endictya sp. 1

(Plate 3, Figure 5,6)

Description: Valve circular, with flat valve face and steep mantle. Areolae of equal size from the center to the margins, hexagonal, in tangential rows. Marginal areolae elongated, 6-7 in 10 µm. Mantle sharp, 7 µm high, with smaller areolae, 10-12 in 10 µm. Ornamentation on the mantle gives the margin of the valve a "scalloped appearance" in valve view . Short thick spines are sometimes visible on the margin.

Dimensions: Diam: 25-35 µm. Areolae: 5-6 ITM across the valve. Elongate marginal areolae: 6-7 ITM.

Ecology: Tychoplanktonic (?); probably polyhalobous.

Distribution: WB: Very rare in modern mesohalobous lower intertidal samples; rare to common in Holocene samples, probably in part because of the resistant valve.

Remarks: Reported by Schrader (1973, p. 705) and Tynni (1986, p. 18) as "*Endictya oceanica* Ehrenberg (1854). However, this taxon differs from *Endictya oceanica* Ehrenberg (1854) by the smaller valve size, and the smaller, equidimensional areolae in tangential rows across the valve. Reported also by Laws (1983, p. 174) as "*Stephanodiscus* (?) sp. 1." However, it differs from species of *Stephanopyxis* with dimorphic valves from the absence of any connecting spines or mucous pores.

EPITHEMIA Brébisson 1838

*Epithemia sorex* Kützing 1844

Description: Patrick & Reimer, 1975, p. 188, pl. 27, fig. 4.

Hustedt, 1930, p. 388, fig. 736; Riznyk, 1973, p. 122, pl. 8, fig. 1; Foged, 1978, p. 54, pl. 42, fig. 6; 1979, p. 45, pl. 38, fig. 2,6,10,11; 1981, p. 82, pl. 55, fig. 8, 12; Germain, 1981, p. 318, pl. 118, fig. 5,6; John, 1983, p. 161, pl. 67, fig. 7-8; Krammer & Lange-Bertalot, 1988, p. 154, pl. 106, fig. 1-14; Laws, 1988, p. 161, pl. 30, fig. 4.

Dimensions: L: 20-65 µm. W: 6-15 µm. Costae: 5-7 ITM, 2-3 striae inbetween costae.

Ecology: Epiphytic (?). Periphytic, aerophilous; euryhalobous (Lowe, 1974). Oligohalobous (indifferent); alkalibiontic (Foged, 1981) Hustedt (1930, p. 840): "Found in the littoral of standing water, very widely distributed and often in massive "bloom," as well as also in brackish water..."

Distribution: WB: Most frequent in β–mesohalobous channel bank and marsh samples from the Willapa River; very rare to rare in Holocene samples. Cosmopolitan.

Remarks: This species distinguished by relatively small size, capitate and dorsally arched apices, and the strongly dorsally-arched canal raphe.

*Epithemia turgida* (Ehrenberg) Kützing 1844

(Plate 3, Figure 7)

Description: Patrick & Reimer, 1975, p. 182, pl. 25, fig. 1a-1b.

Hustedt, 1930, p. 387, fig. 733; Riznyk, 1973, p. 122, pl. 8, fig. 2; Germain, 1981, p. 318, pl. 118, fig. 1-4; Foged, 1981, p. 82, pl. 55, fig. 10; Jensen, 1985, p. 839, fig. 733; John, 1988, p. 161, pl. 30, fig. 1; Krammer and Lange-Bertalot, 1988, p. 155, pl. 109, fig. 4-7.

Dimensions: L: 60-150 µm. W: 15-20 µm. Costae: 3-5 ITM, 2-3 striae between costae.

Ecology: Epipelic. Oligohalobous (indifferent); alkalibiontic (Foged, 1981). Periphytic, indifferent to salt, alkaliphilous to alkalibiontic (references in Lowe, 1974). Patrick and Reimer (1975, p. 182): "A littoral species which prefers alkaline water."

Distribution: WB: Very rare in mesohalobous lower intertidal samples; rare to common in Holocene samples. Reported as common in San Francisco estuary (Laws, 1988) and on the sandy substrate of the Southbeach tidal flat, in the lower part of Yaquina estuary (Riznyk, 1973). Cosmopolitan.

Remarks: *E. turgida* is common in fossil deposits, but its modern distribution in Willapa Bay has not been clearly documented. It may be indicative of tidal flat conditions.

*Epithemia turgida* var. *westermannii* (Ehrenberg) Grunow 1862

(Plate 3, Figure 8)

Description: Patrick and Reimer, 1975, p. 184, pl. 25, fig. 2a-b.

Foged, 1981, p. 82, pl. 55, fig. 3, 11; Laws, 1988, p. 161, pl. 30, fig. 2; Krammer and Lange-Bertalot, p. 156, pl. 109, fig. 1-3.

Dimensions: L: 40-120 µm W: 16-24 µm. Costae: 3-5 ITM, 2-3 striae inbetween costae.

Ecology: Epipelic. Oligohalobous (indifferent), alkalibiontic (Foged, 1981).

Distribution: WB: Observed with the species.

Remarks: Differs from *E. turgida* by the absence of produced apices, and a generally broader valve. Not as common as *E. turgida* in mesohalobous samples from Willapa Bay; may be less tolerant of elevated salinities.

EUNOTIA Ehrenberg 1837

*Eunotia pectinalis* Rabenhorst 1864

(Plate 4, Figure 1)

Description: Patrick and Reimer, 1966, p. 204, pl. 12, fig. 7.

Hustedt, 1927-66, II, p. 296, fig. 763a,k; Foged, 1978, p. 59, pl. 12, fig. 10; Foged, 1979, p. 49, pl. 9, fig. 15; pl. 11, fig. 5; Germain, 1981, p. 96, pl. 33, 34, 35, 36, 37; John, 1983, p. 67, pl. 28, fig. 10-12; Jensen, 1985, p. 267, fig. 763a,k.

Dimensions: L: 17-140 µm. W: 5-10 µm. Str: 7-12 ITM near the center of the valve, 14 ITM near the ends.

Ecology: Epiphytic. Periphytic; halophobous; acidophilous (Lowe, 1974). Halophobous; acidophilous (Foged, 1979).

Distribution: WB: Rare in β–mesohalobous and oligohalobous channel bank and marsh samples from the Willapa and South Fork Willapa rivers (Figure 1). Cosmopolitan.

Remarks: As noted by Patrick and Reimer (1966) and Foged (1978, 1979), this taxon can be quite variable in shape. Strongly indicative of oligohalobous conditions.

*Eunotia pectinalis* var. *minor* (Kützing) Rabenhorst 1864

Description: Patrick and Reimer, 1966, p. 207, pl. 12, fig. 13-14;

Hustedt, 1927-66, II, p. 296, figs. 763d-f; Foged, 1978, p. 59, pl. 11, fig. 13,15; Foged, 1979, p. 49, pl. 9, fig. 12; John, 1983, p. 68, pl. 28, fig. 13; Jensen, 1985, p. 268, figs 763d-f.

Dimensions: L: 20-60 µm. W: 4-7 µm. Str: 15-20 ITM.

Ecology: Epiphytic. Periphytic; aerophilous; halophobous, pH indifferent to acidophilous (Lowe, 1974).

Distribution: WB: Observed with the species. Cosmopolitan.

Remarks: Differs from the *E. pectinalis* by the smaller, more delicate valve, and the finer striae. Also indicative of oligohalobous conditions.

FRAGILARIA Lyngbye 1819

*Fragilaria brevistriata* Grunow in Van Heurck 1885

Syn: *Pseudostaurosira brevistriata* (Grunow) Williams and Round 1987

Description: Patrick & Reimer, 1966, p. 128, pl. 4, fig. 14.

Hustedt, 1927-66, II, p. 168, fig. 676a-e; Foged, 1979, p. 52, pl. 7, fig. 24,25; Foged, 1981, p. 91, pl. 4, fig. 13; pl. 5, fig. 4; Germain, 1981, p. 68, pl. 20, fig. 22-31; John, 1983, p. 42, pl. 16, fig. 1-3; Jensen, 1985, p. 157, fig. 676a-e; Laws, 1988, p. 162, pl. 16, fig. 23.

Dimensions: L: 12-28 µm. W: 3-5 µm. Str: 13-17 ITM.

Ecology: Epiphytic (Germain, 1981). Periphytic; oligohalobous (indifferent); alkaliphilous (*in* Lowe, 1974).

Distribution: WB: Very rare in β–mesohalobous channel bank sample from the Willapa River; very rare to rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the short transapical striae, wide stemum, and subrostrate apices.

*Fragilaria construens* var. *venter* (Ehrenberg) Grunow 1881

Syn: *Staurosira construens* var. *venter* (Grunow) Williams and Round 1987

Description: John, 1983, p. 42, pl. 16, fig. 4-6.

Hustedt, 1927-66, II, p. 157, fig. 670h-m; Patrick & Reimer, 1966, p. 126, pl. 4, fig. 8-9; Germain, 1981, p. 70, pl. 21, fig. 6-14; Jensen, 1985, p. 146, fig. 670h-m; Laws, 1988, p. 162, pl. 16, fig. 12.

Dimensions: L: 5-16 µm. W: 2.5-6 µm. Str: 12-14 ITM.

Ecology: Periphytic; tychoplanktonic; oligohalobous (indifferent); alkaliphilous (*in* Lowe, 1974).

Distribution: WB: Rare in mesohalobous lower and middle intertidal samples; rare in Holocene samples. Rare in benthic samples in Netarts Bay (Whiting, 1983); common in San Francisco estuary (Laws, 1988). Cosmopolitan. Abundant as epipsammon in False Bay, San Juan Island;

formed colonies on sand grains (Rao and Lewin, 1976). Also observed in tidal flat samples from near Restoration Point in Puget Sound (Hemphill-Haley, unpublished data).

Remarks: According to John (1983, p. 42), the valve shape "varies from linear, rhombic lanceolate with slightly produced apices to elliptic or orbicular." Often quite small (ca. 5-6 µm). Apparently a true tidal flat species (Rao and Lewin, 1976).

*Fragilaria leptostauron* (Ehrenberg) Hustedt 1931

Description: Patrick and Reimer, 1966, p. 124, pl. 4, fig. 2.

Hustedt, 1927-66, I, p. 153, fig. 668; Foged, 1979, p. 53, pl. 7, fig. 26; Foged, 1981, p. 93, pl. 4, fig. 26; Jensen, 1985, p. 143, fig. 668; Laws, 1988, p. 162, pl. 16, fig. 24.

Dimensions: L: 15-36 µm. W: 10-23 µm at the middle. Str: 5-9 ITM.

Ecology: Epipelic; epilithic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Patrick and Reimer (1966, p. 124): "Common in fresh water, usually in shallow water, often on mud surfaces."

Distribution: WB: Rare in β–mesohalobous channel bank samples from the Willapa River; very rare in Holocene samples. Cosmopolitan.

Remarks: The species is easily distinguished by the valve shape; the variety *dubia* may superficially resemble *F. construens* var. *venter*, but differs by having coarser striae (5-9 in 10 µm as compared with 14-17 in 10 µm for *F. construens* var. *venter*).

*Fragilaria pinnata* Ehrenberg 1843

Syn: *Staurosirella pinnata* Williams and Round 1987

Description: Patrick and Reimer, 1966, p. 127, pl. 4, fig. 10.

Hustedt, 1927-66, II, p. 110, fig. 671a-i; Foged, 1978, p. 64, pl. 8, fig. 7; 1979, p. 54, pl. 7, fig. 8-10; Germain, 1981, p. 72, pl. 21, fig. 44-52; 1981, p. 93, pl. 4, fig. 21; pl. 5, fig. 3; Jensen, 1985, p. 149, fig. 671a-i.

Dimensions: L: 3-35 µm. W: 2-6 µm. Str: 7-12 ITM.

Ecology: Epipsammic. Periphytic; tychoplanktonic; oligohalobous (indifferent); alkaliphilous (*in* Lowe, 1974). Also abundant as epipsammon in False Bay, San Juan Island; formed colonies on sand grains (Rao and Lewin, 1976).

Distribution: WB: Very rare to rare in Holocene samples; not well documented in modern Willapa Bay. Not reported at Ledbetter Point by Tynni (1986). Hendey (1964, p. 153): "Common littoral species on all British coasts." Common in benthic samples in Netarts Bay (Whiting, 1983).

Remarks: Distinguished by the coarse striae that are offset from one another across the sternum.

FRUSTULIA Rabenhorst 1853

*Frustulia linkei* Hustedt 1952

Description: Hustedt, 1952, p. 393, fig. 102.

Hendey, 1964, p. 240.

Dimensions: L: 32µm. W: 4.5 µm. Str: 28-30 ITM.

Ecology: Epipelic; mesohalobous. Rare in benthic samples, absent from epiphyte (*Zostera*) samples from Netarts Bay (Whiting).

Distribution: WB: Common in α–mesohalobous low-marsh samples from the Niawiakum River; rare in late Holocene sediments. Hendey (1964, p. 240): "A salt-marsh species, fairly frequent at Blakeney Point, Norfolk."

Remarks: Best identified by the small linear valve, and the strong siliceous ribs enclosing the raphe.

*Frustulia rhomboides* (Ehrenberg) De Toni 1891

Description: John, 1983, p. 112, pl. 46, fig. 10.

Hustedt, 1927-66, II, p. 728, fig. 1098a; Patrick and Reimer, 1966, p. 308, pl. 21, fig. 5; Jensen, 1985, p. 608, fig. 1098a; Krammer and Lange-Bertalot, 1988, p. 258, pl. 95, fig. 1-7; pl. 96, fig. 1-5.

Dimensions: L: 55-68 µm. W: 13-14 µm. Str: 30-32 ITM (longitudinal); 30 ITM (transverse).

Ecology: Epipelic. Halophobous, pH acidophilous to circumneutral (Foged, 1981).

Distribution: WB: Rare; live cells observed in a few oligohalobous marsh and channel bank samples. Hendey (1964, p. 240): "A common freshwater diatom often found on the shore, where it occurs in drainage from agricultural land. Common in mucous masses on the stems of aquatic plants in all European countries bordering the North Sea." Cosmopolitan.

Remarks: The thick siliceous ribs on either side of the raphe branches are fused at the middle of the valve, and thus appear slightly constricted in the middle in LM.

*Frustulia vulgaris* (Thwaites) De Toni 1891

(Plate 4, Figure 2)

Description: Patrick and Reimer, 1966, p. 309, pl. 22, fig. 3.

Hustedt, 1927-66, II, p. 730, fig. 1100a; Foged 1978, p. 66, pl. 20, fig. 1; Germain, 1981, p. 140, pl. 53, fig. 3-6; John, 1983, p. 113, pl. 46, figs. 11-12; Jensen, 1985, p. 611, fig. 1100a; Krammer and Lange-Bertalot, p. 260, pl. 97, figs. 1-6.

Dimensions: L: 50-70 µm. W: 10-13 µm. Str: 26-35 ITM (longitudinal); 34 ITM (transverse).

Ecology: Epipelic (may form tubes). Oligohalobous (indifferent); alkaliphilous(Foged, 1981).

Distribution: WB: Widely distributed. Live cells observed most frequently in oligohalobous and β–mesohalobous low marsh samples, but also observed in oligohalobous channel bank samples and mesohalobous high marsh samples. Cosmopolitan.

Remarks: Distinguished by the narrow-oval central area, and the sharply pointed terminal ends of the raphe ("shaped like a 'pencil point.'" (John, 1983, p. 113)). WB occurrences include "var. *capitata* " (Hustedt, 1927-66, II, p. 730, fig. 1100b).

GOMPHONEIS Cleve 1894

*Gomphoneis herculeana* (Ehrenberg) Cleve 1894

(Plate 4, Figure 3)

Description: Patrick & Reimer, 1975, p. 149, pl. 21, fig. 1.

Foged, 1979, p. 56, pl. 36, fig. 1-4; Tynni, 1986, pl. 28, fig. 175; Laws, 1988, p. 163, pl. 29, fig. 12.

Dimensions: L: 60-100 µm. W: 20-22 µm. Double row of puncta between the radiating costae, 10-12 in 10 µm.

Ecology: Epiphytic; epipelic. Oligohalobous (indifferent).

Distribution: WB: Very rare; only a few live cells observed in lower channel-bank samples from the oligohalobous/β–mesohalobous Willapa River site. Also very rare in Holocene sediments. Laws (1988, p. 163): "Rare in Sangamon and Recent sediment, most abundant in Suisun Bay sediments."

Remarks: A large, robust diatom, distinguished by longitudinal lines that lie parallel to the axial area and thus terminate towards the basis where the valve narrows, the closely-spaced striae, and the oval central area with one stigma. Foged (1979, p. 56): "...varies very much as regards size and outline of the valves."

GOMPHONEMA Ehrenberg 1832

*Gomphonema angustatum* (Kützing) Rabenhorst 1864

(Plate 4, Figure 4)

Description: Patrick and Reimer, 1975, p. 125, pl. 17, fig. 17-19.

Foged, 1978, p. 67, pl. 40, fig. 18; Germain, 1981, p. 306, pl. 114, fig. 1-21; Jensen, 1985, p. 826, fig. 690; Krammer & Lange-Bertalot, 1986, p. 360, pl. 155, fig. 1-21.

Dimensions: L: 12-45 µm. W: 5-9 µm. Str: 9-12 in 10 µm.

Ecology: Epiphyte. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: WB: Live cells observed in channel bank and marsh samples from oligohalobous and β–mesohalobous sites. Occurs with *G. parvulum*. Cosmopolitan.

Remarks: Similar to *G. parvulum*, but differs in having fewer striae in 10 µm which are radiate throughout, with the middle striae more distantly placed and thus a more distinct central area than *G. parvulum*. Apices variable, but sometimes more capitate than *G. parvulum*.

*Gomphonema olivaceum* (Hornemann) Brébisson 1838

Syn: *Gomphoneis olivacea* (Hornemann) Dawson ex Ross and Sims 1978; *Gomphonema olivaceum* (Lyngb.) Kützing 1844

Description: Patrick and Reimer, 1975, p. 139, pl. 18, fig. 13-14.

Hustedt, 1930, p. 378, fig. 719; Foged, 1981, p. 101, pl. 52, fig. 12, pl. 53, fig. 20; Jensen, 1985, p. 831, fig. 719; Krammer and Lange-Bertalot, 1986, p. 374, pl. 165, fig. 1-18.

(As *Gomphoneis olivacea* (Lyngbye) Dawson 1974): Germain, 1981, p. 312, pl. 111, fig. 14-16.

Dimensions: L: 15-40 µm. W: 5-10 µm. Str: 11-14 ITM.

Ecology: Epiphytic; epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: WB: Rare in channel bank and marsh samples from the oligohalobous/β–mesohalobous Willapa River site. Hustedt (*in* Jensen, 1985, p. 832): "Very widely distributed and common in standing waters; also in brackish water..." Cosmopolitan.

Remarks: Superficially resembles *G. truncatum*. Distinguished by the valve shape, straight raphe branches, irregular central area formed by striae of different lengths, and the absence of an isolated stigma or punctum.

*Gomphonema parvulum* (Kützing) Kützing 1849

(Plate 4, Figure 5)

Description: Patrick & Reimer, 1975, p. 122, pl. 17, fig. 7-12.

Foged, 1978, p. 71, pl. 40, fig. 12, 15; Foged, 1979, p. 59, pl. 37, fig. 7; Germain, 1981, p. 308, pl. 114, fig. 23-28; John, 1983, p. 142, pl. 59, fig. 7-9; Krammer and Lange-Bertalot, 1986, p. 358, pl. 154, fig. 1-25; Laws, 1988, p. 163, pl. 29, fig. 7.

Dimensions: L: 15-30 μm. W: 5-8 μm. Str: 13-16 ITM.

Ecology: Epiphyte. Oligohalobous (indifferent); pH circumneutral (Foged, 1981). John (1983, p. 142): "Occurred as a common epiphyte in the upper stations of Canning River and Swan River."

Distribution: WB: Very common in oligohalobous and β–mesohalobous channel bank and low-marsh samples along the South Fork Willapa and Willapa rivers. Observed less frequently in high marsh samples from oligohalobous and mesohalobous sites. Cosmopolitan.

Remarks: Differs from *G. angustatum* by denser striae (13-16 in 10 μm vs. ~ 9-12 in 10 μm), parallel throughout, with the central ones less distantly placed and thus with a less well-developed asymmetrical central area. Apices variable, but may be a bit more narrowly rostrate than in *G. angustatum*.

GRAMMATOPHORA Ehrenberg 1840

*Grammatophora oceanica* (Ehrenberg) Grunow 1881.

(Plate 4, Figure 6-8)

Description: John, 1983, p. 47, pl. 18, fig. 1-12;

Hustedt, 1927-66, II, p. 45, fig. 573, 574; Foged, 1975, p. 25, pl. 7, fig. 1,2; Foged, 1978, p. 73, pl. 6, fig. 14; Sullivan, 1979, p. 244, fig. 4; Jensen, 1985, p. 44, fig. 573, 574.

Dimensions: L: 9-95 µm. W: 4-6 µm. Str: 22-25 ITM. Pervalvar axis: 9-13 µm.

Ecology: Epiphytic; epipelic. α–mesohalobous/polyhalobous. Foged (1978, p. 73): "Polyhalobous. Presumably cosmopolitan."

Distribution: WB: Common in mesohalobous middle and lower intertidal samples; rare valves also observed in upper intertidal samples. Rare to common and widely dispersed in Holocene samples, similar to occurrences in modern samples. Reported from Ledbetter Point by Tynni (1986). Hendey (1964, p. 170): "A common littoral species on all North Sea and North Atlantic coasts, English Channel." Cosmopolitan.

Remarks: Differs from *G. marina* by the smaller, narrower valve with finer striae; both species have septa with a single undulation near the end of the valve, and an oval loop where they terminate near the middle of the valve. According to Brockmann (1950, p. 13), often occurs with *G. marina* on seaweed and grasses. Sullivan (1979, p. 244): "*G. oceanica* and *G. marina* (Lyngb.) Kütz. and their varieties represent a complex of closely related forms that are difficult to separate taxonomically."

GYROSIGMA Hassall 1845

*Gyrosigma balticum* (Ehrenberg) Rabenhorst 1853

Description: Patrick & Reimer, 1966, p. 324, pl. 25, fig. 1.

Hustedt, 1930, p. 224, fig. 331; Hendey, 1964, p. 248, pl. 35, fig. 9; Riznyk, 1973, p. 123, pl. 9, fig. 1; Germain, 1981, p. 132, pl. 48, fig. 2; Jensen, 1985, p. 783, fig. 331; John, 1983, p. 113, pl. 47, fig. 1-3; Krammer and Lange-Bertalot, 1986, p. 299, pl. 115, fig. 5; Laws, 1988, p. 164, pl. 20, fig. 5.

Dimensions: L: 200-400 µm. W: 20-32 µm. Str: 11-16 ITM.

Ecology: Epipelic. Mesohalobous; alkaliphilous (Foged, 1981). Patrick and Reimer (1966, p. 325): "Brackish-water, coastal species." Hendey (1964, p. 248): "A common marine littoral species, often found in harbours and estuaries, lying in large colonies on mud or sand. Frequent in brackish water."

