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# Recent Benthonic Foraminifera from Samish and Padilla Bays, Washington

### Abstract

Seventeen species of living benthonic foraminifera, forming six species assemblages, are identified from Samish and Padilla bays, Washington. Four of these assemblages are dominated by *Trochammina pacifica* Cushman in varying percentages with *Miliammina fusca* (Brady) also being common. One assemblage is dominated by *M. fusca* with *Ammonia beccarii* (Linné), *Cribroelphidium spp.*, and *Ammotium salsum* (Cushman and Bronnimann). The sixth assemblage is dominated by *Elphidiella hannai* (Cushman and Grant).

Several variables appear to control foraminifera distributions. The most important of these variables appear to be water depth, water temperature, and sediment patterns.

### Introduction

This paper describes the distribution and abundance of foraminifera found on the mudflat areas in Samish and Padilla bays (Fig. 1). Cushman and Todd (1947) examined foraminifera from the San Juan Islands and noted a close relationship to the faunas from the coast of New England and the Pliccene of California. Cockbain (1963) identified foraminifera from 175 stations in the Strait of Georgia, Fraser River delta, and the Strait of Juan de Fuca. Phleger (1967) reported on foraminifera from marsh areas along the Pacific coast of North America and included data from Grays Harbor, Washington and a marsh area on the Fraser River delta.

### Methods and Techniques

*Collection of Samples*

Samples for study were collected during the late fall of 1972 and winter of 1973 (Fig. 2). Sediment samples were collected at all stations, and water samples were collected at 16 of 23 stations. At two stations (1 and 4) samples were collected by hand on a low tide; at the remaining stations samples were collected on high tide from a small boat with a clamshell dredge.

A wet 25-ml fraction was removed from each sediment sample and sieved through a 0.84 mm screen to extract wood fragments and eel grass. A 0.088 mm screen located below retained the smaller particles and foraminifera. This fraction was dried, weighed, and the foraminifera examined. Rose Bengal was added to the sediment samples at the time of collection but for some reason failed to be taken up by any foraminifera. The author believes, however, that sizable fractions of the populations were alive because of work done on some specimens using other organic stains.

Temperature and salinity were determined for all water samples. In addition ten samples were treated to determine pH and dissolved oxygen. The sediment samples were analyzed using the methods of Folk (1968).