Distribution: WB: Rare in mesohalobous intertidal samples. Present (but typically broken) in Holocene samples. Frequent in San Francisco Bay (Laws, 1988); rare in Yaquina estuary (Riznyk, 1973); absent from Netarts Bay (Whiting, 1983). Cosmopolitan.

Remarks: Distinguished by the large linear valve, sigmoid-obtuse apices, distinctly punctate transverse and longitudinal striae (11-16 in 10 μm), and raphe branches that are undulate towards the center.

*Gyrosigma eximium* (Thwaites) Boyer 1927

(Plate 4, Figure 9)

Syn: *Gyrosigma scalproides* var. *eximia* (Thwaites) Cleve 1894

Description: John, 1983, p. 114, pl. 47, fig. 4.

Patrick & Reimer, 1966, p. 317, pl. 23, fig. 6; Laws, 1988, p. 164, pl. 19, fig. 10-11.

(As *G. scalproides* var. *eximia*): Hustedt, 1930, p. 226, fig. 339; Foged, 1978, p. 74, pl. 21, fig. 9; Jensen, 1985, p. 784, fig. 339.

Dimensions: L: 50-65 μm. W: 7-10 μm. Str: 20-22 ITM (transverse); 24-28 ITM (longitudinal).

Ecology: Epipelic (forms tubes). Halophilous (mesohalobous ?); alkaliphilous (Foged, 1981).

Distribution: WB: A dominant species in α–mesohalobous low-marsh samples (Niawiakum River sites); common in low marsh samples at the α–mesohalobous/polyhalobous Stony Point site. Rare cells observed in high marsh and channel bank samples. Laws, 1988 (p. 164):" Intertidal mud flats and marshes in present (San Francisco) bay." Rare in benthic samples in Netarts Bay (Whiting, 1983, p. 132). Cosmopolitan.

Remarks: Distinguished by the linear valve and blunt apices; the proximal ends of the raphe are deflected in the same direction as the apices. Isolated valves observed more frequently than clusters in tubes.

*Gyrosigma fasciola* (Ehrenberg) Griffith and Henfrey 1856

Syn: *Ceratoneis fasciola* Ehrenberg 1841

Description: John, 1983, p. 114, pl. 47, fig. 5,6.

Patrick and Reimer, 1966, p. 328, pl. 26, fig. 4; Riznyk, 1973, p. 124, pl. 8, fig. 9; Foged, 1978, p. 61, pl. 19, fig. 3; Krammer and Lange-Bertalot, 1986, p. 300, pl. 116, fig. 6; Laws, 1988, p. 164, pl. 20, fig. 2.

Dimensions: L: 90-110 µm. W: 11-15 µm. Str: 20-22 ITM (transverse); 18-22 ITM (longitudinal).

Ecology: Planktonic (tychoplanktonic?). Patrick and Reimer (1966, p. 328): "Brackish to marine; appears quite commonly in salinities from about 1000-20,000 p.p.m." Krammer and Lange-Bertalot (1986, p. 300): "Cosmopolitan, marine planktonic species..." (mesohalobe?)."

Distribution: WB: Common in mesohalobous channel bank samples, particularly along the upper Niawiakum River (where it is allochthonous from the plankton?). Common and widespread in San Francisco Bay (Laws, 1988) and Yaquina Bay (Riznyk, 1973). Present in benthic samples but absent from planktonic samples in Netarts Bay (Whiting, 1983) and Swan River estuary (John, 1983). Cosmopolitan.

Remarks: Easily distinguished by the long narrowed apices, the straight raphe branches in the wide middle part of the valve, and the small orbicular central area.

*Gyrosigma spencerii* (Quekett) Griffith and Henfrey 1856

Syn: *Gyrosigma kützingii* (Grunow) Cleve 1894

Description: Hustedt, 1930, p. 225, fig. 336.

Patrick & Reimer, 1966, p. 315, pl. 23, fig. 4; John, 1983, p. 115, pl. 47, fig. 7-8; pl. 48, fig. 4-6; Jensen, 1985, p. 785, fig. 336; Krammer and Lange-Bertalot, 1986, p. 298, pl. 115, fig. 2.

Dimensions: L: 95-140 µm. W: 13-15 µm. Str: 18-20 ITM (transverse); 22-24 ITM (longitudinal).

Ecology: Epipelic. Mesohalobous; alkaliphilous (Foged, 1981).

Distribution: WB: Observed most frequently in mesohalobous low marsh samples along the Niawiakum River and near Stony Point. Less frequent in lower intertidal samples from channel banks and tidal flats. Present in benthic samples in Netarts Bay (Whiting, 1983, p. 133). Cosmopolitan.

Remarks: Variable in size; distinguished by the narrowed apices, oval central area, fine striae, and the sigmoid raphe branches that are equidistant from the margins along the length of the valve.

HANNAEA Patrick 1966

*Hannaea arcus* (Ehrenberg) Patrick 1966

Syn: *Ceratoneis arcus* (Ehrenberg) Kützing 1844

Description: Patrick and Reimer, 1966, p. 132, pl. 4, fig. 20.

(As *Ceratoneis arcus*): Hustedt, 1927-66, II, p. 179, fig. 684a-c; Germain, 1981, p. 58, pl. 17, fig. 3-6; Foged, 1981, p. 60, pl. 5, fig. 16,17; Jensen, 1985, p. 168, fig. 684a-c;

Dimensions: L: 15-150 µm. W: 4-7 µm. Str: 13-14 ITM.

Ecology: Epilithic; periphytic; tychoplanktonic. Oligohalobous (indifferent) to halophobous; alkaliphilous to indifferent; (*in* Lowe, 1974).

Distribution: WB: Common along the Willapa River; very rare in Holocene deposits.

Remarks: Distinguished by the capitate ends, the arched valve, and a distinctive inflated area at the middle of the ventral margin. According to Round et al. (1990, p. 366): "the shape of the cell is almost the only feature distinguishing *Hannaea* from *Fragilaria*, and the genus can be maintained only on its distinctive morphological character and possibly its very restricted ecological range."

HANTZSCHIA Grunow in Cleve and Grunow 1880

*Hantzschia amphioxys* (Ehrenberg) Grunow in Cleve and Grunow 1880

(Plate 4, Figure 10)

Description: Krammer and Lange-Bertalot, 1988, p. 128, pl. 88, fig. 1-7.

Hustedt, 1930, p. 394, fig. 747; Foged, 1979, p. 62, pl. 41, fig. 3,4; Germain, 1981, p. 326, pl. 122, fig. 5-10; John, 1983, p. 163, pl. 68, fig. 8,9; Jensen, 1985, p. 847, fig. 747; Laws, 1988, p. 164, pl. 31, fig. 4.

Dimensions: L: 20-210(300) µm. W: 5-15(25 µm). Fib: 4-11 ITM. Str: 11-28 ITM.

Ecology: Epipelic; aerophilous. Oligohalobous (indifferent); alkaliphilous (Foged, 1978).

Distribution: WB: Rare in peaty Holocene samples; very rare in β–mesohalobous and oligohalobous marsh samples. "The most widespread soil diatom, being found in the soil in all parts of the world" (*in* Lowe, 1974). Cosmopolitan.

Remarks: Distinguished by the nearly parallel, finely-punctate striae, and the marginal costae that are nearly the same length throughout.

*Hantzschia virgata* (Roper) Grunow in Cleve and Grunow 1880

Description: Krammer and Lange-Bertalot, 1988, p. 130, pl. 90, fig. 1-8.

Hustedt, 1930, p. 395, fig. 753; Brockmannnn, 1950, p. 23, pl. 5, fig. 6,7; Hendey, 1964, p. 285, pl. 39, fig. 1; Riznyk, 1973, p. 124, pl. 9, fig. 3,4; Foged, 1979, p. 63, pl. 40, fig. 10; John, 1983, p. 164, pl. 58, fig. 12; Jensen, 1985, p. 848, fig. 752.

Dimensions: L: 50-150 µm. W: 5-12 µm. Fib: 3.5-7 ITM. Str: 7-15 ITM.

Ecology: Epipelic. Marine and brackish water; euryhaline (Brockmannnn, 1950). "A common littoral species on all North Sea coasts, preferring clean sandy shores to estuarine mud" (Hendey, 1964, p. 285).

Distribution: WB: Rare in Holocene samples; modern distribution not recorded. Recorded at Ledbetter Point by Tynni (1986); very rare in Yaquina estuary (Riznyk, 1973). Cosmopolitan.

Remarks: Distinguished by the coarse punctate striae, and the alternating short and long marginal costae.

HYALODISCUS Ehrenberg 1845

*Hyalodiscus laevis* Ehrenberg 1854

Description: Hustedt, 1927-66, I, p. 294, fig. 134

Tynni, 1986, p. 19, pl. 2, fig. 14,15.

Dimensions: Diam: 70-200 µm.

Ecology: Epiphytic(?). Mesohalobous.

Distribution: WB: Very rare in mesohalobous lower intertidal samples; rare to common in Holocene samples, possibly concentrated because of the robust valve. Recorded at Ledbetter Point by Tynni (1986, p. 19).

Remarks: As noted by Tynni (1986, p. 19), there are some difference from the specimens described by Hustedt and those in Willapa Bay. Best distinguished by the large, and often robust, valve, the central area more than one-half the valve diameter, fine areolae on the valve face, and fine radiate striae in the marginal zone.

*Hyalodiscus scoticus* (Kützing) Grunow 1879

(Plate 4, Figure 11,12)

Description: Hustedt, 1927-66, I, p. 293, fig. 133a,b.

Foged, 1979, p. 63, pl. 4, fig. 5; John, 1983, p. 18, pl. 3, fig. 6-8; Tynni, 1986, pl. 2, fig. 3; Laws, 1988, p. 164, pl. 12, fig. 10,11.

Dimensions: Diam: 10-40 µm

Ecology: Epiphytic; tychopelagic. Euryhaline. "Polyhalobous" (Foged, 1979, p. 63).

Distribution: WB: Abundant in α–mesohalobous lower intertidal samples where *Zostera* is present; rare in Holocene samples. Not reported from Yaquina estuary (Riznyk, 1973) or Netarts Bay (Whiting, 1983); rare in San Francisco estuary (Laws, 1988). Hendey (1964, p. 90): "A euryhaline species common on all North Sea coasts, in marine and brackish waters." Cosmopolitan.

Remarks: Resistant to dissolution, and preserves well in fossil deposits.

MASTOGLOIA Thwaites ex W. Smith 1856

*Mastogloia exigua* Lewis 1862

Description: Hustedt, 1927-66, II, p. 569, fig. 1003.

Riznyk, 1973, p. 124, pl. 10, fig. 6; Foged, 1978, p. 78, pl. 19, fig. 4,5; 1979, p. 64, pl. 16, fig. 14, 15; pl. 17, fig. 4; John, 1983, p. 118, pl. 50, fig. 1,2; Jensen, 1985, p. 482, fig. 1003; Laws, 1988, p. 165, pl. 19, fig. 8-9

Dimensions: L: 25-40 µm. W: 9-11 µm. Str: 20-24 ITM.

Ecology: Epipelic; periphytic (?). Mesohalobous, euryhaline (Foged, 1979). Reported by Foged (1979, p. 10) in samples from a sandy beach.

Distribution: WB: Indicative of middle intertidal salt marshes in Willapa Bay; particularly frequent at Toke Point (Figure 1); rare in Holocene samples. Reported at Ledbetter Point by Tynni (1986). Rare in Yaquina estuary (Riznyk, 1973); present in benthic samples in Netarts Bay (Whiting, 1983).

Remarks: Distinguished by the size and number of marginal chambers.

MELOSIRA Agardh 1824

*Melosira moniliformis* (O.F. Müller) Agardh 1824

Description: Crawford, 1977, p. 285, fig. 1-23.

Hustedt, 1927-66 I, p. 236, fig. 98; Hendey, 1964, p. 72, pl. 1, fig. 2; John, 1983, p. 15, pl. 1, fig. 6-12; Laws, 1988, p. 165, pl. 1, fig. 1-6.

Dimensions: Diam: 19-70 µm. Length of valves: 11-30 µm.

Ecology: Epiphytic. Hendey (1964, p. 72): "Common in brackish water, particularly in estuarine conditions and in harbours. Frequent on rocks around the south and west coasts of the British Isles."

Distribution: WB: Widely distributed in lower intertidal samples where salinities > 10 ‰, particularly where *Zostera* is present. Rare to common in Holocene samples. Reported at Ledbetter Point by Tynni (1986). Reported by Whiting (9183) as common in benthic samples, and present in epiphytic (*Zostera*) samples in Netarts Bay. Common on mud flats in San Francisco estuary (Laws, 1988).

Remarks: This is one of the most abundant diatoms observed in Recent sediment, but the large delicate valve does not preserve well in fossil deposits.

*Melosira nummuloides* Agardh 1824

Description: Crawford, 1975, p. 323-338.

Hustedt, 1927-66, I, p. 231, fig. 95; Foged 1978, p. 82, pl. 1, fig. 8; Hendey, 1964, p. 72, pl. 1, fig. 1; John, 1983, p. 15, pl. 2, fig. 1-2; Laws, 1988, p. 165, pl. 1, fig. 7.

Dimensions: Diam: 10-40 µm

Ecology: Epiphytic. Mesohalobous; alkaliphilous (Foged, 1978).

Distribution: WB: Occurs with *M. moniliformis*. Reported at Ledbetter Point by Tynni (1986). Reported by Whiting (9183) as common in benthic samples, and present in epiphytic (*Zostera*) samples in Netarts Bay. Common on mud flats in San Francisco estuary (Laws, 1988).

Remarks: Similar to *M. moniliformis*, but differs by having a hyaline collar, a hemispherical valve, and marginal spines arranged in a distinct ring (Crawford, 1977, p. 283).

*Melosira* cf. *Melosira octogona* A. Schmidt 1874

Description: Frustules similar to *M. nummuloides*, but more rounded, and without an obvious collar or ring between adjoing cells. Valves round, strongly convex, about 12-20 µm in diameter. Similar to *M. octogona* as described by John (1983, p. 16, pl 2, fig. 3-5), but not as perfectly round. May possibly be a form of *M. nummuloides*.

Dimensions: Diam: 12-20 µm.

Ecology: Epiphytic. Mesohalobous.

Distribution: WB: Occurs with *M. moniliformis* and *M. nummuloides* in mesohalobous lower intertidal samples.

Remarks: Distinguished by the rounded, globose valves.

NAVICULA Bory 1824

*Navicula accomoda* Hustedt 1950

Syn: *Craticula accomoda* Mann in Round et al. 1990

Description: Patrick and Reimer, 1966, , p. 468, pl. 44, fig. 7; Rivera, 1973, p. 52, pl. 9, fig. 90; Germain, 1981, p. 170, pl. 63, fig. 5; Foged, 1981,, p. 106, pl. 38, fig. 27; Krammer and Lange-Bertalot, 1986, p. 128, pl. 45, fig. 13-20.

Dimensions: L: 19-35 µm. W: 7-10 µm. Str: 20-25 ITM (center); 32 ITM (ends).

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: WB: Oligohalobous to β–mesohalobous upper intertidal sediments (transect T1 and T2). Cosmopolitan.

Remarks: Patrick and Reimer, 1966, (p. 468): "This species is similar to *Navicula halophila* (Grun.) Cl. but differs from it in that the striae are more distant in the middle portion of the valve."

*Navicula cancellata* Donkin 1872

Description: Krammer and Lange-Bertalot, 1986, p. 118, pl. 39, fig. 3.

Hendey, 1964, p. 203, pl. 30, fig. 18-20; Riznyk, 1973, p. 125, pl. 10, fig. 12,13; Foged 1981, p. 109, pl. 31, fig. 6; John, 1983,p. 84, pl. 37, fig. 3.

Dimensions: L: 30-100 µm. W: 6-16µm. Str: 5-11 ITM.

Ecology: Epipsammic. Polyhalobous. Reported as rare in estuarine epiphyte samples in Oregon (Whiting, 1983) and Australia (John, 1983).

Distribution: WB: Restricted to modern sand flat samples; rare in Holocene sediments. Abundant on sandy substrate in Yaquina estuary (Riznyk, 1973). Hendey (1964, p. 203): "Common on the west coasts of the British Isles, particularly on sandy beaches; less frequent on muddy shores." Cosmopolitan.

Remarks: Striae are robust, slightly radiate at the middle, parallel at the apices; mantle is steep, well defined, and a distinguishing feature in girdle view. Hendey (1964, p. 203): "A large and very variable species, well adapted to marked changes in salinity and environment."

*Navicula capitata* Ehrenberg 1838

(Plate 4, Figure 13)

Syn: *Navicula hungarica* var. *capitata* (Ehrenberg) Cleve1895

Description: Patrick & Reimer, 1966, p. 536, pl. 52, fig. 1-2.

Schmidt's Atlas, pl. 272, fig. 41-43; Hustedt, 1930, p. 298, fig. 508; John, 1983, p. 84, pl. 37, fig. 4-5; Krammer & Lange-Bertalot, 1986, p. 123, pl. 42, fig. 1-4; Pankow, 1990, p. 219, pl. 48, fig. 12.

(As *N. hungarica* var. *capitata*): Germain, 1981, p. 186, pl. 71, fig. 5 ; Foged, 1978, p. 91, pl. 32, fig. 15; Foged, 1979, p. 75, pl. 30, fig. 12, 19.

Dimensions: L: 12-47 µm. W: 5-10 µm. Str: 8-10 ITM.

Ecology: Pankow (1990, p. 219): Epiphytic/periphytic. "Oligohalob, mesoeuryh." (i.e., salinities less than ~ 10 ppt). Patrick and Reimer (1966, p. 537): "Seems to tolerate a wide variation in the chemistry of the water. John (1983, p. 84): "Common in periphytic and epiphytic samples from the upper reaches of Swan and Canning Rivers."

Distribution: WB: Autochthonous but very rare on the point bar surface on the South Fork Willapa River; very rare allochthonous valves observed in mesohalobous intertidal samples; not observed in Holocene samples.

Remarks: Distinguished by the small, sturdy valve, the capitate apices, and the thick striae. There is a distinctive hyaline apical area.

*Navicula cincta* (Ehrenberg) Ralfs in Pritchard 1861

(Plate 4, Figure 14)

Syn: Pinnularia cincta Ehrenberg 1854; Navicula cari var. cincta (Ehrenberg) Lange-Bertalot 1980a

Description: Patrick & Reimer, 1966, p. 516, pl. 49, fig. 11.

Brockmannnn, 1950, p. 17, pl. 2, fig. 17-20; Hendey, 1964, p. 196, pl. 30, fig. 8; Foged, 1978, p. 85, pl. 30, fig. 6; 1979, p. 70, pl. 29, fig. 14; Germain, 1981, p. 186, pl. 71, fig. 8-13; John, 1983, p. 84, pl. 37, fig. 6; Krammer and Lange-Bertalot, 1985, p. 61, pl. 17, fig. 6-8, pl. 30, fig. 2); 1986, p. 98, pl. 28, fig. 8-15.

Dimensions: L: 10-42 µm. W: 4-8 µm. Str: 8-10 ITM at the center of the valve; 17 ITM at the ends.

Ecology: Epipelic. Hendey, 1964 (p. 196): "A brackish-water species, common on salt marshes; widely spread on the coasts of all North European countries, English Channel." Foged (1979, p. 70): "Halophilous. Alkaliphilous."

Distribution: WB: Common in marshy intertidal areas above MHW; common in Holocene samples. Cosmopolitan.

Remarks: Willapa Bay specimens are usually 10-20 µm long; central area may be transverse to irregular.

*Navicula contenta* Grunow in Van Heurck 1884-1887

Syn: *Diadesmis contenta* (Grunow ex Van Heurck) Mann in Round et al. 1990; *Diadesmis biceps* Arnott ex Grunow in Van Heurck 1880.

Description: Krammer and Lange-Bertalot, 1986, p. 219, pl. 75, fig. 1-5.

Hustedt, 1927-66, III, p. 205, fig. 1274a-d; Foged, 1979, p. 70, pl. 30, fig. 22; Germain, 1981, p. 228, pl. 85, fig. 15-18

(As *Navicula contenta* var. *biceps*): Patrick and Reimer, 1966, p. 480, pl. 45, fig. 19 ; Foged 1981, p. 110, pl. 37, fig. 9 ;

Dimensions: L: 4-30 µm. W: 2-4 µm. Str: 25-40 ITM.

Ecology: Epipelic; aerophilous. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Patrick and Reimer, 1966 (p. 481): " Often associated with moss; oligohalobe (indifferent), alkaliphil; cosmopolitan; acid to circumneutral water."

Distribution: WB: Only observed in the highest marsh sample at Stony Point. Cosmopolitan.

Remarks: Some authors recognize several forms based on the striae form or shape of the apices. Most Willapa Bay specimens resemble the "form *biceps* (Arnott) Hustedt" (e.g., Foged, 1979, p. 70, pl. 30, fig. 23; Patrick and Reimer, 1966, p. 480, pl. 45, fig. 19). Krammer and Lange-Bertalot (1986) include the forms with the species.

*Navicula cryptocephala* Kützing 1844

Description: Krammer & Lange-Bertalot, 1986, p. 102, pl. 31, fig. 8-14.

Dimensions: Hustedt, 1930, p. 295, fig. 496; Patrick and Reimer, 1966, p. 503, pl. 48, fig. 3; Foged 1978, p. 86, pl. 31, fig. 12; John, 1983,p. 87, pl. 38, fig. 3,4; Laws, 1988, p. 165, pl. 23, fig. 9.

Ecology: Epipelic. Hendey, 1964 (p. 195): "A common freshwater species that is strongly euryhaline and is found frequently in littoral samples from all British coasts." Laws, 1988, (p. 109): "Common only in intertidal mud flats and marsh sediments of present bay, Albany mud flats."

Distribution: WB: Rare in mesohalobous upper intertidal samples; also very rare from lower and middle intertidal samples of the open bay. Rare in Holocene samples. Cosmopolitan.

Remarks: Krammer and Lange-Bertalot (1986, p. 102) reported that this species is often confused with other taxa, particularly *N. veneta* and *N. gregaria*.

*Navicula cryptolyra* Brockmannnn 1950

Syn: *Fallacia cryptolyra* (Brockmannnn) Stickle and Mann in Round et al., 1990

Description: Brockmannnn, 1950, p. 19, pl. 3, fig. 22, 23.

Krammer & Lange-Bertalot, 1986, p. 172, pl. 65, fig. 7-9.

Dimensions: L: 8-11 µm. W: 5 µm. Str: 27-29 ITM.

Ecology: Epipsammic. Mesohalobous (euryhaline?).

Distribution: WB: Indicative of sandy tidal flats of the open bay; common observed attached to sand grains in Holocene deposits.

Remarks: Easy to overlook because of its small size.

*Navicula cryptotenella* Lange-Bertalot in Krammer and Lange-Bertalot, 1985.

Syn: *Navicula tenella* Brébisson ex Kützing 1849 sensu Grunow 1880; *Navicula radiosa* var. *tenella* (Brébisson ex Kützing) Van Heurck 1885

Description: Krammer & Lange-Bertalot, 1985, p. 62, pl. 18, fig. 22-23, pl. 19, fig. 1-10.

Krammer & Lange-Bertalot, 1986, p. 106, pl. 33, fig. 9-11.

(As *Navicula radiosa* var. *tenella*): Patrick & Reimer, 1966, p. 510, pl. 48, fig. 17;

Germain, 1981, p. 184, pl. 70, fig. 9-12.

Dimensions: L: 14-40 µm. W: 5-7 µm. Str: 16(18) ITM.

Ecology: Epipelic. Oligohalobous (indifferent); pH circumneutral (Foged, 1981). Patrick and Reimer, 1966, (p. 509): "Common in all types of circumneutral fresh water; oligohalobous to indifferent to salt concentration."

Distribution: WB: Widely distributed in mesohalobous samples; particularly middle and upper intertidal marsh samples. Rare in Holocene samples.

Remarks: Distinguished by the narrow apices and alternating short and long radiating striae at the middle. See note for *N. stankovicii.*

*Navicula digitoradiata* (Gregory) Ralfs in Pritchard 1861

Description: Hendey, 1964, p. 202, pl. 29, fig. 8,9.

Brockmannnn, 1950, p. 17, pl. 2, fig. 1-3; Rao and Lewin, 1976, p. 201, fig. 286-288; Germain, 1981, p. 196, pl. 75, fig. 4-6; Foged 1981, , p. 112, pl. 35, fig. 3; Krammer and Lange-Bertalot, 1985, p. 66, pl. 22, fig. 17,18; Krammer and Lange-Bertalot, 1986, p. 108, pl. 34, fig. 1-9; L88, p. 166, pl. 23, fig. 16; Laws, 1988, p. 166, pl. 23, fig. 16.

Dimensions: L: 44-84 µm. W: 16-20 µm. Str: 7-14 ITM.

Ecology: Benthic; epipelic. Mesohalobous; alkaliphilous (Foged, 1981). Frequent on tidal flats and salt marshes (Brockmannnn, 1950; Laws, 1988).

Hendey, 1964, (p. 202): "Prefers a muddy shore to one of clean sand."

Distribution: WB: Common in a mesohalobous/polyhalobous middle intertidal marsh samples from Toke Point; very rare in tidal flat sediment. Rare to common in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the robust valve, and the strongly radiate, alternating short and long central striae.

*Navicula granulata* Bailey 1854

(Plate 4, Figure 15)

Syn: *Petroneis granulata* (Bailey) Mann in Round et al. 1990

Description: John, 1983, p. 91, pl. 39, fig. 1-3.

Hustedt, 1927-66, III, p. 799, fig. 1771; Hendey, 1964, p. 208, pl. 31, fig. 6; Riznyk, 1973, p. 126, pl. 11, fig. 10; Laws, 1988, p. 166, pl. 24, fig. 2.

Dimensions: L: 50-100 µm. W: 26-40 µm. Str: 10-11 ITM. Pnct: 10-11 ITM.

Ecology: Epipelic. α–mesohalobous/polyhalobous.

Distribution: WB: Rare in tidal flat samples. Common on tidal flats in Yaquina estuary (Riznyk, 1973); rare in San Francisco Bay (Laws, 1988).

Remarks: Distinguished by the widely-scattered puncta on the valve face. As noted by Laws (1988), is probably closely related to *N. punctulata*, differing only by the distancing of the middle puncta on the valve, and may be ecological or geographical expressions of the same species.

*Navicula gregaria* Donkin 1861

Syn: *Navicula gotlandica* Grunow sensu Hustedt; *Navicula phyllepta* Kützing sensu Brockmann and sensu Hustedt

Description: Patrick & Reimer, 1966, p. 467, pl. 44, fig. 6.

Brockmann, 1950, p. 16, pl. 2, fig. 10, 12 (as *N. phyllepta*); Foged, 1978, p. 90, pl. 30, fig. 8; Germain, 1981, p. 170, pl. 63, fig. 7; Krammer & Lange-Bertalot, 1988, p. 116, pl. 38, fig. 10-15; Laws, 1988, p. 166, pl. 24, fig. 4,5, 9-11.

Dimensions: L: 15-35 µm. W: 5-9 µm. Str: 16-22 ITM.

Ecology: Epipelic. Halophilous; alkaliphilous (Foged, 1981). Patrick and Reimer, 1966, (p. 468): "Prefers brackish water and fresh water with high mineral content."

Distribution: WB: Observed with *N. halophila* in mesohalobous upper intertidal deposits. Very widely distributed. Laws (1988, p. 166): "Intertidal salt-marsh sediments of present (San Francisco) bay, Albany mud flats." Cosmopolitan.

Remarks: Distinguished by the irregular to suboval central area, produced rostrate apices, and slightly radiate punctate striae.

*Navicula halophila* (Grunow) Cleve 1894

Syn: *Craticula halophila* (Kützing) Mann in Round et al. 1990; *Navicula cuspidata* var. *halophila* Grunow in Van Heurck 1885

Description: Patrick and Reimer, 1966, , p. 467, pl. 44, fig. 4.

Brockmann, 1950, p. 15, pl. 2, fig. 23; Foged, 1978, p. 90, pl. 27, fig. 7; Germain, 1981, p. 170, pl. 65, fig. 1-11; Krammer and Lange-Bertalot, 1986, p. 126, pl. 44, fig. 1-11, 14-18.

Dimensions: L: 20-50 µm. W: 6-12 µm. Str: 16-20 ITM.

Ecology: Epipelic. Mesohalobous; alkaliphilous (Foged, 1981). Cosmoplitan, marine and brackish water (Krammer and Lange-Bertalot, 1986) or water of high mineral content (Patrick and Reimer, 1966).

Distribution: WB: Widely distributed in mesohalobous fine-grained intertidal sediments. Hendey, (1964, p. 190): "A brackish-water species, frequent on English Channel coasts." Cosmopolitan.

Remarks: Very variable in valve outline and size. Krammer and Lange-Bertalot (1986, p. 126) report ranges of 7-140 µm in length, and 4.5-18 µm in width. There is no obvious central area. Striae are parallel along most of the valve, slightly convergent near the apices.

*Navicula lanceolata* (Agardh) Ehrenberg 1838

(Plate 4, Figure 16)

Syn: *Frustulia lanceolata* Agardh 1827; *Navicula avenacea* de Brébisson ex Grunow 1878; *Navicula* (*viridula* var. ?) *avenacea* (Brébisson) Grunow in Schneider 1878

Description: Krammer & Lange-Bertalot, 1986, p. 100, pl. 29, 5-7.

Dimensions: L: 28-70 µm. W: 8(9)-12 µm. Str: 10-13 ITM.

Germain, 1981, p. 180, pl. 68, fig. 1-6; Lange-Bertalot, 1980, p. 6.

(As *N. avenacea*): Patrick and Reimer, 1966, p. 507, pl. 48, fig. 10; Brockmann, 1950, p. 17, pl. 1, fig. 6; Foged 1977, p. 76, pl. 28, fig. 19.

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Hendey, 1964, (p. 200, as *N. avenacea*): "A common and widespread species in brackish conditions, strongly euryhaline."

Distribution: WB: Abundant in β–mesohalobous lower and middle intertidal sediments along the Willapa River, and in high marsh sediments near Stony Point on the open bay. Cosmopolitan.

Remarks: This taxon is widely distributed, and cited in the literature usually as either *N. avenacea* de Brébisson ex Grunow 1878, or as *N. viridula* var. *avenacea* (Brébisson ex Grunow) Van Heurck 1885. Discrepancies among these investigators is based on whether or not the taxon warrants a position as a separate species (Hendey, 1964; Brockmann, 1950; Foged, 1977, 1981) or should be maintained as a variety of *N. viridula* (Patrick and Reimer, 1966). However, Lange-Bertalot (1980, p. 30) reported that *N. avenacea* Brébisson ex Grunow 1878 is a junior synonym of *Navicula lanceolata* (Agardh) Ehrenberg 1838. Further, this taxon should not be confused with *N. lanceolata* sensu Kützing 1844 (Patrick & Reimer, 1966, p. 511, pl. 48, fig. 19-20), which Lange-Bertalot (1980) transferred to *Navicula trivialis*, or *Navicula lanceolata* sensu Hustedt 1930 (Foged, 1981, p. 117, pl. 31, fig. 17), which Lange-Bertalot (1980, p. 32) transferred to *N. pseudolanceolata*.

*Navicula lyra* Ehrenberg 1843

(Plate 5, Figure 1)

Syn: *Lyrella lyra* (Ehrenberg) Karayeva 1978

Description: Hendey, 1964, p. 209, pl. 33, fig. 2.

Hustedt, 1927-66, III, p. 500, fig. 1550-51; Patrick and Reimer, 1966, p. 443, pl. 39, fig. 5-6; Riznyk, 1973, p.127, pl. 12, fig. 1; Rao and Lewin, 1976, p. 195, fig. 239-245; John, 1983, p. 94, pl. 40, fig. 1-4.

Dimensions: L: 70-120 µm. W: 27-40 µm. Str: 10-20 ITM.

Ecology: Epipsammic; epipelic. α–mesohalobous/polyhalobous. Patrick and Reimer (1966, p. 443): "Brackish to marine water." Hendey, 1964, (p. 209): "The species favours a fairly high salinity and clean seawater, without pollution or excess organic material."

Distribution: WB: Indicative of sand flats from the open bay; rare in Holocene samples. Recorded at Ledbetter Point by Tynni (1986). Common in Yaquina estuary, on sandy substratum (Riznyk, 1973). Cosmopolitan.

Remarks: John (1983, p. 94): "Considerable variation in the shape of valves, observed ranging from elliptic to lanceolate with several intermediate forms."

Differs from *N. lyra* var. *elliptical* ("*Navicula lyroides* Hendey 1958") by having more puncta per "axial striae" (Hendey, 1964, p. 209), reaching "four or more at the valve apices" compared to one or two for *N. lyra* var. *elliptica*..

*Navicula lyra* var. *elliptica* A. Schmidt 1874

(Plate 5, Figure 2)

Syn: *Navicula lyroides* Hendey 1958; *Lyrella lyroides* (Hendey) Mann in Round et al., 1990

Description: Hendey, 1964, p. 209, pl. 33, fig. 3,4. (As *N. lyroides*).

Riznyk, 1973, p. 127, pl. 12, fig. 2.

(As *N. lyroides*): Hendey, 1958, p. 60, pl. 5, fig. 3.

(As *Navicula lyra*): Brockmannnn, 1950, p. 19, pl. 3, fig. 15.

Dimensions: L: 70-120 µm. W: 30-46 µm

Ecology: Epipsammic; epipelic. α–mesohalobous/polyhalobous.

Distribution: WB: Indicative of sand flats in Willapa Bay; more common than *N. lyra*. Rare in Holocene samples. Found only on sandy substrate in Yaquina estuary (Riznyk, 1973). Hendey (1964, p. 210): "A littoral species, widely distributed on the shores of all North Sea countries... The species favours clean water conditions and while seldom found in large numbers enjoys and almost ubiquitous distribution."

Remarks: Differs from *N. lyra* by lacking produced apices, and therefore the shorter axial striae near the apices of the valve do not force the lateral areas outward, as they do for *N. lyra* (Hendey 1964, p. 209). The two taxa are usually found together, but *N. lyra* var. *elliptica* is the more common form in Willapa Bay samples.

*Navicula mutica* Kützing 1844

(Plate 5, Figure 3)

Syn: *Luticola mutica* (Kützing) Mann in Round et al. 1990

Description: Patrick and Reimer, 1966, p. 454, pl. 42, fig. 2.

Hustedt, 1927-66, III, p. 583, fig. 1592a-f; Foged, 1978, p. 76, pl. 25, fig. 13; Foged, 1979, p. 93, pl. 28, fig. 11; Germain, 1981, p. 209, pl. 79, fig. 1-4.; John, 1983, p. 94, pl. 40, fig. 5-8; Laws, 1988, p. 166, pl. 24, fig. 13, 14; Krammer & Lange-Bertalot, 1986, p. 149, pl. 61, fig. 1-7.

Dimensions: L: 10-40 µm. W: 7-12 µm. Str: 14-20 ITM.

Ecology: Epipelic; periphytic; aerophilous. Oligohalobous (indifferent); pH circumneutral (Foged, 1979). Patrick and Reimer, 1966, (p. 454): "Found in fresh, brackish, and alkaline water; often an aerophil."

Distribution: WB: A dominant species in oligohalobous and mesohalobous middle and upper intertidal samples. Particularly abundant in samples from the highest part of a *Deschampsia* marsh on the lower Niawiakum River. Rare to common in Holocene samples; particularly frequent in peaty sediment. Cosmopolitan.

Remarks: Distinguished by the narrow raphe sternum, the radiate striae, and the distinct single stigma. Some variety in form was observed, similar to that reported by John (1983).

*Navicula muticoides* Hustedt 1949

(Plate 5, Figure 4)

Syn: *Luticula muticoides* (Hustedt) Mann 1990

Description: John, 1983, p. 95, pl. 40, fig. 12-14.

Hustedt, 1927-66, III, p. 598, fig. 1602;Patrick & Reimer, 166, p. 457, pl. 42, fig. 10.

Dimensions: L: 12-37 µm. W: 8-15 µm. Str: 24-26 ITM.

Ecology: Oligohalobous (indifferent); periphytic, benthic (John, 1983).

Distribution: WB: Very rare in modern samples; observed only in Holocene samples collected farthest up-valley (Site 4, Niawiakum River; Figure 2).

*Navicula phyllepta* Kützing 1844

(Plate 5, Figure 5)

Syn: *Navicula lanceolata* var. *phyllepta* (Kützing) Van Heurck 1885

Description: Krammer and Lange-Bertalot, 1986, p. 104, pl. 32, fig. 5-11.

Germain, 1981, p. 190, pl. 72, fig. 14-17; Krammer & Lange-Bertalot, 1985, p. 85, pl. 21, fig. 5.

(As *N. cryptocephala*): Brockmannnn, p. 16, pl. 2, fig. 24-30 as *N. cryptocephala*).

Dimensions: L: 12-45 µm. W: 4-8 µm. Str: 14-20 ITM.

Ecology: Epipelic. Mesohalobous (euryhaline?).

Distribution: WB: Rare in salt marsh samples; rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the valve shape, strongly radiate striae, and absence of a central area. Superficially similar to *N. veneta*, which has coarser striae, and well-defined central and apical nodules. Compare Krammer and Lange-Bertalot, 1986, pl. 32: fig. 1-4 for *N. veneta*, and fig. 5-11 for *N. phyllepta*. Hendey (1964, p. 190, pl. 37, fig. 3) shows "*Navicula phyllepta*" with a large

orbicular central area that differs from specimens figured by Germain and Krammer and Lange-Bertalot. Hendey's specimen is closer to *N. trivialis* as figured by Krammer and Lange-Bertalot (1986, p. 110, pl. 35, fig. 1-4).

*Navicula punctulata* W. Smith 1853

Syn: *Navicula marina* Ralfs in Pritchard 1861; *Petroneis marina* Mann in Round et al. 1990

Description: Patrick & Reimer, 1966, p. 449, pl. 41, fig. 1.

John, 1983, p. 96, pl. 41, fig. 1,2.

(As *Navicula marina* Ralfs in Pritchard 1861): Hustedt, 1927-66, III, p. 705, fig. 1697; Brockmann, 1950, p. 19, pl. 3, fig. 17; Hendey, 1964, p. 207, pl. 31, fig. 1-3; Foged, 1979, p. 76, pl. 28, fig. 5,7,8; Foged, 1981, p. 117, pl. 37, fig. 2.

Dimensions: L: 39-65 µm. W: 25-30 µm. Str: 10-13 ITM. Puncta: 8-12 ITM near the center of the valve, 16-18 ITM near the ends of the valve.

Ecology: Epipelic. α–mesohalobous/polyhalobous.

Distribution: WB: Rare in Holocene samples; modern distribution not recorded. John (1983, p. 96): "Occurred frequently in small numbers in the lower stations of Swan River."

Remarks: Laws (1988, p. 167) discussed the rules of priority making *punctulata* the proper epithet for this taxon. Distinguished by the coarse puncta interrupted by wavy longitudinal lines, the sub-oval central area, and the axial areas which broaden along the middle part of the raphe branches.

*Navicula pusilla* Wm. Smith 1853

Syn: *Cosmioneis pusilla* (Wm. Smith) Mann and Stickle in Round et al. 1990

Description: Patrick and Reimer, 1966, p. 452, pl. 41, fig. 7.

Hustedt, 1927-1966, III, p. 722, fig. 1704; Hendey, 1964, p. 208; Foged 1978, p. 97, pl. 32, fig. 9; Foged 1979, p. 79, pl. 30, fig. 1; Foged 1981, p. 122, pl. 34, fig. 7,8; Germain, 1981, p. 216, pl. 81, fig. 9; Krammer & Lange-Bertalot, 1986, p. 167, pl. 57, fig. 7-9.

Dimensions: L: 25-50 µm. W: 12-25 µm. Str: 10-14 ITM (center); 18-20 ITM (ends). Puncta: 16-20 ITM.

Ecology: Epipelic; aerophilous. Oligohalobous (indifferent); circumneutral pH (Foged, 1981). Patrick and Reimer (1966, p. 452): "Seems to prefer fresh water of high mineral content or slightly brackish water; aerophil; often found in cool temperate areas."

Distribution: WB: A common mesohalobous high marsh species associated with thick stands of *Deschampsia*; apparently aerophilic. Rare cells also observed in channel-bank samples from the Niawiakum River. Cosmopolitan.

Remarks: This is one of the indicator species for the brackish high marsh environment. The valve is robust, and is well-preserved in Holocene deposits around Willapa Bay.

*Navicula pusilla* variety 1

(Plate 5, Figure 6)

Description: Valve broadly lanceolate with very slightly produced broad apices. Striae distinctly punctate, radiate, more widely separated at the middle than near the apices. Raphe filiform, hooked in same direction at apices, with rounded central fissures. Axial area linear, widening gradually toward an oval central area. Only a few of the central striae are of irregular length.

Dimensions: L: 60-65 µm. B: 26-28 µm. Str: 7-10 ITM at the middle; 16-18 ITM near the apices.

Ecology: Epipelic; aerophilic. Mesohalobous euryhaline (?).

Distribution: WB: Live specimens observed in middle and upper intertidal samples from the South Fork Willapa and Niawiakum rivers; occurs with the *N. pusilla*. Common in late Holocene sediments in the Niawiakum River valley.

Remarks: Hustedt (1927-66, III) and Krammer & Lange-Bertalot (1986) consider this taxon to be conspecific with *Navicula pusilla* var. *pusilla*. Brockmann (1950, pl. 2, fig. 31) recorded it as "*Navicula pusilla* var. *lanceolata*." I have documented the two forms separately because of apparent differences in their modern distributions. *N. pusilla* (sensu stricto) is a common aerophilous on high marshes; "*N. pusilla* var." is more rare, and may be associated with the transition between high and low marsh.

In addition, this species resembles the marine tideflat benthic species *N. punctulata*. However, the interior parts of the striae of *N. punctulata* are interrupted by longitudinal lines, giving puncta the appearance of being more widely separated. Also, the central area of *N. punctulata* is extended laterally in a small stauros shape, while the central area of *N. delawarensis* is a distinctly oval extension of the axial area.

*Navicula pygmaea* Kützing 1849

Syn: *Fallacia pygmaea* (Kützing) Stickle and Mann in Round et al. 1990

Description: Patrick and Reimer, 1966, p. 442, pl. 39, fig. 4;
Hustedt, 1927-66, III, p. 538, fig. 1574; John, 1983, p. 97, pl. 41, fig. 6; Krammer & Lange-Bertalot, 1986, p. 171, pl. 65, fig. 1-6; Laws, 1988, p. 167, pl. 24, fig. 18, pl. 25, fig. 3,4.

Dimensions: L: 16-45 µm. W: 8-24 µm. Str: 24-26 µm.

Ecology: Epipelic. Mesohalobous; alkaliphilous (Foged, 1981). Patrick and Reimer (1966, p. 442): "Fresh water of high mineral content and brackish water; sometimes polluted water."

Distribution: WB: Rare in mesohalobous marsh samples from the Niawiakum River; not observed on tidal flats of the open bay. Rare in Holocene samples. Frequent on mud flats and salt marshes of San Francisco estuary (Laws, 1988). Cosmopolitan.

Remarks: The lateral areas narrow towards the central area and the apices; the striae are more widely spaced at the center than near the ends.

*Navicula radiosa* Kützing 1844

Description: Patrick & Reimer, 1966, p. 509, pl. 48, fig. 15.

Foged, 1981, p. 123, pl. 32, fig. 1, pl. 35, fig. 5; Germain, 1981, p. 182, pl. 70, fig. 1-5; Krammer & Lange-Bertalot, p. 99, pl. 29, fig. 1-4.

Dimensions: L: 40-120 µm. W: 10-19 µm. Str: 10-12 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); circumneutral pH (Foged, 1981). Patrick and Reimer (1966, p. 509): "Common in all types of circumneutral fresh water; oligohalobous to indifferent to salt concentration."

Distribution: WB: Common in mesohalobous middle intertidal samples from the upper Niawiakum River; rare valves also observed in lower and upper intertidal samples. Cosmopolitan.

Remarks: Distinguished by the tapered valve shape and strongly radiate striae. Patrick and Reimer, 1966, (p. 509): "Axial area and central nodule often appearing more heavily silicified than the rest of the valve."

*Navicula ramosissima* (Agardh) Cleve 1895

Description: John, 1983, p. 98, pl. 41, fig. 7,8.

Hendey, 1951, p. 54, pl. 14, fig. 3; Hendey, 1964, p. 194, pl. 30, fig. 9.

Dimensions: L: 27-45 µm. W: 4-5.5. µm. Str: 12-13 ITM.

Ecology: Epiphytic; periphytic. Mesohalobous euryhaline.

Distribution: WB: Rare to common in silty tidal flat samples; very rare (allochthonous) valves observed in mesohalobous marsh samples. Not recorded in Holocene samples. Hendey, 1964 (p. 194): "Common and widespread on almost any hard substratum on all North European coasts. Often abundant on English Channel coasts." Observed in large numbers as an epiphyte in Swan River estuary (John, 1983).

Remarks: The striae are parallel and closely spaced; the axial area and central area are indistinct.

*Navicula salinarum* Grunow in Cleve and Grunow 1880

Description: Patrick and Reimer, 1966, p. 502, pl. 48, fig. 1,2.

Hustedt, 1930, p. 295, fig. 498; Rao and Lewin, 1976, p. 203, fig. 249-251; Foged, 1978, p. 98, pl. 30, fig. 9; John, 1983, p. 99, pl. 42, fig. 1,2; Krammer and Lange-Bertalot, 1986, p. 110, pl. 35, fig. 5-8; Laws, 1988, p. 167, pl. 24, fig. 6-8.

Dimensions: L: 23-41 µm. W: 8-12 µm. Str: 14-18 ITM.

Ecology: Epipelic. Mesohalobous, euryhaline, circumneutral pH (Foged, 1978). Patrick and Reimer (1966, p. 502): "Seems to prefer brackish water or fresh water of high mineral content."

Distribution: WB: Most frequent in mesohalobous middle and upper intertidal marsh samples; very rare in Holocene samples. Laws (1988, p. 167): "Common in intertidal salt-marsh and mud-flat sediments of present (San Francisco) bay."

Remarks: Closely related to *N. trivialis*, but with more strongly produced apices and well-developed alternating short and long central striae, and lacking distinctly punctate striae.

*Navicula seminulum* Grunow 1860

Syn: *Stellaphora seminulum* (Grunow) Mann 1989; *Navicula atomoides* Grunow in Van Heurck 1880 pro parte.

Description: Patrick and Reimer, 1966, p. 489, pl. 46, fig. 19-20.

Hustedt, 1927-66, III, p. 241, fig. 1367; Germain, 1981, p. 230, pl. 85, fig. 22-30; Krammer and Lange-Bertalot, 1986, p. 230, pl. 76, fig. 30-36.

Dimensions: L: 7-18 µm. W: 4-5 µm. Str: 18-20 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); pH circumneutral to alkaliphilous (Foged, 1981).

Distribution: WB: Common in oligohalobous channel bank and marsh sediments from the South Fork Willapa River. Cosmopolitan.

Remarks: Observations for Willapa Bay samples include the variety *hustedtii* as recognized by Patrick and Reimer (1966).

*Navicula stankovicii* Hustedt 1945

(Plate 5, Figure 7)

Description: Krammer and Lange-Bertalot, 1986, p. 106, pl. 33, fig. 1-4.

Dimensions: L: 25-46 µm. W: 6-8 µm. Str: 14-18 ITM.

Ecology: Epipelic. Oligohalobous (indifferent) (?).

Distribution: WB: Epipelic in low-marsh sediments along the open bay. Occurs in Holocene sediments with *N. cryptotenella.*

Remarks: This diatom very similar to *N. cryptotenella* but with a larger valve, and a wider, more distinct raphe sternum. The two species are possibly transitional. Also strongly resembles more symmetrical forms of *Cymbella pusilla.*

*Navicula tenneloides* Hustedt 1937

Syn: *Navicula carniolensis* Hustedt 1945

Description: Krammer and Lange-Bertalot, 1986, p. 117, pl. 38, fig. 16-20.

Patrick and Reimer, 1966, p. 534, pl. 51, fig. 7.

Dimensions: L: 14-21 µm. W: 2.5-4 µm. Str: 15-17 ITM.

Ecology: Epipelic; aerophilous. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Aerophile; pH 7.5-7.8 (Patrick and Reimer, 1966). Found in springs, creeks, and aerophilic on wet mossy surfaces (Krammer and Lange-Bertalot, 1986).

Distribution: WB: Observed in upland-transition samples from the Niawiakum River.

Remarks: Associated with aerophilous conditions in Willapa Bay. Recognized by the small lanceolate valve with strongly radiate striae; hyaline thickening at apices appear distinct in LM.

*Navicula tripunctata* (O.F. Muller) Bory 1824

Syn: *Navicula gracilis* Ehrenberg 1838

Description: John, 1983, p. 103, pl. 43, fig. 2-5.

Patrick & Reimer, 1966, p. 513, pl. 49, fig. 3; Cox, 1979, p. 150, pl. 1-3, fig. 1-6; Krammer & Lange-Bertalot, 1986, p. 95, pl. 27, fig. 1-3; Laws, 1988, p. 167, pl. 25, fig. 15-18.

(As *N. gracilis*): Germain, 1981, p. 184, pl. 71, fig. 1-3.

Dimensions: L: 30-52 µm. W: 5.5-7 µm. Striae 12-13 in 10 µm.

Ecology: Epipelic. Oligohalobous (indifferent); circumneutral pH (Foged, 1981). Observations by Laws (1988, p. 168) suggest that *N. tripunctata* is euryhaline.

Distribution: WB: Rare in mesohalobous lower intertidal samples from the Niawiakum River; rare valves allochthonous in middle and upper intertidal samples. Common in benthic samples, but absent from epiphyte samples in Netarts Bay (Whiting, 1983).

Remarks: Distinguished by the broad linear-lanceolate valve with parallel or slightly constricted margins, the nearly parallel striae, and the rectangular central area.

NEIDIUM Pfitzer 1871

*Neidium densestriatum* (Østrup) Krammer 1985

Description: Krammer and Lange-Bertalot, 1986, p. 269, pl. 100, fig. 10-13.

(As *N. ladogensis* var. *densestriatum*): Patrick & Reimer, 1966, p. 406, pl. 37, fig. 7.

(As *C. ladogensis* var. *densestriatum*): Hustedt, 193, p. 234, fig. 354;

Germain, 1981, p. 240, pl. 86, fig. 29; Jensen, 1985, p. 771, fig. 354;

Dimensions: L: 19-46 µm. W: 12-17 µm. Str: 26-28 ITM.

Ecology: Benthic. Oligohalobous (Patrick and Reimer, 1966); euryhaline (Germain, 1981). Patrick and Reimer (1966, p. 406): "Most characteristic of smaller, dystrophic streams." Reported from a lake with a sandy bottom by Hustedt (1930).

Distribution: WB: Rare in Holocene samples; modern distribution not recorded.

Remarks: The proximal ends of the raphe are straight to very slightly bent in opposite directions; puncta and striae are of equal densities.

NITZSCHIA Hassall 1845

*Nitzschia acuminata* (W. Smith) Grunow 1878

Description: Krammer and Lange-Bertalot, 1988, p. 44, pl. 34, fig. 4-6.

Hustedt, 1930, p. 401, fig. 764; Hendey, 1964, p. 280, pl. 39, fig. 10; Riznyk, 1973, p. 128, pl. 13, fig. 1; John, 1983, p. 165, pl. 69, fig. 1,2; Jensen, 1985, p. 854, fig. 764.

Dimensions: L: 50-100 µm. W: 13-18 µm. Str: 12-16 ITM. Fib: 12-16 ITM.

Ecology: Epipelic; mesohalobous/polyhalobous. Common in silty tidal flat sediments from Yaquina estuary (Riznyk, 1973), and common in Recent and Sangamon sediments in San Francisco Bay (Laws, 1988). John (1983, p. 165) reports this taxon from "benthic, periphytic and epiphytic samples" from β–mesohalobous stations of the Swan River estuary; Whiting (1983) reported it as present in benthic samples but absent from epiphyte samples in Netarts Bay.

Distribution: WB: Rare in silty tidal flat samples; very rare in Holocene samples. Hendey (1964, p. 280): "A brackish water form common in all European countries." Cosmopolitan.

Remarks: Superficially similar to *N. hungarica*, but differs by the broader valve and keel fibulae that appear to be continuous with the striae.

*Nitzschia aerophila* Hustedt 1944

Syn: *Tryblionella aerophila* (Hustedt) Mann in Round et al. 1990

Description: Krammer & Lange-Bertalot, 1988, p. 44, pl. 51, fig. 12-15

Dimensions: L: 23-31 µm. W: 6-8 µm. Str: 26-30 ITM. Fib: 9-11 ITM.

Ecology: Epipelic; aerophile. Mesohalobous.

Distribution: WB: Very rare in β–mesohalobous samples; rare in a few Holocene samples.

Remarks: Distinguished by the broad valve, indented midway, with fine striae and robust keel fibulae.

*Nitzschia angularis* Smith 1853

Description: Hendey, 1964, p. 281, pl. 39, fig. 6.

Riznyk, 1973, p. 128, pl. 13, fig. 2; Laws, 1988, p. 168, pl. 33, fig. 10.

Dimensions: L: 80-160 µm. Fibulae: 4-5 ITM. Str: 30 ITM.

Ecology: Epipelic; epiphytic. Mesohalobous (euryhaline ?).

Distribution: WB: Very rare in marsh-edge tidal flat samples at Stony Point; very rare in Holocene sample. Present in epiphyte (*Zostera*) samples in Netarts Bay (Whiting, 1983). Frequent in intertidal mud flats of San Francisco estuary (Laws, 1988). Cosmopolitan.

Remarks: Distinguished by the valve shape and the prominent, central keel.

*Nitzschia* cf. *Nitzschia angustata*

Description: Valve linear-lanceolate with slightly undulate margins and capitate apices. Transapical striae distinct; keel fibulae cannot be distinguished from striae.

Dimensions: L: 24-28 µm. W: 4-6 µm. Fibulae: 9-11 ITM. Str: 9-11 ITM.

Ecology: Epipelic. Oligohalobous (indifferent) (?).

Distribution: WB: Most frequent in oligohalobous/β–mesohalobous middle intertidal samples; not observed in Holocene samples.

Remarks: This taxon resembles *Nitzschia angustatula* Lange-Bertalot (in Lange-Bertalot and Krammer, 1987, p. 6, pl. 18, fig 1-4), but with a somewhat larger valve, and coarser overall structure.

*Nitzschia brevissima* Grunow in Van Heurck 1881

Syn: *Nitzschia obtusa* var. *brevissima* (Grunow) Van Heurck 1885

Description: Krammer and Lange-Bertalot, 1988, p. 30, pl. 22, fig. 1-6.

Dimensions: L: 18-54 µm. W: 3.5-6.5 µm. Fibulae: 5-10 ITM. Str: 30-38 ITM.

Ecology: Epipelic. Brackish, estuarine (Krammer and Lange-Bertalot, 1988).

Distribution: WB: Common in oligohalobous upper intertidal samples; very rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the short sigmoid valve and blunt apices. According to Lange-Bertalot and Krammer (1987), other closely-related species include *N. obtusa* , *N. nana*, and *N. terrestris.*

*Nitzschia coarctata* Grunow in Cleve and Möller 1878

(Plate 5, Figure 8)

Syn: *Nitzschia punctata* var. *coarctata* Hustedt in Schmidt 1922; *Nitzschia punctata* f. *coarctata* (Grunow) Hustedt 1957; *Tryblionella coarctata* (Grunow in Cleve and Grunow) Mann in Round et al. 1990

Description: John, 1983, p. 173, pl. 72, fig. 4 (as *Nitzschia punctata* var. *coarctata* ).

Krammer and Lange-Bertalot, p. 50, pl. 38, fig. 13-15A

(As *Nitzschia punctata* var. *coarctata*): Riznyk, 1973, p. 129, pl. 13, fig. 9.

Foged, 1978, p. 109, pl. 43, fig. 10; 1979, pl. 40, fig. 16, 17; Laws, 1988, p. 169, pl. 32, fig. 6

Dimensions: L: 40-50 µm. W: 8-10 µm. Str: 11-12 ITM.

Ecology: Epipelic, epipsammic (?). Polyhalobous, euryhaline (Foged, 1978)..

Distribution: WB: Rare in mesohalobous lower intertidal samples, most frequent at Toke Point; rare in a few Holocene samples. Cosmopolitan.

Remarks: Distinguished by the robust, punctate panduriform valve.

*Nitzschia commutata* Grunow in Cleve and Grunow 1880

Description: Hustedt, 1930, p. 405, fig. 774;

Germain, 1981, p. 338, pl. 126, fig. 11-13; Foged, 1981, p. 137, pl. 57, fig. 7,9; Jensen, 1985, p. 857, fig. 774; Krammer and Lange-Bertalot, 1987, p. 10, pl. 22, fig. 1-9; Krammer and Lange-Bertalot, 1988, p. 56, pl. 42, fig. 1-6.

Dimensions: L: 50-80 µm. W: 7-12 µm. Fibulae: 7-10 ITM. Str: 20-24 ITM.

Ecology: Epipelic. Foged (1981, p. 86): "Halophilous (mesohalobous ?). pH: circumneutral.

Distribution: WB: Common in mesohalobous middle and upper intertidal samples. Observed in marsh samples at Ledbetter Point. Rare to common in Holocene samples. Cosmopolitan.

Remarks: Distinguished in girdle view by the squarish ends and slightly constricted middle. In valve view the inflected keel, strong keel fibulae (about 10 ITM) and striae (about 20 ITM), and the asymmetrical capitate apices are all distinctive features.

*Nitzschia compressa* (Bailey) Boyer 1916

(Plate 5, Figure 9)

Syn: *Tryblionella punctata* Wm. Smith 1853; *Nitzschia punctata* (W. Smith) Grunow 1878

Description: John, 1983, p. 172, pl. 72, fig. 1-3 (as *N. punctata*).

Krammer and Lange-Bertalot, 1986, p. 46, pl. 37, fig. 1-10.

(As *N. punctata*): Jensen, 1985, p. 853, fig. 762; Hendey, 1964, p. 278, pl. 39, fig. 11; Foged, 1978, p. 109, pl. 44, fig. 7, 12; Laws, 1988, p. 169, pl. 31, fig. 11-14.

Dimensions: L: 17-44 µm. W: 8-11 µm. Str: 8-10 ITM. Puncta: 14 ITM.

Ecology: Epipelic. Foged (1978, p. 109): "Polyhalobous, euryhaline."

Distribution: WB: Rare in silty tidal flat samples; rare in Holocene sediment. Laws (1988, p. 169): "This is one of the most common species of *Nitzschia* in the Sangamon and Recent flora. The specimens from San Francisco Bay show a wide range of sizes and shapes but seem clear to

belong to this species." Rare in benthic samples in Netarts Bay (Whiting, 1983), not reported by Riznyk (1973) for Yaquina estuary, or by Tynni (1986) for Ledbetter Point.

Remarks: Distinguished by the broadly lanceolate to elliptical valves, the apiculate apices, and the distinct punctate striae.

*Nitzschia compressa* var. *vexans* (Grunow) Lange-Bertalot 1987

Syn: *Nitzschia obscura* Grunow in Cleve and Grunow 1880; *Nitzschia vexans* Grunow in Van Heurck 1881

Description: Krammer and Lange-Bertalot, 1988, p. 46, pl. 38, fig. 5-8;

Dimensions: L: 12.5-30 µm. W: 3.5-8 µm. Str: 16-21 ITM.

Ecology: Epipelic. Polyhalobous/euryhaline.

Distribution: WB: Rare in mesohalobous lower and middle intertidal samples; rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the elliptical valve with nearly parallel margins that are abruptly reduced to small subrostrate apices. Transapical striae are distinctly punctate.

*Nitzschia constricta* (Kützing) Ralfs in Pritchard 1861

Syn: *Nitzschia apiculata* (Gregory) Grunow 1878

Description: Krammer & Lange-Bertalot, 1988, p. 43, pl. 35, fig. 1-6.

(As *Nitzschia apiculata*): Hustedt, 1930, p. 401, fig. 765; Riznyk, 1973, p. 128, pl. 13, fig. 3; Foged, 1978, p. 103, pl. 45, fig. 13; Germain, 1981, p. 336, pl. 127, fig. 8; John, 1983, p. 166, pl. 69, fig. 3-4; Jensen, 1985, p. 854, fig. 764.

Dimensions: L: 20-58 µm. W: 4.5-8.5 µm. Str: (14)15-20 ITM.

Ecology: Epipelic. Foged (1978, p. 103): "Mesohalobous, euryhaline, alkaliphilous."

Distribution: WB: Rare in mesohalobous lower intertidal samples; rare in Holocene samples. Rare in Netarts Bay (Whiting, 1983) and Yaquina estuary (Riznyk, 1973). Reported at Ledbetter Point by Tynni (1986). Cosmopolitan.

Remarks: Distinguished by linear valve, slightly constricted at the middle, with produced apices. Striae are the same number as keel fibulae, and are interrupted by a distinct hyaline fold.

*Nitzschia debilis* (Arnott) Grunow in Cleve & Grunow 1880

Syn: *Nitzschia tryblionella* var. *debilis* (Arnott) Hustedt 1913

Description: Krammer & Lange-Bertalot, 1988, p. 39, pl. 27, fig. 9-11.

(As *Nitzschia tryblionella* var. *debilis*): Hustedt, 1930, p. 400, fig. 759; Jensen, 1985, p. 852, fig. 759.

Dimensions: L: 13-26 (31?) µm. W: 7-10 µm. Fibulae: (6)8-10 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: WB: Common in mesohalobous deposits about MHW; rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the delicate valve with a distinct median fold. Common marsh diatom.

*Nitzschia dissipata* (Kützing) Grunow 1862

Description: Krammer and Lange-Bertalot, 1988, p. 19, pl. 11, fig. 11-14.

Hustedt, 1930, p. 412, fig. 789; Germain, 1981, p. 344, pl. 130, fig. 1-10; John, 1983, p. 167, pl. 69, fig. 6,7; Jensen, 1985, p. 864, fig. 789.

Dimensions: L: 12.5-85 µm. W: 3.5-7 (8) µm. Fibulae: 5-11 ITM. Str: 39-50 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1978).

Distribution: WB: Widely distributed in oligohalobous and mesohalobous intertidal samples; rare in Holocene samples. Rare in Netarts Bay (Whiting, 1983); a single specimen reported from San Francisco Bay (Laws, 1988). Cosmopolitan.

Remarks: The keel is strongly eccentric, and marked with distinctive rectangular fibulae. This is one of the most widely-distributed diatoms in Willapa Bay.

*Nitzschia fasciculata* (Grunow) Grunow in Van Heurck 1881

(Plate 5, Figure 10)

Description: John, 1983, p. 168, pl. 49, fig. 8

Hustedt, 1930, p. 421, fig. 815; Germain, 1981, p. 368, pl. 139, fig. 12, 13; Jensen, 1985, p. 874, fig. 815; Laws, 1988, p. 168, pl. 33, fig. 14,15; Krammer and Lange-Bertalot, 1988, p. 33, pl. 22, fig. 12, 13.

Dimensions: L: 43-75 µm. W: 3-7 µm. Str: 28-30 ITM. Fibulae: 6-7 ITM.

Ecology: Epipelic. Mesohalobous.

Distribution: WB: Observed most frequently in α–mesohalobous high and low marsh samples from the Niawiakum River. Laws (1988, p. 168, ): "Frequent from intertidal mud-flat and salt-marsh samples, Recent sediments, Albany mud flats" (of San Francisco estuary).

Remarks: Distinguished by the sigmoid valve and robust keel fibulae, 6-7 in 10 µm.

*Nitzschia frustulum* (Kützing) Grunow in Cleve and Grunow 1880

Syn: *Synedra frustulum* Kützing 1844; *Synedra minutissima* Kützing 1844; *Nitzschia frustulum* var. *subsalina* Hustedt 1925.

Description: Krammer and Lange-Bertalot, 1988, p. 94, pl. 68, fig. 1-19.

Hustedt, 1930, p. 414, fig. 795; Foged, 1974, p. 89, pl. 31, fig. 6; Jensen, 1985, p. 868, fig. 795; Pankow, 1990, p. 283, pl. 70, fig. 1.

Dimensions: L: L: 5-60 µm. W: 2-4.5 µm. Fibulae: 10-16 ITM. Str: 19-30 ITM.

Ecology: Oligohalobous (halophil); benthic (Pankow, 1990).

Distribution: WB: Rare in the intertidal marsh at transect T1 (Willapa River). Very rare in Holocene samples. Cosmopolitan.

Remarks: The sides of the valve are parallel to gently constricted at the middle, and the apices are usually rounded to slightly subrostrate. Very variable in size, but fibulae and striae are distinct. WB specimens are often less than 20 µm long.

*Nitzschia gandersheimiensis* Krasske 1927

Syn: *Nitzschia tubicola* Grunow in Cleve and Grunow 1880

Description: Lange-Bertalot and Simonsen, 1987, p. 28, fig. 40-53, 60-112, 289.

Laws, 1988, p. 168, pl. 33, fig. 2-4.

(As *N. tubicola*): Krammer and Lange-Bertalot, 1988, p. 90, pl. 63, fig. 8-12, pl. 64, fig. 1-16.

Dimensions: L: 14-70 µm. W: 3-6 µm. Fibulae: 8-18 ITM. Str: 23-42 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous (?) (Foged, 1981).

Distribution: WB: Widely distributed in middle and upper intertidal samples; rare in Holocene samples.

Remarks: Lange-Bertalot and Simonsen (1978) discussed "*N. gandersheimiensis*" in some detail, but Krammer and Lange-Bertalot (1988) included this taxon as a subgroup of "*Nitzschia tubicola*". According to Lange-Bertalot and Simonsen (1978), very similar to *N. capitellata [= N. intermedia]*, but differs in the spacing of the median fibulae.

*Nitzschia granulata* Grunow in Cleve and Möller 1879

(Plate 5, Figure 11)

Syn: *Tryblionella granulata* (Grunow) Mann in Round et al. 1990

Description: John, 1983, p. 168, pl. 49, fig. 9-10.

Riznyk, 1973, p. 128, pl. 13, fig. 4; Foged, 1978, p. 105, pl. 54, fig. 10; Foged, 1979, p. 87, pl. 40, fig. 14, 15; Laws, 1988, p. 168, pl. 32, fig. 2; Krammer and Lange-Bertalot, 1988, p. 45, pl. 35, fig. 9-13.

Dimensions: L: 22-34 µm. W: 12-15 µm. Fibulae: 6-7 ITM. Rows of puncta on valve face: 6 ITM.

Ecology: Epipelic. Euhalobous; cosmopolitan (Foged, 1979).

Distribution: WB: Rare live cells observed in mesohalobous intertidal samples. Rare in modern benthic samples from Netarts Bay (Whiting, 1983); common on tidal flats in Yaquina estuary (Riznyk, 1973). John (1983, p. 168): "Occurred frequently as a benthic form in the lower stations and occasionally in the upper stations."

Remarks: Distinguished by the valve shape and coarse puncta. Very fossilizable, and thus common in Holocene deposits.

*Nitzschia lanceola* Grunow in Cleve and Grunow 1880

(Plate 5, Figure 12)

Description: Cleve and Grunow, p. 68.

Krammer and Lange-Bertalot, pl. 38, fig. 11,12

Dimensions: L: 30-55 µm. W: 9-10 µm. Puncta: 7.5-9 ITM.

Ecology: Epipelic. Mesohalobous/polyhalobous.

Distribution: WB: Rare in mesohalobous lower intertidal samples, particularly at Stony Point and the lower Niawiakum River.

Remarks: Distinguished by the broadly lanceolate valve with narrowed apices; the strongly eccentric keel stands out in LM.

*Nitzschia levidensis* (Smith) Grunow in Van Heurck 1881

Syn: *Nitzschia tryblionella* var. *levidensis* Wm. Smith 1856

Description: Krammer & Lange-Bertalot, 1988, p. 37, pl. 28, fig. 1-11; pl. 29, fig. 1-5.

Hendey, 1964, p. 277, pl. 44, fig. 4; Foged, 1981, p. 140, pl. 56, fig. 33,35;

Laws, 1988, p. 169, pl. 31, fig. 10.

(As *N. tryblionella* var. *levidensis*): Germain, 1981, p. 334, pl. 126, fig. 1-6

Jensen, 1985, p. 852, fig. 760; Hustedt, 1930, p. 399, fig. 760; Foged, 1978, p. 106, pl. 44, fig. 6; pl. 45, fig. 1.

Dimensions: L: 18-65 (82) Mm. W: 8-23 (26) µm. Fibulae: 6-12 ITM. Str: 35-36 ITM. Transapical costae 5-12 (14?) ITM.

Ecology: Epipelic. Foged (1981, p. 140): Halophil to mesohalobe. pH circumneutral" Hendey (1964, p. 277): "A common species in brackish water, frequent on all British coasts."

Distribution: WB: Most frequent in β–mesohalobous lower intertidal (channel bank) samples. Rare in modern San Francisco Bay (Laws, 1988). Not reported for Yaquina estuary (Riznyk, 1973) or Netarts Bay (Whiting, 1983).

Remarks: Differs from *N. tryblionella* by the smaller, broadly lanceolate valve with cuneate apices, and the transapical costae not interrupted by a hyaline space.

*Nitzschia levidensis* var. *victoriae* (Grunow) Cholnoky 1966

(Plate 6, Figure 1)

Syn: Syn: *Nitzschia tryblionella* var. *victorae* Grunow in Cleve and Grunow 1880

Description: John, 1983, p. 175, pl. 73, fig. 6-9.

Krammer & Lange-Bertalot, 1988, p. 38, pl. 29, fig. 1-5.

(As *N. tryblionella* var. *victorae*): John, 1983, p. 175, pl. 73, fig. 6-9; Jensen, 1985, p. 852, fig. 758; Foged, 1978, p. 111, pl. 43, fig. 9; Foged, 1979, p. 91, pl. 41, fig. 9,10; pl. 42, fig. 1; Foged, 1981, p. 140, pl. 56, fig. 11.

Dimensions: L: 25-80 µµ. W: 11-31 µm. Fibulae: 5-9 ITM.. Transapical costae: 6-9 ITM.

Ecology: Same as *N. levidensis*.

Distribution: Same as *N. levidensis*.

Remarks: Transitional forms between this taxon and *N levidensis* were observed; this was also noted by Foged (1981, p. 140). Differs from *N. levidensis* by having fewer transapical costae, and possibly a coarser valve.

*Nitzschia lorenziana* Grunow in Cleve and Gruno 1880

Syn: *Nitzschia lorenziana* var. *subtilis* Grunow in Cleve and Grunow 1880

Description: Krammer and Lange-Bertalot, 1988, p. 125, pl. 86, fig. 6-10;

(As *N. lorenziana* var. *subtilis*): Hustedt, 1930, p. 423, fig. 820; Jensen, 1985, p. 878, fig. 820; John, 1983, p. 171, pl. 70, fig. 5-6; Pankow, 1990, p. 273, pl. 66, fig. 3.

Dimensions: L: (37)50-190 µm. W: (3)4-7 µm. Fibulae: 6-10 ITM. Str: 13-19 ITM.

Ecology: Benthic; mesohalobous; euryhaline (Pankow, 1990). Brackish water of coastal regions (Krammer and Lange-Bertalot, 1988).

Distribution: WB: Frequent in the upper intertidal (high marsh) and rare in the middle intertidal (low marsh) samples transects T3 and T4 (Niawiakum River; Figure 1). Rare to common in Holocene samples at Site 2 (Figure 2). Cosmopolitan.

Remarks: The protracted apices, sigmoid shape, and the distinct transapical striae are distinguishing characteristics.

*Nitzschia nana* Grunow in Van Heurck 1881

Syn: *Nitzschia obtusa* var. *nana* (Grunow) Van Heurck 1885; *Nitzschia ignorata* Krasske 1929

Description: Krammer and Lange-Bertalot, 1988, p. 26, pl. 17, fig. 4-8.

(As *Nitzschia ignorata* Krasske 1929): Jensen, 1985, p. 876, fig. 819; Germain, 1981, p. 370, pl. 140, fig. 5; Foged, 1981, p. 139, pl. 58, fig. 4; pl. 59, fig. 2.

Dimensions: L: 35-120. W: 3-4.5 µm. Fibulae: 7-11 ITM. Str: 30-36 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); circumneutral pH. (Foged, 1981).

Distribution: WB: Common to abundant in mesohalobous middle and upper intertidal samples; rare in lower intertidal samples; very widely distributed. Cosmopolitan.

Remarks: Distinguished by the sigmoid shape, narrowed apices, and the separated median fibulae.

*Nitzschia navicularis* (de Brébisson ex Kützing) Grunow 1880

(Plate 5, Figure 13,14 )

Description: Krammer and Lange-Bertalot, 1988, p. 45, pl. 35, fig. 7,8. Hendey, 1951, p. 71, pl. 14, fig. 13-14; Hendey, 1964, p. 276, pl. 39, fig. 3-5; Riznyk, 1973, p. 128, pl. 13, fig. 6; Germain, 1981, pl. 127, fig. 9; Jensen, 1985, p. 853, fig. 763; Laws, 1988, p. 169, pl. 32, fig. 1.

Dimensions: L: 30-80 µm. W: 15-25 µm. Fibulae: 6-8 ITM.

Ecology: Epipelic. α–mesohalobous.

Distribution: WB: Observed most frequently in mesohalobous low-marsh samples, particularly at the lower Niawiakum River site. Rare cells also observed in channel bank samples. Hendey (1964, p. 276): "Common and widespread around British coasts; probably favours brackish conditions." Very rare on tidal flat from Yaquina estuary (Riznyk, 1973); not reported in benthic samples from Netarts Bay (Whiting, 1983).

Remarks: Remarks: Distinguished by short coarse striae formed by double rows of small puncta, shorter on one margin than the other, forming a broad eccentric hyaline axial area.

*Nitzschia palea* (Kützing) W. Smith 1856

Description: Krammer and Lange-Bertalot, 1988, p. 85, pl. 59, fig. 1-24, pl. 60, fig. 1-7. Hustedt, 1930, p. 416, fig. 801; John, 1983, p. 171, pl. 70, fig. 12; Germain, 1981, p. 350, pl. 132, fig. 1-11; Foged, 1981, p. 140, pl. 18, fig.2, pl. 19, fig. 6,7; Jensen, 1985, p. 870, fig. 801; Pankow, 1990, p. 285, pl. 71, fig. 1.

Dimensions: L: 15-70 µm. W: 2.5-5 µm. Fibulae: 9-17 ITM. Str: 28-40 ITM.

Ecology: Oligohalobous (indifferent) (Foged, 1981). Oligohalobous, meioeuryhaline (i.e., salinity < 5 ppt) (Pankow, 1990).

Distribution: WB: Common in channel bank and low marsh samples at transects T1 (Willapa River) and T2 (South Fork Willapa River); rare on the high marsh at transects T3 and T4 (Niawiakum River). Cosmopolitan.

Remarks: *N. palea* is a morphologically variable species, and its distribution in Willapa Bay may reflect the inclusion of other closely-related *Nitzschias*.

*Nitzschia pellucida* Grunow in Cleve & Geunow 1880

Description: Krammer & Lange-Bertalot, 1988, p. 63, pl. 47, fig. 4-6; pl. 48, fig. 1-9.

Dimensions: L: ~40-80. W: ~4-8. Fibulae: 12-18 ITM. Str: 30-40 ITM.

Ecology: Brackish water of sea coasts (Krammer and Lange-Bertalot, 1988).

Distribution: WB: Rare to common in upper intertidal (high marsh) samples from the Niawiakum River and Stony Point (Figure 1); very rare in channel bank samples from the Willapa River. Very rare in Holocene samples. Cosmopolitan.

Remarks: Similar but more delicate than *N. bilobata*, and with short rounded fibulae rather than the characteristically long fibulae of *N. bilobata*. Also similar to *N. hybrida*, but more delicate, with narrower valves, and smaller fibulae. The spacing between fibulae may be somewhat irregular, and the central fibulae are more widely spaced on either side of a central nodule.

*Nitzschia perminuta* (Grunow) M. Peragallo 1903

Syn: *Nitzschia palea* var. *perminuta* Grunow in Cleve and Grunow 1880; *Nitzschia frustulum* var. *tenella* Grunow in Van Heurck 1881 non *Nitzschia tenella* Brébisson ex W. Smith; *Nitzschia hiemalis* Hustedt 1943.

Description: Krammer and Lange-Bertalot, 1988, p. 99, pl. 72, fig. 1-23A;

Foged, 1974, p. 91, pl. 31, fig. 13; Lange-Bertalot, 1977, p. 263, pl. 2, fig. 9-10.

(As *Nitzschia frustulum* var. *tenella*): Hustedt, 1930, p. 415; Jensen, 1985, p. 868.

Dimensions: Dimensions: L: 8-45 µm. W: 2.5-3 µm. Fibulae: 10-16 ITM. Str: 26-32 ITM.

Ecology: Foged (1981, p. 141): "Oligohalobe (indifferent). Alkaliphil."

Distribution: WB: Rare at Holocene site 3 (Figure 2). Cosmopolitan.

Remarks: Remarks: The valve has mostly parallel sides that taper sharply to subcapitate apices. Striae are delicate, punctate, and keel fibulae are rounded. Overall dimensions are similar to *N. frustulum*, but valve is narrower, apices are more produced, and fibulae are rounded.

*Nitzschia pusilla* (Kützing) Grunow 1862

Syn: *Nitzschia kützingiana* Hilse ex Rabenhorst 1862

Description: Krammer and Lange-Bertalot, p. 111, pl. 79, fig. 12-15.

Lange-Bertalot and Simonsen, 1978, fig. 198-202; Germain, 1981, p. 348, pl. 131, fig. 16-20.

(As *N. kützingiana*): Hustedt, 1930, p. 416, fig. 802; Jensen, 1985, p. 870, fig. 802.

Dimensions: L: 8-33 µm. W: 2.5-5 µm. Fibulae: 14-20 ITM. Str: 43-55 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: WB: Most frequent in samples from the transition between marsh and upland; very rare in Holocene samples.

Remarks: An indicator of upland-transition samples.

*Nitzschia scapelliformis* (Grunow) in Cleve and Grunow 1880

Syn: *Nitzschia obtusa* var. *scalpelliformis* Grunow in Cleve and Möller 1879

Description: Krammer and Lange-Bertalot, 1988, p. 26, pl. 18, fig. 2-5, 7,11,12;

(As *Nitzschia obtusa* var. *scapelliformis*): John, 1983, p. 171, pl. 70, fig. 7-11

Dimensions: L: 20-110 µm. W: 4.5-7.4 µm. Fibulae: 7-10 ITM. Str: 27-38 ITM.

Ecology: Epipelic. Oligohalobous (indifferent) (?).

Distribution: WB: Most frequent in mesohalobous middle intertidal (low marsh) samples; rare in Holocene samples.

Remarks: Distinguished by the shape of the valve, the obtuse sigmoid apices, the indented, submarginal keel. John (1983) reported considerable variation in the nature of the apices of this taxon.

*Nitzschia sigma* (Kützing) Wm. Smith 1853

Description: Krammer & Lange-Bertalot, 1988, p. 32, pl. 23, fig. 1-9; pl. 24, fig. 1. Hustedt, 1930, p. 420, fig. 813; Hendey, 1964, p. 281, pl. 42, fig. 1; John, 1983, p. 173, pl. 72, fig. 10-11; Jensen, 1985, p. 873, fig. 813.

Dimensions: L: 35-1000 µm. W: 4-15(26) µm. Fibulae: (3)7-12 ITM. Str: (15)19-38 ITM.

Ecology: Epipelic. Mesohalobous; alkaliphilous (Foged, 1981). John (1983, p. 173): "Common in epiphytic and periphytic samples."

Distribution: WB: Very rare in mesohalobous lower intertidal samples; rare in a few Holocene samples. Hendey (1964, p. 281): "One of the commonest and most widely spread diatoms around British coasts." Cosmopolitan.

Remarks: Distinguished by the sigmoid valve, and the wavy punctate striae.

*Nitzschia* cf. *Nitzschia sigma*

Description: Valve sigmoid, wider along the middle with parallel margins, tapering to subcapitate apices. Keel fibulae distinct, squarish, not interrupted at the middle; apical nodules distinct. Striae very delicate, in wavy lines, barely discernible at magnification less than 1250x. Differs from *N. sigma* s.s. by the finer striae, by not showing the distinctive inflation at the middle that tapers sharply to the apices, and by a more delicate overall structure overall. According to This species fits the overall description of *N. sigma* in Krammer and Lange-Bertalot (1988). The more robust valves may be associated with higher salinity.

Dimensions: L: 130 µm. W: 16 µm. Fibulae: 8-10 ITM. Str: 38-40 ITM

Ecology: Epipelic. Mesohalobous.

Distribution: WB: Common in middle and upper intertidal deposits; rare in Holocene samples.

Remarks: Differs from *N. sigma* by the more delicately-silicified valve, and striae that are barely discernible in LM.

*Nitzschia terrestris* (Petersen) Hustedt 1934

(Plate 6, Figure 2)

Description: Krammer & Lange-Bertalot, 1988, p. 30, pl. 22, fig. 7-11.

Krammer & Lange-Bertalot, 1987, p. 56, pl. 10, fig. 10-13.

Dimensions: L: 25-115 µm. W: 3-5 µm. Fibulae: 5-8 ITM. Str: 32-35 ITM.

Ecology: Epipelic. Oligohalobous (indifferent) (?).

Distribution: WB: Rare in mesohalobous lower and middle intertidal samples; rare in Holocene sediments.

Remarks: Similar to *N. brevissima*, but with a more elongate valve. Observed with *N. brevissima* in some high marsh samples. Indicative of high marsh sediments.

ODONTELLA Agardh 1832

*Odontella aurita* (Lyngbye) Agardh 1832

Description: John, 1983, p. 32, pl. 11, fig. 8,9;

Sancetta, 1982, p. 234, pl. 3, fig. 11-12.

(As *Biddulphia aurita*): Hustedt, 1927-1966, I, p. 847, fig. 501; Cupp, 1943, p. 161, fig. 112; Hendey, 1964, p. 103, pl. 24, fig. 6; Riznyk, 1973, p. 118, pl. 3, fig. 9; Laws, 1988, p. 155, pl. 14, fig. 2.

Dimensions: Apical axis: 33-44 µm. Areolae: 9-12 ITM.

Ecology: Periphytic; tychopelagic. Polyhalobous (Foged, 1981). Hendey (1964, p. 103): "A neritic and littoral species, sometimes found free, but usually in long chains attached to a

substratum." Common in Yaquina estuary (Riznyk, 1973) and San Francisco estuary (Laws, 1988); present in benthic samples and rare in epiphyte (*Zostera*) samples in Netarts Bay (Whiting, 1983).

Distribution: WB: Very rare in mesohalobous/polyhalobous lower intertidal samples from the open bay and Niawiakum River; rare in Holocene samples. Cosmoplitan.

Remarks: The valve is resistant and may be prone to reworking.

*Odontella obtusa* Kützing 1844

(Plate 6, Figure 3)

Description: Rao and Lewin 1976, p. 179, fig. 5,6, 14-25.

Hustedt, 1927-66, I, p. 848, fig. 502.

Dimensions: Apical axis: 40-60 µm. Transapical axis: 35-40 µm. Areolae: 8-10 ITM.

Ecology: Epipsammic; polyhalobous (Rao and Lewin, 1976).

Distribution: WB: Very rare in mesohalobous/polyhalobous samples lower intertidal from the open bay; very rare to rare in Holocene samples.

Remarks: Distinguished by the broad bipolar valve, center part elevating, with distinct radiating striae. Similar to "*Biddulphia edwardsii* Febiger" as shown by Tynni (1986, p. 16, pl. 12, fig. 52).

OPEPHORA Petit 1888

*Opephora marina* (Gregory) Petit 1888

Description: Hustedt, 1927-66, II, p. 136, fig. 656.

Hendey, 1964, p. 160; Rao and Lewin, 1976, p. 185, fig. 95-100; Jensen, 1985, p. 128, fig. 656.

Dimensions: L; 30-70 µm. W: 4-6 µm. Costae: 7-9 ITM.

Ecology: Epipsammic; Mesohalobous/polyhalobous. Hustedt (1927-66, I, p. 136): "In the littoral of the entire European coastal area; widely distributed and not rare." Hendey (1964, p. 160): "Frequent on sandy beaches on all North Sea coasts." Epipsammic on the tidal flat at False Bay,

San Juan Island (Rao and Lewin, 1976). Common in benthic samples, and rare in epiphyte (*Zostera*) samples in Netarts Bay (Whiting, 1983).

Distribution: WB: Rare in mesohalobous lower intertidal samples from the Niawiakum River channel; are in a few Holocene samples. Cosmopolitan.

Remarks: Distinguished by the narrow valve with a wide sternum and short marginal areolae; apical hyaline areas are distinct.

*Opephora pacifica* (Grunow) Petit 1888

Description: Hustedt, 1927-66, II, p. 135, fig. 655.

Brockmannnn, 1950, p. 13, pl. 4, fig. 13, 15; Hendey, 1964, p. 159; Rao and Lewin, 1976, p. 185, fig. 90-94; Jensen, 1985, p. 128, fig. 655; Laws, 9188, p. 170, pl. 16, fig. 3.

Dimensions: L: 20-60 µm. W: 5-7 µm. Costae: 6 ITM.

Ecology: Epipsammic; mesohalobous/polyhalobous. A dominant species in benthic samples, and present in epiphyte (*Zostera*) samples in Netarts Bay (Whiting, 1983).

Distribution: WB: Rare to common in sandy Holocene samples; modern distribution not recorded. Cosmopolitan.

Remarks: Distinguished by the narrow valve, narrow sternum, and closely-spaced costae.

PARALIA Heiberg 1863

*Paralia sulcata* (Ehrenberg) Cleve 1873

(Plate 6, Figure 4)

Syn: Melosira sulcata (Ehrenberg) Kützing

Description: Crawford, 1979, p. 200- 210, fig. 1-33.

Gran and Angst, 1931, p. 430, fig. 4; Hendey, 1964, p. 73, pl. 23, fig. 5; Sancetta, 1982, p. 235, pl. 3, fig. 13-15; Laws, 1988, p. 170, pl. 2, fig. 5-17.

(As Melosira sulcata): Hustedt, 1927-66, I, p. 276, fig. 118-120; Cupp, 1943, p. 40, fig. 2; Riznyk, 1973, p 124, pl. 10, fig. 8.

Dimensions: Diam: 15-70 µm.

Ecology: Benthic; tychopelagic. Mesohalobous/polyhalobous. Crawford (1979, p. 210): "Occurs as bottom-living form in coastal waters but is also seen in coastal plankton." Hendey (1964, p. 73): "A true bottom form, found in neritic plankton, particularly after winter gales. Cupp (1943, p. 40): "Very common in littoral zone. Occurs in plankton accidentally (tychopelagic). Cold-water species.

Distribution: WB: Common in modern samples with salinities > 10‰; larger forms (> 20 µm diameter) are common on silty tidal flats of the open bay. Common in most Holocene samples. Cosmopolitan.

Remarks: Remarks: As reported by Crawford (1979) and Laws (1988), *P. sulcata* is heterovalvar, and thus "f. *coronata*" and "f. *radiosa*" are invalid. I observed a positive correlation between higher salinity and valve diameter for Willapa Bay specimens. This was also reported by Roelofs (9184) for *P. sulcata* in British Columbia fjords. Large diameters reported by Crawford (40-130 µm) are based on specimens from marine-neritic type material in the British Museum. My observations of diameters for Willapa Bay specimens are 15-70 µm.

PINNULARIA Ehrenberg 1843

*Pinnularia appendiculata* (Agardh) Cleve 1895

Description: Patrick & Reimer, 1966, p. 593, pl. 55, fig. 2.

Hustedt, 1930, p. 317, fig. 570a; Germain, 1981, p. 245, pl. 88, fig. 29-32; Jensen, 1985, p. 723, fig. 570a; Krammer and Lange-Bertalot, 1986, p. 427, pl. 193, fig. 19-29.

Dimensions: L: 18-36 µm. W: 4-6 µm. Str: 16-18 ITM.

Ecology: Benthic; aerophilous. Halophobous; pH circumneutral (Foged, 1981). Patrick & Reimer (1966, p. 593): "Aerophil; widely distributed in fresh water."

Distribution: WB: Common to abundant in oligohalobous upper intertidal (high marsh) samples from the South Fork Willapa River; also scattered in channel bank and marsh samples from the β–mesohalobous Willapa River transect. Not recorded in fossil samples. Cosmopolitan.

Remarks: Superficially similar to *P. subcapitata*, but differs by the finer striae and the raphe sternum that broadens progressively to the central area.

*Pinnularia borealis* Ehrenberg 1843

(Plate 6, Figure 5)

Description: Patrick & Reimer, 1966, p. 618, pl. 58, fig. 13.

Foged, 1978, p. 113, pl. 33, fig. 15, pl. 34, fig. 9; 1981, p. 145, pl. 40, fig. 6,7; Germain, 1981, p. 270, pl. 98, fig. 1-8; John, 1983, p. 125, pl. 53, fig. 4; Krammer and Lange-Bertalot, 1986, p. 405, pl. 177, fig. 1-12; pl. 178, fig, 7; Laws, 1988, p. 170; pl. 25, fig. 14.

Dimensions: L: 28-100 µm. W: 7-18 µm. Str: 4-6 ITM.

Ecology: Epipelic; aerophilous. Oligohalobous (indifferent); circumneutral pH (Foged, 1981).

Distribution: WB: Very rare in β–mesohalobous middle intertidal samples; very rare in Holocene samples. Cosmopolitan.

Remarks: Included in this study as a contrast to the smaller *P. lagerstedtii*, which is an important high-marsh diatom. Patrick and Reimer (1966, p. 618): "This species is distinguished by its slightly curved raphe and the shape of the axial and central areas."

*Pinnularia lagerstedtii* (Cleve) Cleve-Euler 1934

(Plate 6, Figure 6,7)

Syn: *Pinnularia parva* var. *lagerstedtii* Cleve 1895; *Pinnularia parva* var. *munita* Østrup 1918

Description: Krammer and Lange-Bertalot, 1986, p. 404, pl. 176, fig. 8-10.

(As *Pinnularia parva* var. *minuta*): Foged, 1981, p. 153, pl. 39, fig. 18,22.

Dimensions: L: 16-40 µm. W: 5-8 µm. Str: 8.5-10 ITM.

Ecology: Benthic; aerophilous. Oligohalobous (indifferent); circumneutral pH (Foged, 1981). Often found in moss (Krammer and Lange-Bertalot, 1986).

Distribution: WB: Indicative of high *Deschampsia* marshes; common in peaty Holocene samples. Possibly cosmopolitan (Foged, 1981).

Remarks: Superficially resembles *Pinnularia borealis* (particularly *P. borealis* var. *rectangularis*) but differs by the smaller valve dimensions, and the greater number of striae in 10 μm. Very common in marsh samples from Willapa Bay.

*Pinnularia subcapitata* Gregory 1856

Description: Patrick & Reimer, 1966, p. 596, pl. 55, fig. 8-10.

Hustedt, 1930, p. 317, fig. 571; Germain, 1981, p. 244, pl. 88, fig. 1-8; Foged, 1981, p. 155, pl. 39, fig. 11, pl. 44, fig. 8; Jensen, 1985, p. 723, fig. 571; Krammer & Lange-Bertalot, 1986, p. 426, pl. 193, fig. 1-18.

Dimensions:

Ecology: Epipelic. Oligohalobous (indifferent); circumneutral pH (Foged, 1981). Widely distributed in fresh water (Hustedt, 1930).

Distribution: WB: Common to abundant in oligohalobous upper intertidal (high marsh) samples from the South Fork Willapa River; also scattered in channel bank and marsh samples from the β–mesohalobous Willapa River transect; occurs with *P. appendiculata*.. Very rare in Holocene samples. Cosmopolitan.

Remarks: Striae are radiate at the center and strongly convergent at the apices; the central area may be asymmetrical, extending to the margin on one side.

PLAGIOGRAMMA Greville 1859

*Plagiogramma staurophorum* (Gregory) Heiberg 1863

Description: Hustedt, 1927-66, II, p. 110, fig. 635.

Hendey, 1964, p. 166, pl. 36, fig. 1; Riznyk, 1973, p. 131, pl. 14, fig. 4; Rao and Lewin, 1976, p. 181, fig. 53-55; John, 1983, p. 52, pl. 20, fig. 14-15; Jensen, 1985, p. 106, fig. 635.

Dimensions: L: 12-65 µm. W: 5-11 µm. Str: 8-11 ITM.

Ecology: Epipsammic. Mesohalobous/polyhalobous. Hendey (1964, p. 166): "Common marine littoral species on all North Sea coasts, favouring sandy shores." Common on the sand flats of Yaquina estuary (Riznyk, 1973) and False Bay (Rao and Lewin, 1976).

Distribution: WB: Only observed on the Bone River tidal flat (Figure 1); rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the lanceolate valve, distinct apical hyaline areas, and transapical striae with robust areolae.

RHABDONEMA Kützing 1844

*Rhabdonema arcuatum* (Lyngbye) Kützing 1844

(Plate 6, Figure 8)

Description: Hendey, 1964, p. 172, pl. 35, fig. 10-12.

Hendey, 1964, p. 172, pl. 35, fig. 10-12; Riznyk, 1973, p. 131, pl. 15, fig. 9; Jensen, 1985, p. 18, fig. 549; Laws, 1988, p. 172, pl. 16, fig. 5.

Dimensions: L: 30-70 µm. W: 12-15 µm.

Ecology: Epiphytic. Mesohalobous/polyhalobous. Hendey (1964, p. 172): "Epiphytic on marine algae and found attached to almost any hard substrate in the littoral zone. Common on all North Sea coasts."

Distribution: WB: Only observed in a few α–mesohalobous lower and middle intertidal samples from the Niawiakum River; sometimes common in Holocene sediment. Cosmopolitan.

Remarks: Often observed in semi-intact chains; the robust valve may be prone to reworking.

RHAPHONEIS Ehrenberg 1844

*Rhaphoneis amphiceros* (Ehrenberg) Ehrenberg 1844

Description: Hustedt, 1927-66, II, p. 174, fig. 680.

Hendey, 1964, p. 154, pl. 26, fig. 1-4; Riznyk, 1973, p. 131, pl. 15, fig. 1,2; Rao and Lewin, 1976, p. 183, fig. 56-59; Germain, 1981, p. 60, pl. 17, fig. 9; John, 1983, p. 53, pl. 21, fig. 7; Jensen, 1985, p. 162, fig. 680.

Dimensions: L: 20-100 µm. W: 18-25 µm. Str: 6-7 ITM.

Ecology: Benthic; epipsammic. Mesohalobous, euryhaline (Germain, 1981).

Distribution: WB: Rare in mesohalobous lower intertidal samples, but not observed in sand flat samples; rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the typically drawn-out apices, the narrow sternum, and the parallel striae.

*Rhaphoneis* cf. *R. margaritalimbata* Mertz 1966

Description: Valve broadly elliptical. Striae formed by 2-3 puncta, arranged normal to margin, about 15 striae in 10 µm. Sternum wide, making up two-thirds to three-fourths of the valve area. There appear to be two pores in the central area, in the position of terminal fissures, although there is no raphe visible on the valve.

Dimensions: L: 9.6 µm. W: 5.6 µm. Str: 15 ITM.

Ecology: Benthic; mesohalobous.

Distribution: WB: Rare in mesohalobous channel bank and marsh samples from the Niawiakum River; ecological significance uncertain. Rare in Holocene sediment.

Remarks: Similar to the diatom figured by Laws (Laws, 1988, p. 172, pl. 16, fig. 7) and Schrader(1973, p. 709, pl. 25, fig. 13) as *"Rhaphoneis margaritalimbata* Mertz 1966."

*Rhaphoneis psammicola* Riznyk 1973

(Plate 6, Figure 9)

Description: Riznyk, 1973, p. 131, pl. 15, fig. 3; pl. 20, fig. 4.

Whiting and Schrader, 1985, p. 6, fig. 6-8.

Dimensions: L: 15-30 µm. W: 10-17 µm. Str: 7-10 ITM.

Ecology: Benthic; epipsammic (?). Mesohalobous/polyhalobous.

Distribution: WB: Very rare in mesohalobous/polyhalobous lower intertidal samples; rare to common in Holocene samples.

Remarks: Distinguished by the coarsely punctate striae, and the irregularly shaped central area. The apical hyaline areas are well developed, as in *R. amphiceros.*

RHOICOSPHENIA Grunow 1860

*Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot 1980

Syn: *Rhoicosphenia curvata* (Kützing) Grunow ex Rabenhorst 1864

Description: Krammer & Lange-Bertalot, p. 381, pl. 91, fig. 20-28.

(As Rhoicosphenia curvata (Kützing) Grunow in Rabenhorst 1864): Hustedt, 1927-66, II, p. 430, fig. 879;

Patrick and Reimer, 1966, p. 282, pl. 20, fig. 1-5; Riznyk, 1973, p. 132, pl. 15, fig. 5,6; Rao and Lewin, 1976, p. 193, fig. 200-203; Foged, 1978, p. 122, pl. 17, fig. 1-3; 1979, p. 102, pl. 16, fig.

1-4; 1981, p. 157, pl. 14, fig. 1; Germain, 1981, p. 118, pl. 44, fig. 21-25; Jensen, 1985, p. 373, fig. 879; Laws, 1988, p. 172, pl. 19, fig. 6.

Dimensions: L: 10-75 µm. W: 3-8 µm. Str: 15-20 ITM (concave valve); 11-14 ITM (convex valve),

Ecology: Epiphytic; periphytic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Hustedt (1927-66, II, p. 420): "Halophile fresh water form, euryhaline, widely distributed and very abundant especially on brackish coasts, but also distributed and very abundant in waters of low salinity as well as in fresh water of the interior, rare in mountain water." Attaches to floating objects, macrophytes, filamentous algae (e.g., *Cladophora*) and rocks (Germain, 1981).

Distribution: WB: Common to abundant in oligohalobous and β–mesohalobous channel bank and marsh samples from the Willapa and South Fork Willapa Rivers; also rare in channel bank samples from the Niawiakum River. Rare in Holocene samples. Reported at Ledbetter Point by Tynni (1986). Rare in San Francisco estuary (Laws, 1988), Yaquina estuary (Riznyk, 1973), Netarts Bay (Whiting, 1983) and False Bay (Rao and Lewin, 1976).

Remarks: Distinguished by the convex-concave valves in girdle view, and the usually clavate form in girdle view.

RHOPALODIA Müller 1895

*Rhopalodia gibberula* (Ehrenberg) O. Müller 1899

(Plate 6, Figure 10)

Description: Patrick & Reimer, 1975, p. 191, pl. 28, fig. 6.

Hustedt, 1930, p. 391, fig. 742; Foged, 1978, p. 123, pl. 43, fig. 1; John, 1983, p. 161, pl. 67, fig. 11,12; Jensen, 1985, p. 843, fig. 742; Laws, 1988, p. 172, pl. 30, fig. 7-10; Krammer and Lange-Bertalot, 1988, p. 160, pl. 110, fig. 2; pl. 112, fig. 1-6; pl. 113, fig. 4-6.

Dimensions: L: 25-80 µm. W: 7-14 µm. Costae: 3-4 ITM. Rows of alveolae: 12-17 ITM.

Ecology: Patrick and Reimer (1975, p. 191): "Seems to prefer water with some chloride (halophil), but may be found in low conductivity water. It is a widely tolerant species." Hustedt (*in* Jensen, 1985, p. 843): "Salt water form, distributed predominantly in the ocean area, but also in saline waters of the interior, common in salt works, saline lakes."

Ecology: Epiphytic/epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1979).

Distribution: WB: Common in low marsh and marsh-edge silt flats where salinities >10‰. Cosmopolitan.

Remarks: Distinguished by the nearly straight ventral margin that gives way to rounded to produced apices. Dorsal margin may be slightly notched or indented. There are two to eight rows of areolae between costae.

*Rhopalodia musculus* (Kützing) O. Müller 1899

(Plate 6, Figure 11)

Syn: Rhopalodia operculata (C.A. Agardh) Håkansson 1979, p. 166, fig. 1-5

Description: Patrick and Reimer, 1975, p. 191, pl. 28, fig. 5.

Foged, 1981, p. 157, pl. 66, fig. 6,8; Krammer and Lange-Bertalot, 1988, p. 163, pl. 110, fig. 4; pl. 114, fig. 1-8.

(As *Rh. operculata*): Laws, 1988, p. 172 , pl. 30, fig. 11.

Dimensions: L: 30-80 µm. W: 11-15 µm. Costae: 3-5 ITM. Str: 12-16 ITM.

Ecology: Epiphytic/epipelic; euryhaline. Foged (1981, p. 157): "Mesohalobe (euryhaline)."

Distribution: WB: Common in low marsh and marsh-edge silt flats where salinities >10‰. Cosmopolitan.

Remarks: Various authors (e.g. Patrick and Reimer, 1975; Laws, 1988) have suggested that *R. gibberula* and *R. musculus* should be combined. However, Krammer and Lange-Bertalot (1988) separate these species. Differences in valve form include weakly to strongly radiate costae for *R. musculus* as opposed to parallel or only weakly radiate costae for *R. gibberula*. The ventral margin

is straight along most of its length for both species, and apices are drawn ventrally; the dorsal margin may show be indented at the central nodule. The number of rows of areolae inbetween costae are reported to be 2-8 for both species, but *R. musculus* is usually figured with 2-3 (e.g., Patrick and Reimer, 1975, pl. 28, fig. 5; Krammer and Lange-Bertalot, 1988, pl. 114, fig. 1-8).

SCOLIOPLEURA Grunow 1860

*Scoliopleura tumida* (Brébisson ex Kützing) Rabenhorst 1864

Description: Hendey, 1964, p. 234, pl. 29, fig. 6-7.

Laws, 1988, p. 173, pl. 26, fig. 9.

Dimensions: L: 76-160 µm. W: 20-36 µm.

Ecology: Epipelic. Polyhalobous (Foged, 1981). Hendey (1964, p. 234): "A brackish-water species, euryhaline, common on all shores of the North Sea."

Distribution: WB: Rare in middle intertidal samples with *Caloneis westii*, very rare in lower intertidal samples. Rare to common in Holocene samples. Reported from Ledbetter Point by Tynni (1986). Rare in San Francisco estuary (Laws, 1988); not recorded in Yaquina estuary (Riznyk, 1973), Netarts Bay (Whiting, 1983) or False Bay (Rao and Lewin, 1976).

Remarks: Brockmann (1950) recorded *S. tumida* as an important diatom on mud flats, and also in mud embankments with *Navicula cincta* (in "silting up" areas).

STAURONEIS Ehrenberg 1843

*Stauroneis anceps* Ehrenberg

Description: Patrick and Reimer, 1966, p. 361, pl. 30, fig. 1.

Hustedt, 1927-66, II, p. 771, fig. 1120; Foged, 1978, p. 123, pl. 25, fig. 5, pl. 26, fig. 2; Foged, 1979, p. 104, pl. 22, fig. 7,8; Foged, 1981, p. 158, pl. 20, fig. 3, 8; Germain, 1981, p. 156, pl. 60,

fig. 1-4; John, 1983, p. 136, pl. 77, fig. 5-6; Jensen, 1985, p. 647, fig. 1120; Krammer & Lange-Bertalot, 1986, p. 240, pl. 87, fig. 3-9; pl. 88, fig. 1-4.

Dimensions: L: 24-75 µm. W: 6-18 µm. Str: 20-25 ITM.

Ecology: Benthic. Oligohalobous (indifferent); circumneutral pH (Foged, 1981).

Distribution: WB: Very rare in oligohalobous/β–mesohalobous marsh samples; rare in a sample collected from the highest part of the marsh at Stony Point; very rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the broadly lanceolate valve with produced capitate apices, and the delicate radiate striae. Patrick and Reimer (1966, p. 361): "This quite variable species is generally smaller and more finely striate than *Stauroneis phoenicenteron* and its varieties to which it is allied."

STEPHANODISCUS Ehrenberg 1845

*Stephanodiscus astraea* (Ehrenberg) Grunow 1880

Syn: *Stephanodiscus rotula* (Kützing) Hendey 1964

Description: Hustedt, 1927-66, I, p. 368, fig. 193a-c.

Schrader, 1978, p. 863, pl. 2, fig. 7,11; pl. 3, fig. 11-12; pl. 4, fig. 15, 22, 23; pl. 8, fig. 13, pl. 12, fig. 15; pl. 13, fig. 2, 8; pl. 16, fig. 5-6; Foged, 1981, p. 163, pl. 2, fig. 22; pl. 3, fig. 1; Laws, 1988, p. 173, pl. 4, fig. 9,10.

Dimensions: Diam: 30-70 µm.

Ecology: Planktonic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: WB: Scattered and very rare in modern mesohalobous samples; very rare to rare in Holocene samples. Cosmopolitan.

Remarks: Identified by the concentrically undulate valve, with the center slightly concave.

*Stephanodiscus niagarae* Ehrenberg 1841

Description: Schrader, 1978, p. 863, pl. 5, fig. 1; pl. 6 fig. 5; pl. 7, fig. 10; pl. 8, fig. 1, pl. 16, fig. 1; pl. 17, fig. 1,2.

Hustedt, 1942, p. 44, fig. 509; John, 1983, p. 23, pl. 6, fig. 6,7; Laws, 1988, p. 174, pl. 4, fig. 5-8.

Dimensions: Diam: 30-32 µm. Str: 6-8 ITM. Marginal spines: 5 ITM.

Ecology: Planktonic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981).

Distribution: WB: Scattered and very rare in modern mesohalobous samples; very rare to rare in Holocene samples. Cosmopolitan..

Remarks: The marginal spines are distinct in LM, and are separated by two striae fascicles.

SURIRELLA Turpin 1828

*Surirella brebissonii* Krammer and Lange-Bertalot 1987

(Plate 6, Figure 12)

Description: Krammer and Lange-Bertalot, 1987, fig. 21-33.

Lange-Bertalot and Krammer, 1987, p. 94, pl. 53, fig. 5; Krammer and Lange-Bertalot, 1988, p. 179, pl. 126, fig. 2-11; pl. 127, fig. 1-13.

(As *Surirella ovata*): Hustedt, 1930, p. 442, fig. 863, 864; Germain, 1981, p. 390, pl. 152, fig. 1-21; Hendey, 1951, p. 77, pl. 14, fig. 4-7; Hendey, 1964, p. 287, pl. XL, fig. 7-9; Riznyk, 1973, p. 133, pl. 16, fig. 7; Rao and Lewin, 1976, p. 209, fig. 352; Foged, 1981, p. 168, pl. 63, fig. 11; Jensen, 1985, p. 895, fig. 863-864; Laws, 1988, p. 174, pl. 34, fig. 2.

Dimensions: L: 8-70 µm. W: 8-30 µm. Fibulae: 3.5-6 ITM. Str: 17-19 ITM.

Ecology: Epipelic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). Reported by Hendey (1964, p. 287) as: "One of the commonest diatoms on British coasts, particularly in brackish conditions. Prefers a muddy shore to one of clean sand." However, reported as present

but sparse in intertidal samples from San Francisco Bay (Laws, 1988); Yaquina estuary (Riznyk, 1973), Netarts Bay (Whiting, 1983), and False Bay, San Juan Island (Rao and Lewin, 1976).

Distribution: WB: Common in β–mesohalobous lower and middle intertidal samples from the Willapa River; also rare in oligohalobous and α–mesohalobous samples. Very rare in Holocene samples. Cosmopolitan.

Remarks: According to the recent revisions by Krammer and Lange-Bertalot (1987), *S. brebissonii* is synonymous with "*S. ovata*" as shown by Hustedt (1930), and *S. brebissonii* var. *kutzingii* is synonymous with "*S. ovata*" as originally described by Kützing (1944). The differences between the taxa are subtle, and as such *S. brebissonii* and *S. brebissonii* var. *kutzingii* were not separated in this study.

*Surirella fastuosa* (Ehrenberg) Kützing 1844

(Plate 6, Figure 13)

Description: John, 1983, p. 179, pl. 75, fig. 6-9.

Hendey, 1951, p. 75, pl. 9, fig. 7; Hendey, 1964, p. 288, pl. 40, fig. 4; Laws, 1988, p. 174, pl. 34, fig. 3,5.

Dimensions: L: 78-120. W: 51-78 µm. Costae: 16 ITM. Striae: 11-12 ITM.

Ecology: Benthic; epipelic. Mesohalobous/polyhalobous.

Distribution: WB: Rare in tidal flat samples; are in Holocene samples. Cosmopolitan.

Remarks: Best distinguished by the large, ovate valve, and the broadly lanceolate central area surrounded by short distinct striae.

SYNEDRA Ehrenberg 1830

*Synedra acus* Kützing 1844

Description: Patrick & Reimer, 1966, p. 135, pl. 5 fig. 1.

Hustedt, 1927-66, II, p. 201, fig. 693a; Germain, 1981, p. 78, pl. 27, fig. 1-12; Jensen, 1985, p. 188, fig. 693a.

Dimensions: L: 90-180 µm. W: 4.5-6 µm. Str: 11-14 ITM.

Ecology: Periphytic; meroplanktonic. Oligohalobous (indifferent); alkaliphilous (Foged, 1981). (Hustedt, 1927-66, p. 201): "Occur as littoral forms, mostly in tufted colonies on filamentous algae.

Distribution: WB: Common in oligohalobous and β–mesohalobous lower and middle intertidal samples from the Willapa and South Fork Willapa rivers; very rare in Holocene samples. Cosmopolitan.

Remarks: The margins are nearly parallel for the middle half of the valve, and then taper to subcapitate apices. The striae are delicate, and parallel; the central area is rectangular, distinct, extending to the margins.

*Synedra fasciculata* (Agardh) Kützing 1844

Syn: *Synedra tabulata* (Agardh) Kützing 1844; Fragilaria tabulata (Agardh) Lange-Bertalot 1980

Description: John, 1983, p. 56, pl. 22, fig. 6-14.

Patrick & Reimer, 1966, p. 141, pl. 5, fig. 17-18.

(As *Synedra tabulata*): Hustedt, 1927-66, II, 218, fig. 710a-d; Foged, 1978, p. 132, pl. 9, fig. 5; Germain, 1981, p. 78, pl. 26, fig. 5-10; Jensen, 1985, p. 201, fig. 710a-d.

(As *Fragilaria tabulata*): Lange-Bertalot, 1980, p. 723; Laws, 1988, p. 162, pl. 16, fig. 13.

Dimensions: L: 60-220 µm. W: 4-7 µm. Str: 11-14 ITM.

Ecology: Epiphytic; benthic. Mesohalobous; euryhaline (Foged, 1981). Common in benthic samples, and dominant in epiphyte (*Zostera*) samples in Netarts Bay (Whiting, 1983).

Distribution: WB: Widely distributed in mesohalobous lower intertidal samples, especially associated with *Zostera* beds on channel banks and at the fringes of the open bay. Rare in Holocene samples. Common in San Francisco estuary (Laws, 1988), Yaquina estuary (Riznyk, 1973); reported at Ledbetter Point by Tynni (1986). Cosmopolitan.

Remarks: The valve of *S. fasciculata* is relatively delicate, and the shape makes it susceptible to fragmentation. Good preservation of *S. fasciculata* in fossil deposits is an indication of excellent overall preservation for the sample.

*Synedra vaucheriae* (Kützing) Kützing 1844

Syn: *Fragilaria intermedia* Grunow 1881; *Fragilaria vaucheriae* (Kützing) Peters 1938.

Description: Hustedt, 1927-66, II, p. 194, fig. 689.

Foged, 1981, p. 172, pl. 4, fig. 14; pl. 5, fig. 25; Germain, 1981, p. 80, pl. 28, fig. 1-13; Jensen, 1985, p. 179, fig. 689.

(As *Fragilaria vaucheriae*): Patrick & Reimer, 1966, p. 120, pl. 3, fig. 14-15;

John, 1983, p. 44, pl. 16, fig. 12-14.

(As *Fragilaria intermedia*): Hustedt, 1927-66, II, p. 153, fig. 666; Germain, 1981, p. 66, pl. 20, fig. 1-10; Jensen, 1985, p. 142, fig. 666.

Dimensions: L: 15-60 µm. W: 2.5-5µm. Str: 9-13 ITM.

Ecology: Periphytic; oligohalobous (indifferent); alkaliphilous (*in* Lowe, 1974).

Distribution: WB: Rare in oligohalobous/β–mesohalobous channel bank and marsh samples; observed in only a few Holocene samples. Hustedt (1927-66, p. 194): "Littoral freshwater form, widely distributed and common." Cosmopolitan.

Remarks: Distinguished by the robust transapical striae and the asymmetrical central area.

TABELLARIA Ehrenberg 1840

*Tabellaria fenestrata* (Lyngbye) Kützing 1844

Description: Patrick & Reimer, 1966, p. 103, pl. 1, fig. 1-2.

Hustedt, 1927-66, II, p. 26, fig. 554; Foged, 1981, p. 172, pl. 4, fig. 4; Germain, 1981, p. 50, pl. 12, fig. 1-7; Jensen, 1985, p.24, fig. 554; Laws, 1988, p. 175, pl. 16, fig. 10.

Dimensions: L: 25-116 µm, usually 40-75 µm. W: 5-10 µm. Str: 14-18 ITM.

Ecology: Periphytic; meroplanktonic. Patrick and Reimer (1966, p. 104): "Seems to prefer lakes or ponds which are usually mesotrophic to eutrophic; seems to prefer circumneutral water; usually in shallow water, often attached to substrate." Hustedt (1927-66, II, p. 26): "Freshwater form; also sporadically living in brackish water. Commonly distributed throughout Europe in standing and slowly flowing waters." Foged (1981, p. 172): "Halophobe. Acidophil."

Distribution: WB: Rare in β–mesohalobous intertidal samples; rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the long, narrow valve with inflated apices, the narrow stemum, and the parallel striae along the length of the valve.

THALASSIONEMA Hustedt 1932

*Thalassionema nitzschioides* Hustedt 1932

Description: Hustedt, 1927-66, II, p. 244, fig. 725.

Hendey, 1964, p. 165; Riznyk, 1973, p. 135, pl. 17, fig. 6; Jensen, 1985, p. 223, fig. 725; Laws, 1988, p. 175, pl. 16, fig. 9.

Dimensions: L: 10-110 µm. W: 2-3 µm. Str: 10-12 ITM.

Ecology: Planktonic (tychoplanktonic?); polyhalobous. Whiting (1983) reported this species as present in planktonic, benthic *and* epiphyte (*Zostera*) samples from Netarts Bay. Riznyk (1973)

reported it as abundant from a tidal flat in the lower part of Yaquina estuary where neritic plankton would be likely to accumulate.

Distribution: WB: Most common in upper intertidal channel bank deposits, presumably deposited by receding tides. Hendey (1964, p. 165): "A common and widespread neritic species, often in great numbers in the North Sea on all coasts, common in the North Atlantic and the English Channel. Cosmopolitan.

Remarks: Probably allochthonous in most benthic samples.

THALASSIOSIRA Cleve 1873

*Thalassiosira decipiens* (Grunow) Jørgenson 1905

Description: Hasle, 1979, p. 85-108, pl. 1-pl. 8.

Cupp, 1943, p. 48, fig. 10; Hendey, 1964, p. 87, pl. 1, fig. 5; Mahood, et al., 1986, p. 138, fig. 62-67, 97-98; Laws, 1988, p. 175, pl. 12, fig. 1-4.

Dimensions: Diam: 15-28 µm.

Ecology: Benthic; tychopelagic. Mesohalobous/polyhalobous. Cupp (1943, p. 48): "Neritic. North temperate seas." Hendey (1964, p. 87): "Widely distributed in temperate seas."

Distribution: (Includes diatoms in the "*T. decipiens* group," which includes several forms similar to *T. decipiens*, but not identified to species). WB: Common to abundant in mesohalobous lower intertidal samples , particularly where *Zostera* is present. Also scattered and rare (probably allochthonous) in mesohalobous middle and upper intertidal samples. Rare to common in Holocene samples. Abundant in San Francisco estuary (Laws, 1988). Cosmopolitan.

Remarks: Hasle (1979) suggested that *T. decipiens* is probably in benthic, possibly epiphytic, living in chains with one end attached to the substrate. This is supported by Whiting (1983) who reported it in Netarts Bay as rare in benthic samples, epiphyte (*Zostera*) samples, and in the

plankton. Laws (1988) discussed the difficulties in separating this species from a related group of small *Thalassiosiras*.

*Thalassiosira eccentrica* (Ehrenberg) Cleve 1904

Description: Mahood et al., 1986, p. 137, fig. 30-35, 102.

Fryxell and Hasle, 1972, p. 300, fig. 1-18; Rao and Lewin, 1976, p. 177, fig. 48-47; Laws, 1988, p. 176, pl. 10, fig. 6,7; pl. 11, fig. 1-9.

(As *Coscinodiscus eccentricus*): Gran and Angst, 1931, p. 441, fig. 17; Cupp, 1943, p. 52, fig. 14, pl. 1, fig. 1; Hendey, 1964, p. 80, pl. 24, fig. 7; Riznyk, 1973, p. 120, pl. 6, fig. 2.

Dimensions: Diam: 12-101 µm. Areolae: 5-8 ITM near the center; 7-10 ITM near the margin.

Ecology: Planktonic. Mesohalobous/polyhalobous (Mahood et al., 1986).

Distribution: WB: Rare in mesohalobous lower intertidal samples from the Niawiakum River; very rare in tidal flat sediments of the open bay. Rare in Holocene samples. Rare in San Francisco Bay (Laws, 1988) and Yaquina estuary (Riznyk, 1973). More common in False Bay (San Juan Island) that is open to marine conditions (Rao and Lewin, 1976). Reported by Tynni (1986) at Ledbetter Point. Cosmopolitan.

Remarks: According to Mahood et al. (1986), the valve is relatively flat, and the central areola is surrounded by seven areolae with a single strutted process next to the central areola.

*Thalassiosira pacifica* Gran and Angst 1931

(Plate 6, Figure 14)

Description: Hasle, 1978 p. 88, fig. 3, 40, 42-69.

Gran & Angst, 1931, p. 436; Mahood et al., 1986, p. 138, fig. 49-55, 105

Dimensions: Diam: 7-46 µm. Areolae: 10-14 ITM.

Ecology: Benthic; tychopelagic. Polyhalobous. Common in benthic samples, rare in epiphyte (*Zostera*) samples, and present in the plankton in Netarts Bay (Whiting, 1983). Present in modern San Francisco estuary (Mahood et al., 1986).

Distribution: WB: Modern distribution similar to *T. eccentrica*. Rare in Holocene samples.

Remarks: According to Gran and Angst (1931) and Whiting (1983), shows the same distribution as *T. aestivalis*. Differs morphologically by having a flat valve face and fewer fascicles than *T. aestivalis* (Hasle, 1978).

TRACHYNEIS Cleve 1894

*Trachyneis aspera* (Ehrenberg) Cleve 1894

Description: John, 1983, p. 138, pl. 53, fig. 1-3.

Hendey, 1964, p. 236, pl. 29, fig. 13; Riznyk, 1973, p. 135, pl. 17, fig. 1,2; Foged, 1975, p. 56, pl. 24, fig. 9-11; 1978, p. 134, pl. 36, fig. 5; 1979, p. 112, pl. 38, fig. 1; Tynni, 1986, pl. 25, fig. 152; Laws, 1988, p. 177, pl. 29, fig. 13.

Dimensions: L: 67-130 µm. W: 15-23 µm. Str: 12-13 in 10 µm.

Ecology: Epipelic; epiphytic. Polyhalobous. (Foged, 1979). Reported by John (1983) and Foged (1979) as epiphytic on seaweed. Rare in benthic samples but absent from epiphyte (*Zostera*) samples in Netarts Bay (Whiting, 1983); rare from tidal flats in Yaquina estuary (Riznyk, 1973).

Distribution: WB: Observed only on a few occasions in the lower intertidal (*Zostera* zone) level of the Niawiakum River channel bank and the Bone River silty tidal flat; more frequent in muddy Holocene deposits. Hendey (1964, p. 236): "A littoral species, widely distributed around North Sea and North Atlantic coasts." Cosmopolitan.

Remarks: Easily recognizable by the large valve with coarse areolae; central area a distinct stauros.

TRACHYSPHENIA Petit 1877

*Trachysphenia australis* Petit 1877

(Plate 6, Figure 15,16)

Description: John, 1983, p. 64, pl. 27, fig. 10.

Hustedt, 1955, p. 13, pl. 4, fig. 55; Hendey, 1964, p. 160; Riznyk, 1973, p. 135, pl. 17, fig. 5; Foged, 1975, p. 56, pl. 7, fig. 15-17;

Dimensions: L: 25-35 µm. W: 5.5-6 µm. Str: 9-10 ITM.

Ecology: Epipsammic; epiphytic. Polyhalobous. Abundant in sandy tidal flat sediments in Yaquina Bay (Riznyk, 1973); common in benthic samples, and rare in epiphytic samples in Netarts Bay (Whiting, 1983). Epiphytic in lower Swan River estuary (John, 1983).

Distribution: WB: modern distribution restricted to sandy tidal flat; very rare in Holocene samples. Cosmopolitan.

Remarks: Distinguished by the club-shaped valve and the coarse puncta in longitudinal lines; axial area indistinct.

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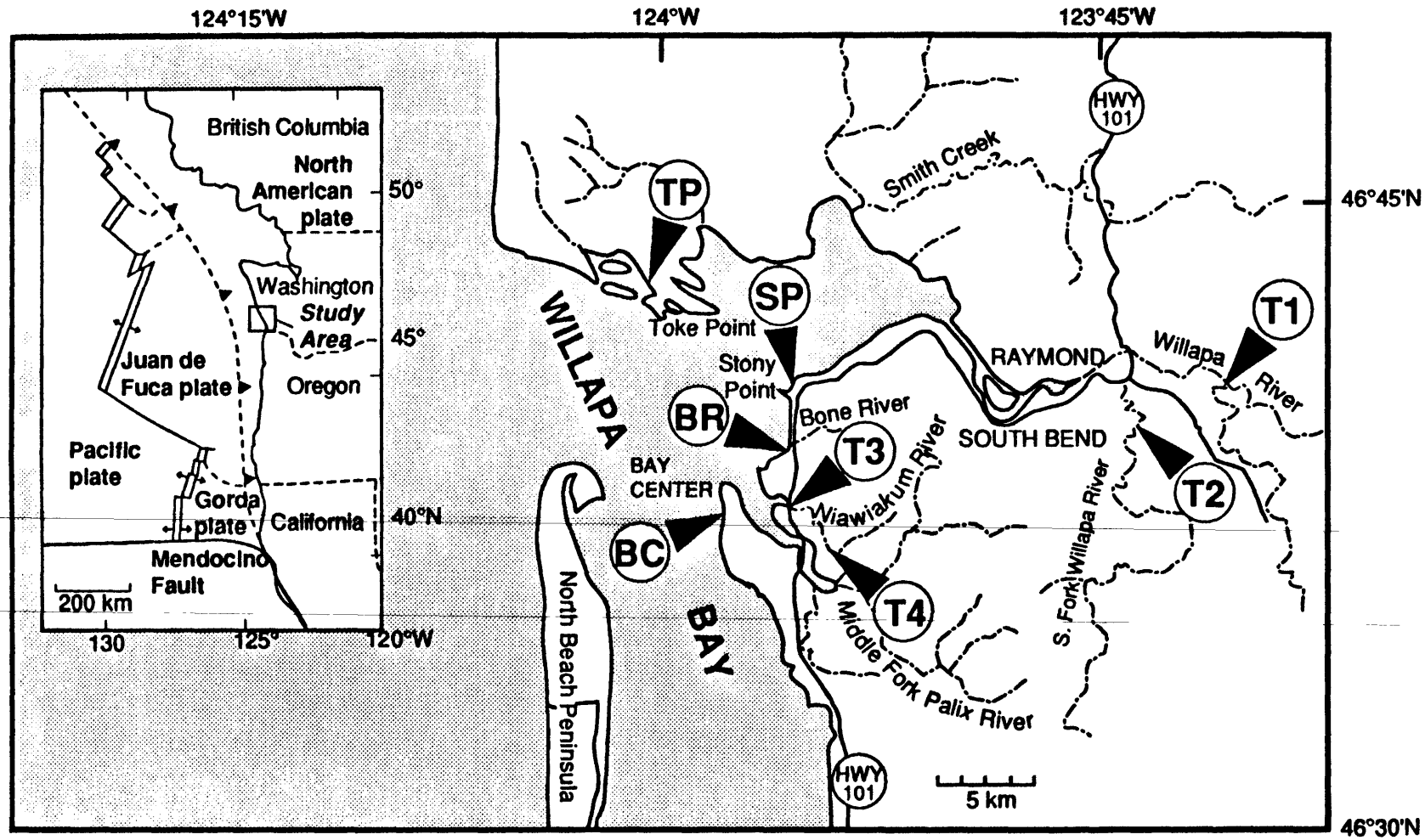


Figure 1. Surface sample locations in northern Willapa Bay, abbreviated as follows: TP - Toke Point; SP - Stony Point; BR - Bone River tidal flat; BC - Bay Center tidal flat; T1 - Transect T1, Willapa River; T2 - Transect T2, South Fork Willapa River; T3 - Transect T3, lower Niawiakum River; T4- Transect T4, upper Niawiakum River.

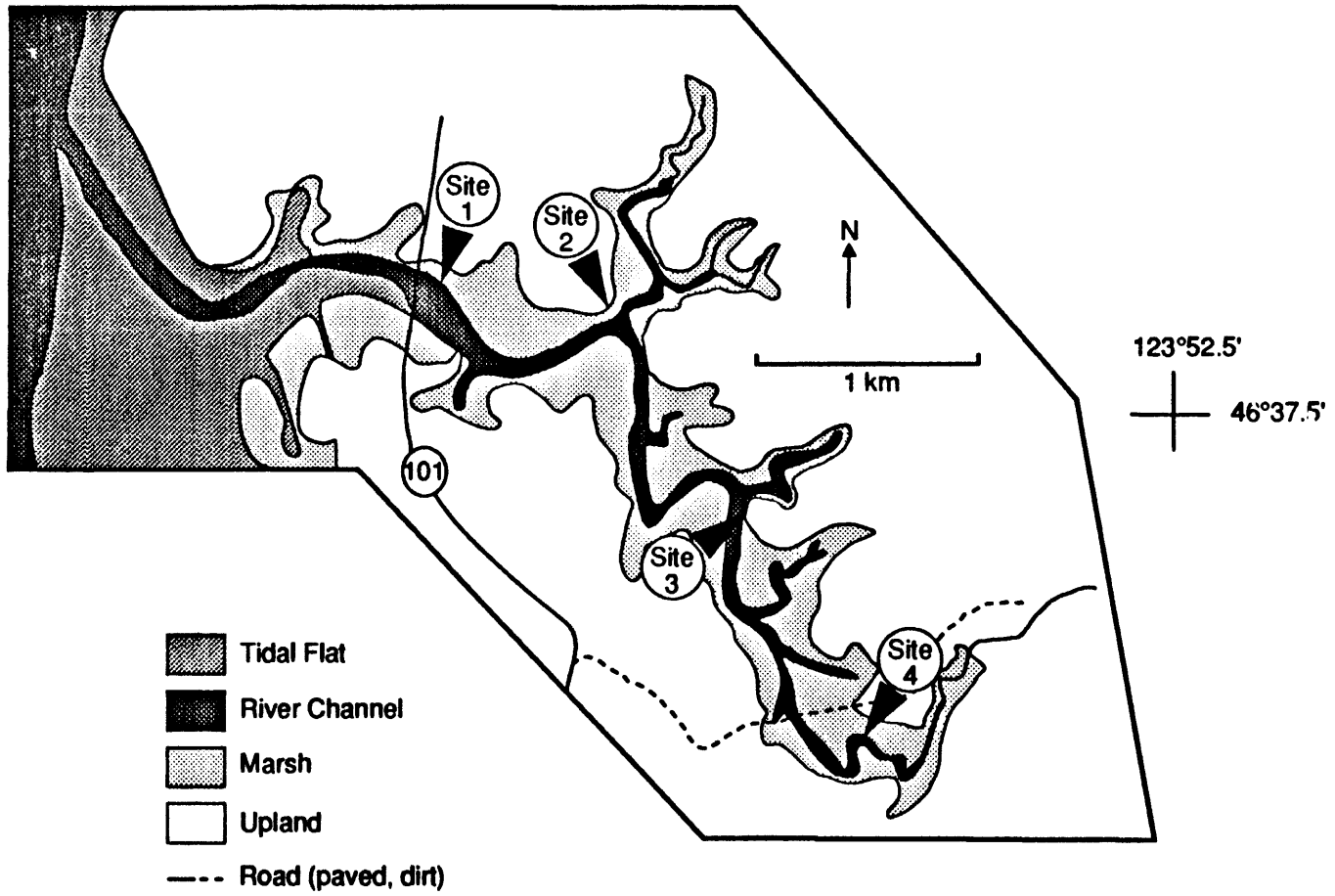


Figure 2. Outcrop locations for Holocene deposits along the Niawiakum River, on the east side of Willapa Bay.

| TABLE 1: DIATOMS >2% OF AT LEAST ONE MODERN OR FOSSIL SAMPLE | | | | | |
|---|---|---|---|---|---|
| species name | > 2% modern | > 2% fossil | species name | > 2% modern | > 2% fossil |
| Achnanthes brevipes | X | X | Cymatosira belgica | X | |
| A. brevipes var. intermedia | X | X | Cymbella aspera | | X |
| A. delicatula | X | X | C. minuta | X | X |
| A. haukiana | X | X | C. tumida | | X |
| A. haukiana var. rostrata | X | X | Delphineis surirella | | X |
| A. lanceolata | X | | Delphineis cf. surirella | X | X |
| A. lanceolata var. dubia | X | | Denticula subtilis | X | X |
| A. minutissima | X | | Diatoma hiemale var. mesodon | X | |
| A. minutissima var. affinis | X | | Dimeregramma minor | X | X |
| A. petersenii | X | | Diploneis didyma | | X |
| A. pusilla | X | | D. interrupta | X | X |
| Actinocyclus curvatulus | | X | D. oblongella | | X |
| A. kützingii | | X | D. ovalis | | X |
| A. normanii | | X | D. pseudovalis | X | X |
| Actinoptychus adriaticus | | X | D. smithii | | X |
| A. vulgaris | | X | D. smithii var. rhombica | | X |
| A. marmoreus | | X | Endictya sp.1 | | X |
| A. senarius | | X | Epithemia sorex | | X |
| A. splendens | | X | E. turgida | | X |
| Amphora coffeiformis | X | | E. turgida var. westermannii | | X |
| A. libyca | | X | Eunotia pectinalis | X | |
| A. mexicana | | X | E. pectinalis var. minor | X | |
| A. pediculus | X | | Fragilaria brevistriata | | X |
| A. proteus | | X | F. construens var. venter | | X |
| A. ventricosa | X | | F. leptostauron | | X |
| Aulacoseira ambigua | X | X | F. pinnata | | X |
| A. granulata | X | X | Frustulia linkei | | X |
| A. islandica | X | X | F. rhomboides | X | |
| A. italica | X | X | F. vulgaris | X | X |
| Bacillaria paxillifer | X | | Gomphoneis herculeana | X | |
| Berkeleya rutilans | | X | Gomphonema angustatum | X | |
| Biddulphia dubia | | X | G. olivaceum | X | |
| Biremis ambigua | X | | G. parvulum | X | X |
| Caloneis bacillum | X | X | Grammatophora oceanica | X | X |
| C. liber | | X | Gyrosigma balticum | | X |
| C. westii | X | X | G. eximium | X | X |
| Camplyodiscus echineis | | X | G. fasciola | X | |
| Catenula adhaerens | | X | G. spencerii | X | |
| Cerataulus turgidus | | X | Hannaea arcus | X | |
| Cocconeis diminuta | X | X | Hantzschia amphioxys | | X |
| C. disculus | | X | H. virgata | | X |
| C. placentula | X | X | Hyalodiscus laevis | | X |
| C. placentula var. euglypta | X | X | H. scoticus | X | X |
| C. scutellum | X | X | Mastogloia exigua | X | X |
| C. scutellum var. parva | X | X | Melosira moniliformis | X | X |
| Coscinodiscus radiatus | | X | M. nummuloides | X | X |
| C. radiatus forma obscurus | | X | M. cf. octogona | X | |
| Cyclotella compta | | X | Navicula accomoda | X | X |
| C. ocellata | | X | N. cancellata | X | |

| TABLE 1 (cont.): DIATOMS >2% OF AT LEAST ONE MODERN OR FOSSIL SAMPLE | | | | | |
|---|---|---|---|---|---|
| species name | > 2% modern | > 2% fossil | species name | > 2% modern | > 2% fossil |
| C. striata | | X | N. capitata | X | |
| N. cincta | X | X | N. levidensis var. victorae | X | X |
| N. contenta | X | | N. lorenziana | X | X |
| N. cryptocephala | X | X | N. nana | X | X |
| N. cryptolyra | | X | N. navicularis | X | X |
| N. cryptotenella | X | | N. palea | X | X |
| N. digitoradiata | X | X | N. perminuta | | X |
| N. granulata | | X | N. pellucida | X | X |
| N. gregaria | X | X | N. pusilla | X | |
| N. halophila | X | X | N. scapelliformis | X | X |
| N. lanceolata | X | | N. sigma | | X |
| N. lyra | X | X | N. cf. sigma | X | X |
| N. lyra var. elliptica | X | X | N. terrestris | | X |
| N. mutica | X | X | Odontella aurita | | X |
| N. muticoides | | X | O. obtusa | | X |
| N. phyllepta | X | X | Opephora marina | | X |
| N. punctulata | | X | O. pacifica | | X |
| N. pusilla | X | X | Paralia sulcata | X | X |
| N. pusilla var. 1 | X | X | Pinnularia appendiculata | X | |
| N. pygmaea | | X | P. borealis | | X |
| N. radiosa | X | | P. lagerstedtii | X | X |
| N. ramosissima | X | | P. subcapitata | X | |
| N. salinarum | X | | Plagiogramma staurophorum | X | |
| N. seminulum | X | | Rhabdonema arcuatum | | X |
| N. stankovicii | X | | Rhaphoneis amphiceros | | X |
| N. tenneloides | X | | R. cf. margaritalimbata | | X |
| N. tripunctata | X | | R. psammicola | | X |
| Neidium densestriatum | X | | Rhoicosphenia abbreviata | X | X |
| Nitzschia acuminata | | X | Rhopalodia gibberula | X | X |
| N. aerophila | | X | R. musculus | X | X |
| N. angularis | X | | Scoliopleura tumida | X | X |
| N. cf. angustata | X | | Stauroneis anceps | X | |
| N. brevissima | X | | Stephanodiscus astraea | | X |
| N. coarctata | X | | S. niagarae | | X |
| N. commutata | X | X | Surirella brébissonii | X | |
| N. compressa | X | | S. fastuosa | | X |
| N. compressa var. vexans | X | | Synedra acus | X | |
| N. constricta | X | | S. fasciculata | X | X |
| N. debilis | X | X | S. vaucheriae | | X |
| N. dissipata | X | X | Tabellaria fenestrata | X | |
| N. fasciculata | X | X | Thalassionema nitzschioides | X | X |
| N. frustulum | | X | Thalassiosira decipiens | X | X |
| N. gandershiemiensis | X | | T. eccentrica | | X |
| N. granulata | | X | T. pacifica | | X |
| N. lanceola | X | X | Trachyneis aspera | | X |
| N. levidensis | X | X | Trachyspenia australis | X | |

**TABLE 2. Definitions for Salinity Terms Used in this Study**

| Term | Salinity Range | Comment |
|---|---|---|
| **Polyhalobous** | > 30 ‰ | **includes "marine" species** |
| **Mesohalobous** | 0.2-30 ‰ | **includes all "brackish" species** |
| α-Mesohalobous | 10-30 ‰ | includes species of"higher" brackish conditions |
| β-Mesohalobous | 0.2-10 ‰ | includes species of "lower" brackish conditions |
| **Oligohalobous** | < 0.2 ‰ | **includes all "freshwater" species** |
| Halophilous | | stimulated by small amounts of salt |
| Indifferent | | tolerates small amounts of salt |
| Halophobous | | does not tolerate small amounts of salt |
| **Euryhalobous (Euryhalinous)** | | occurring over broad ranges of salt concentration, often encompassing two or more large spectral designations |

(Modified from Hustedt (1957))

Plate 1

1. *Achnanthes brevipes* var. *intermedia* (L: 26 µm; W: 9.5 µm; raphe valve).
2. *Actinoptychus senarius* (Diam: 50 µm; focus on raised sectors).
3. *A. senarius* (same specimen; focus on lowered sectors).
4. *Amphora libyca* (L: 40 µm; W: 11 µm).
5. *Amphora proteus* (L: 24 µm; W: 6 µm).
6. *Aulacoseira islandica* (chain of four valves: length of chain = 60 µm).
7. *Caloneis westii* (L: 85 µm; W: 15 µm).
8. *Cocconeis diminuta* (L: 12 µm; W: 8 µ; valves attached to a sand grain).

## PLATE 1

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Plate 2

1. *Cocconeis scutellum*; (L: 42 µm; W: 28 µm; rapheless valve).
2. *Cocconeis scutellum* (L: 50 µm; W: 30 µm; raphe valve).
3. *Cocconeis scutellum* var. *parva*. (L: 18 µm; W: 12 µm; rapheless valve).
4. *Cocconeis scutellum* var. *parva* (L: 15 µm; W: 10 µm; raphe valve).
5. *Coscinodiscus radiatus* f. *obscurus* (Diam: 60 µm).
6. *Cyclotella ocellata* (Diam: 20 µm).
7. *Cyclotella striata* (Diam: 55 µm).
8. *Cymbella tumida* (L: 55 µm; W: 8 µm).
9. *Delphineis* cf. *surirella* (L: 27 µm; W: 8 µm).
10. *Denticula subtilis* (L: 15 µm; W: 2 µm).
11. *Dimeregramma minor* (L: 20 µm; W: 10 µm).
12. *Dimeregramma minor* (L: 26 µm; W: 11 µm; girdle view).

## PLATE 2

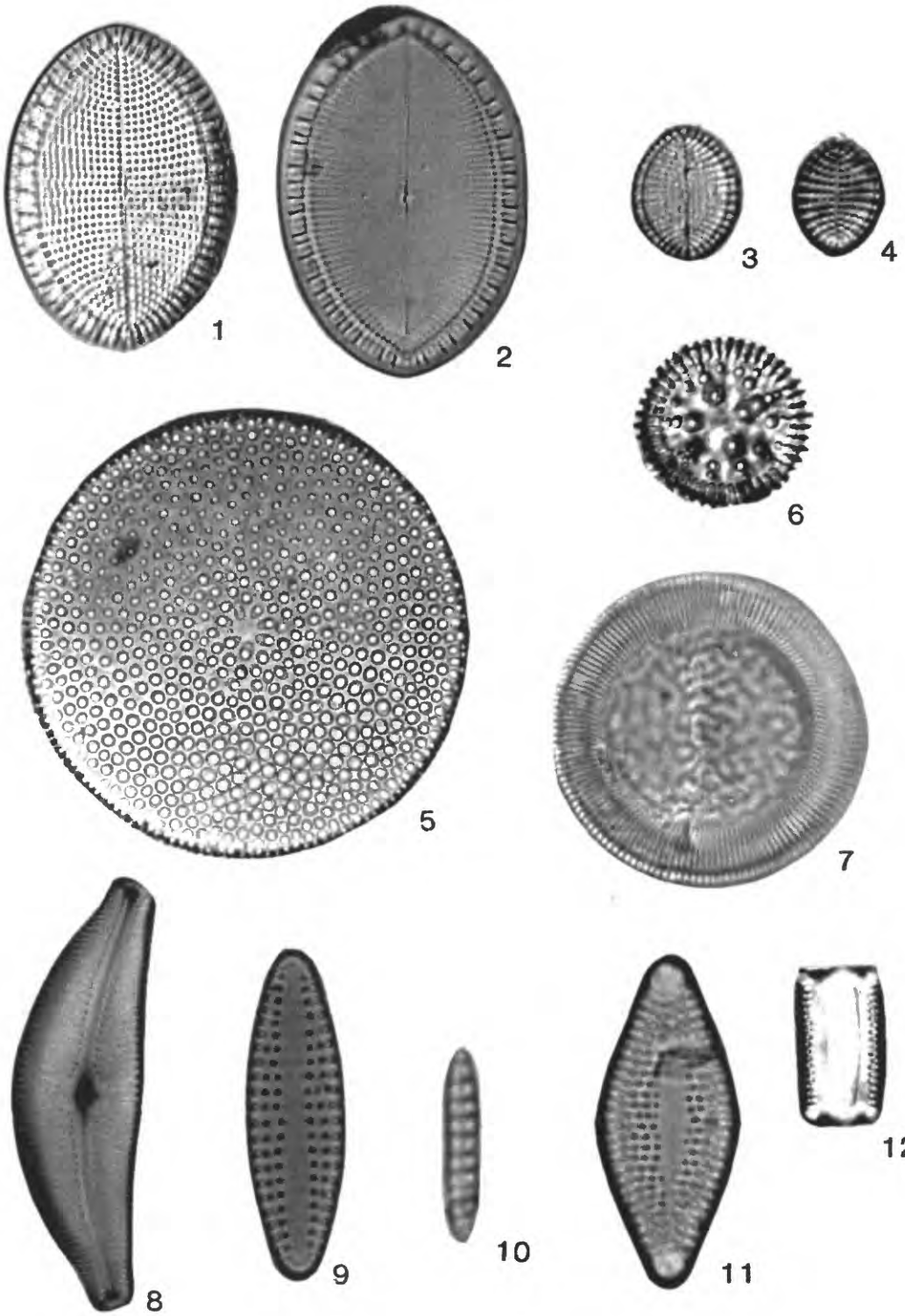

Plate 3

1. *Diploneis didyma* ((L: 42 µm; W: 12 µm).
2. *Diploneis interrupta* (L:55µm; W: 10 µm).
3. *Diploneis pseudovalis* (L: 30 µm; W: 11 µm).
4. *Diploneis smithii* (L: 112 µm; W: 60 µm).
5. *Endictya* sp. 1 (Diam: 36 µm).
6. *Endictya* sp. 1 (Diam: 40 µm)
7. *Epithemia turgida* (L: 90 µm; W: 15 µm).
8. *Epithemia turgida* var. *westermanii* (L: 80 µm; W: 21 µm).

## PLATE 3

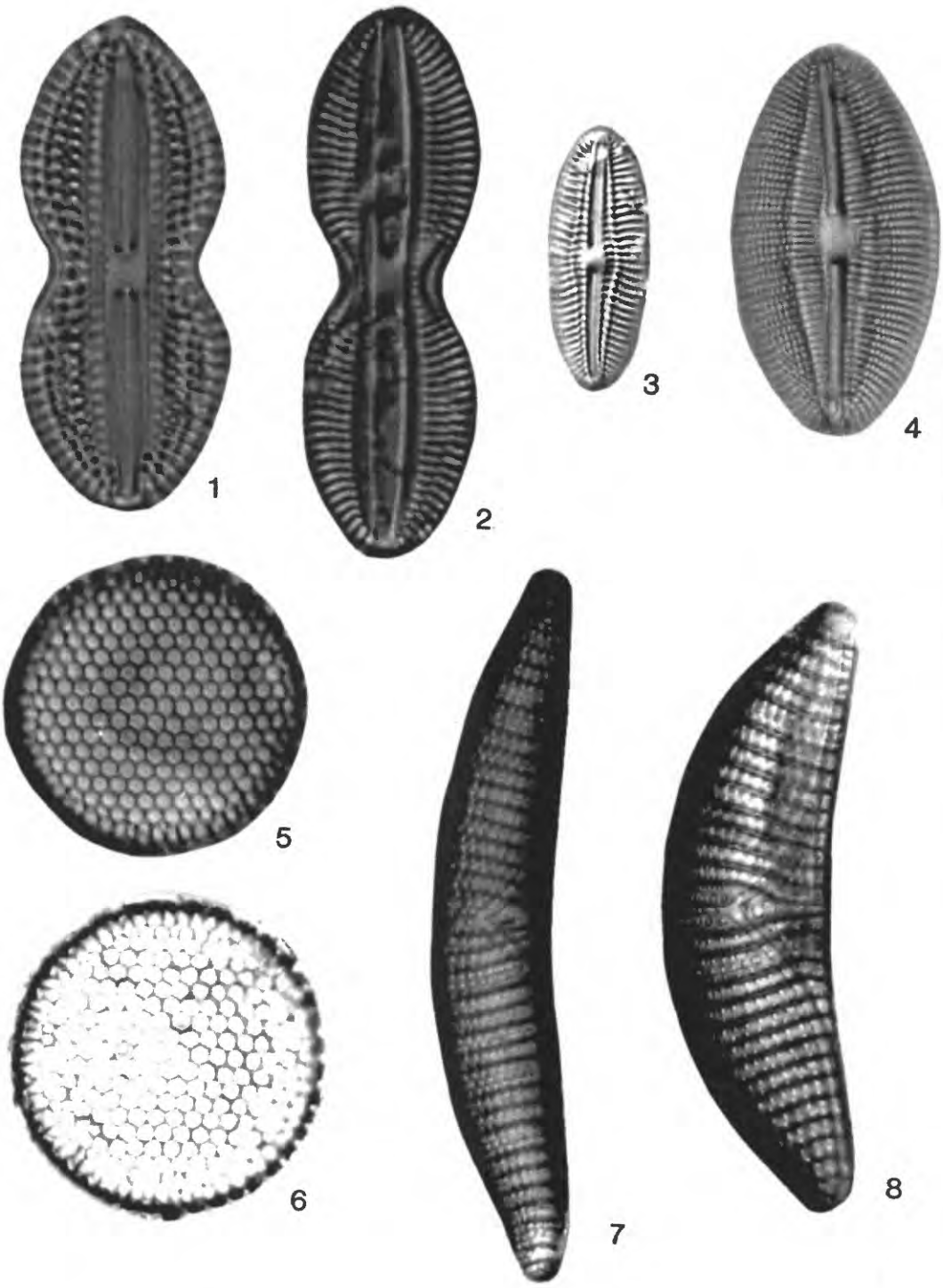

Plate 4

1. *Eunotia pectinalis* (Girdle view; chain of valves; length of valves = 50 µm; width of chain = 48 µm).
2. *Frustulia vulgaris* (L: 65 µm; W: 12µm).
3. *Gomphoneis herculeana* (L: 65 µm; W: 20 µm).
4. *Gonphonema angustatum* (L: 30 µm; W: 7 µm).
5. *Gomphonema parvulum* (L: 33 µm; W: 6 µm).
6. *Grammatophora oceanica* (girdle view; L: 28 µm; W: 12.5 µm).
7. *Grammatophora oceanica* (L: 40 µm; W: 5 µm; focus on striae).
8. *Grammatophora oceanica* (L: 40 µm; W: 5 µm; focus on septum).
9. *Gyrosigma eximium* (L: 50 µm; W: 8 µm).
10. *Hantzschia amphioxys* (L: 48 µm; W: 9 µm).
11. *Hyalodiscus scoticus* (Diam: 22 µm).
12. *Hyalodiscus scoticus* (Diam: 20 µm).
13. *Navicula capitata* (L: 30 µm; W: 5 µm).
14. *Navicula cincta* (L: 23 µm; W: 5 µm).
15. *Navicula granulata* (L: 42 µm; W: 22 µm).
16. *Navicula lanceolata* (L: 52 µm; W: 8 µm).

## PLATE 4

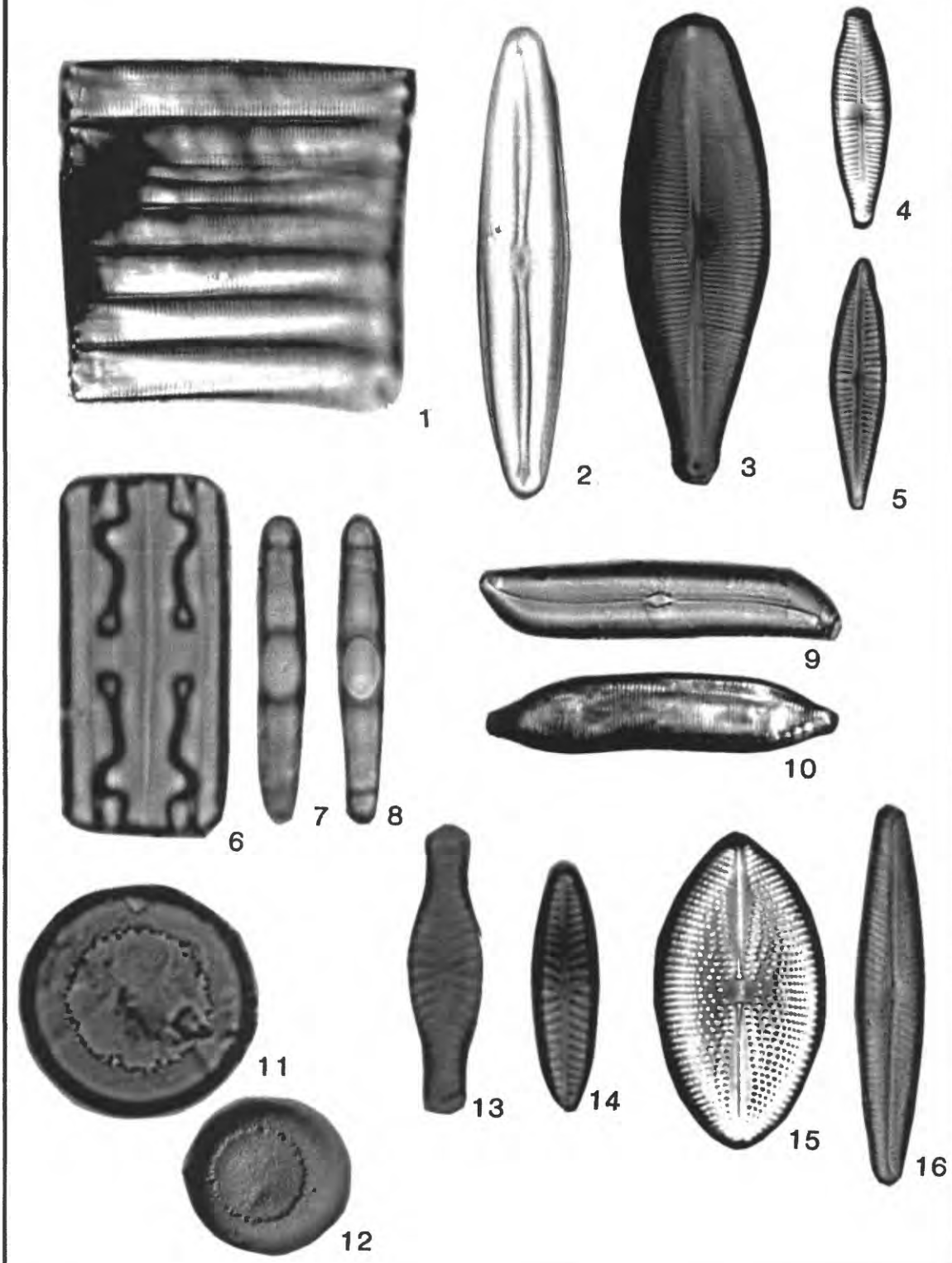

Plate 5

1. *Navicula lyra* (L: 75 µm; W: 34.5 µm).
2. *Navicula lyra* var. *elliptica* (L: 50µm; W: 28 µm).
3. *Navicula mutica* (L: 14 µm; W: 5.6 µm).
4. *Navicula muticoides* (L: 16 µµ; W: 8.8 µm).
5. *Navicula phyllepta* (L: 18 µm; W: 6 µm).
6. *Navicula pusilla* var. 1 (L: 64 µm; W: 28 µm).
7. *Navicula stankovicii* (L: 31 µm; W: 7 µm).
8. *Nitzschia coarctata* (L: 28 µm; W: 9.6 µm).
9. *Nitzschia compressa* (L : 38 µm; W: 17 µm).
10. *Nitzschia fasciculata* (L: 70 µm; W: 5 µm).
11. *Nitzschia granulata* (L: 25 µm; W: 12 µm).
12. *Nitzschia lanceola* (L: 25 µm; W: 6 µm).
13. *Nitzschia navicularis* (L: 50 µm; W: 15 µm).
14. *Nitzschia navicularis* (L: 35 µm; W: 12 µm).

## PLATE 5

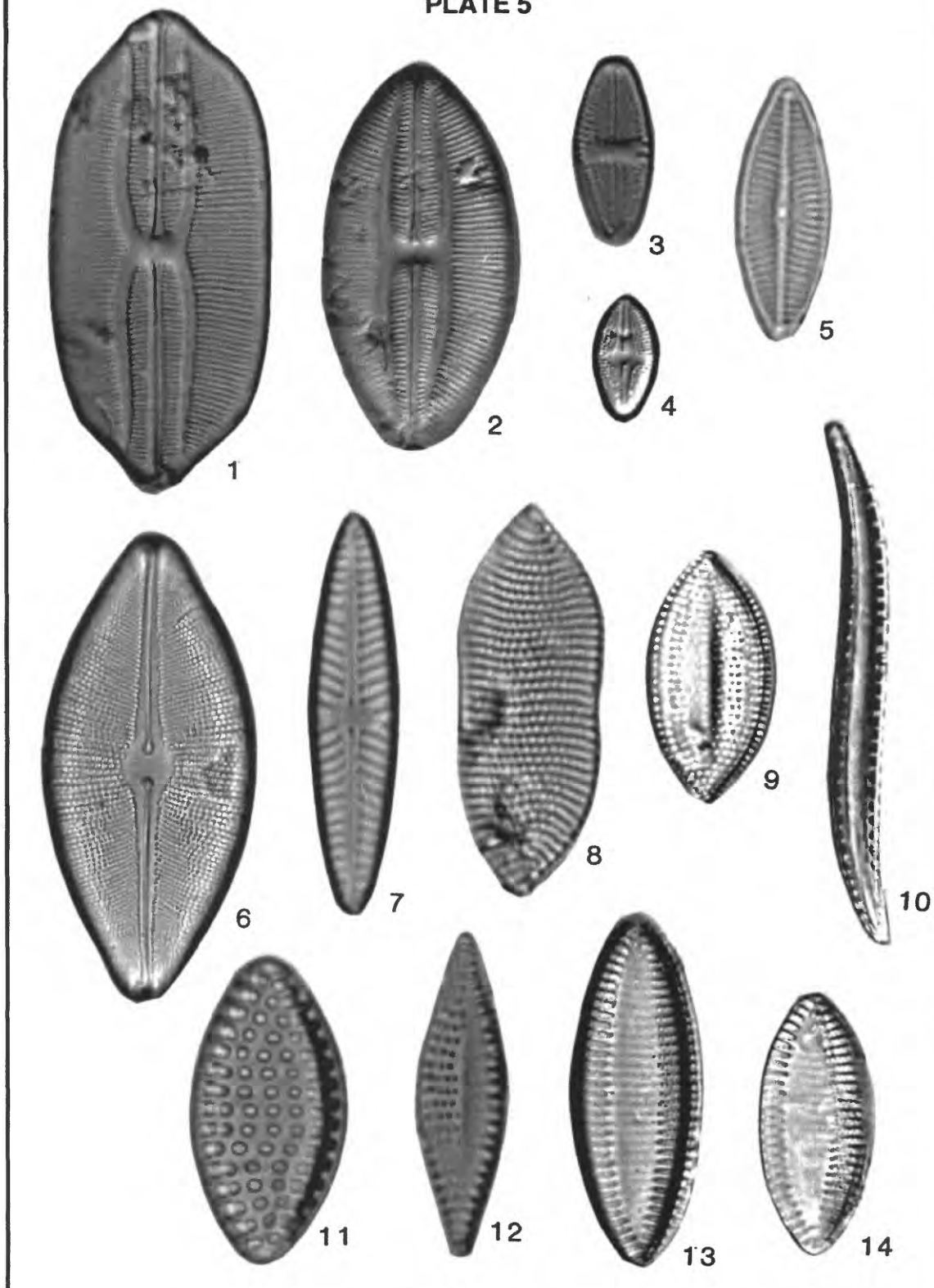

Plate 6

1. *Nitzschia levidensis* var. *victoriae* (L :34µm; W: 16 mm).
2. *Nitzschia terrestris* (L: 45 µm; W: 4.5 µm).
3. *Odontella obtusa* (apical axis: 40 µm; transapical axis: 30 µm).
4. *Paralia sulcata* (Diam: 39 µm).
5. *Pinnularia borealis* (L: 58 µm; W: 7.5 µm).
6. *Pinnularia lagerstedtii* (L: 20 µm; W: 6 µm).
7. *Pinnularia lagerstedtii* (L: 17 µm; W: 5 µm).
8. *Rhabdonema arcuatum* (girdle view; L: 65 µm).
9. *Rhaphoneis psammicola* (L: 30 µm; W: 18 µm).
10. *Rhopalodia gibberula* (L: 48 µm; W: 12 µm).
11. *Rhopalodia musculus* (L: 32 µm; W: 12 µm).
12. *Surirella brébissonii* (L: 35 µm; W: 25 µm).
13. *Surirella fastuosa* (L: 50 µm; W: 30 µm).
14. *Thalassiosira pacifica* (Diam: 28 µm).
15. *Trachysphenia australis* (L: 28 µm; W: 7 µm).
16. *Trachysphenia australis* (L: 63 µm; W: 9 µm).

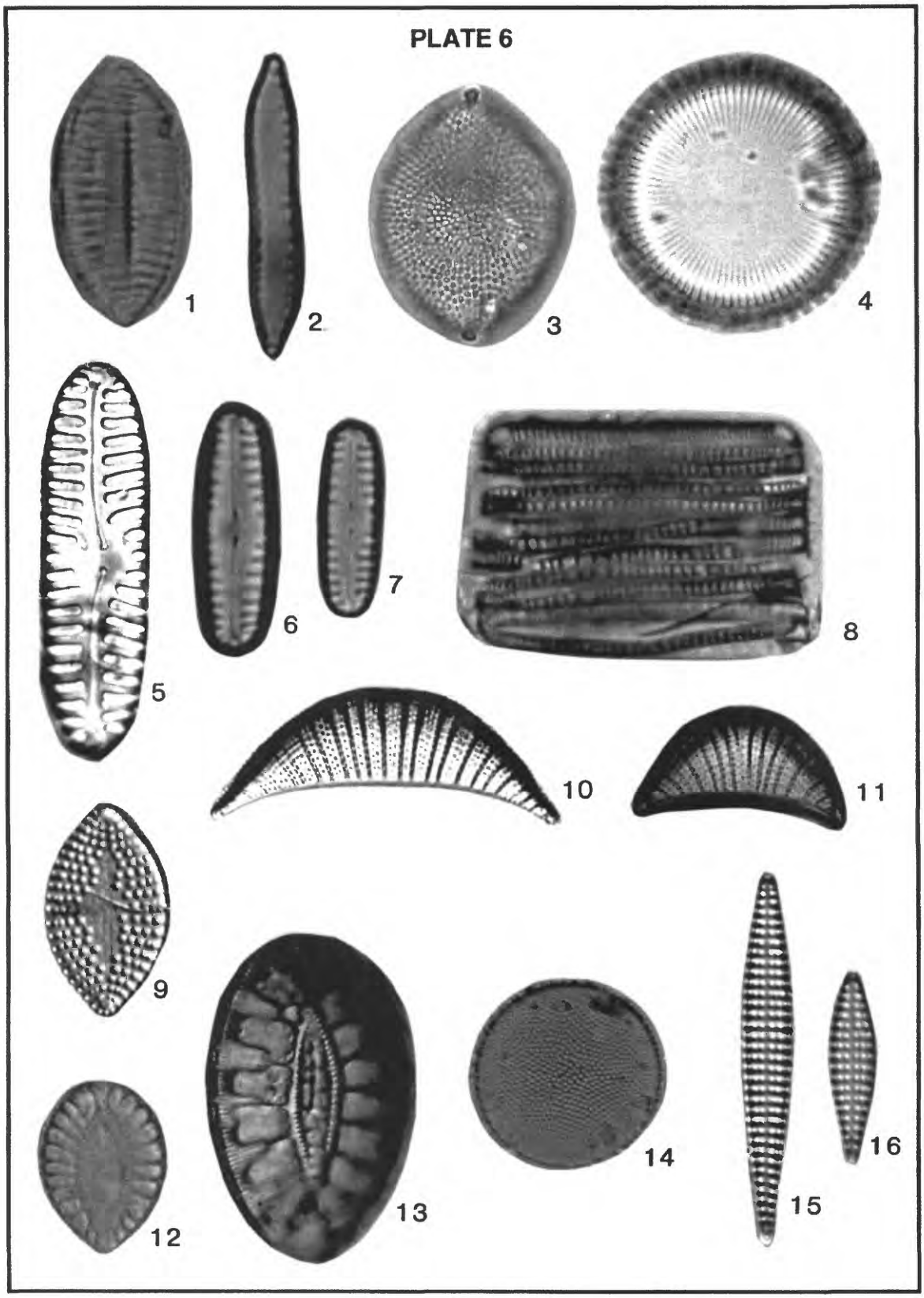
PLATE 6
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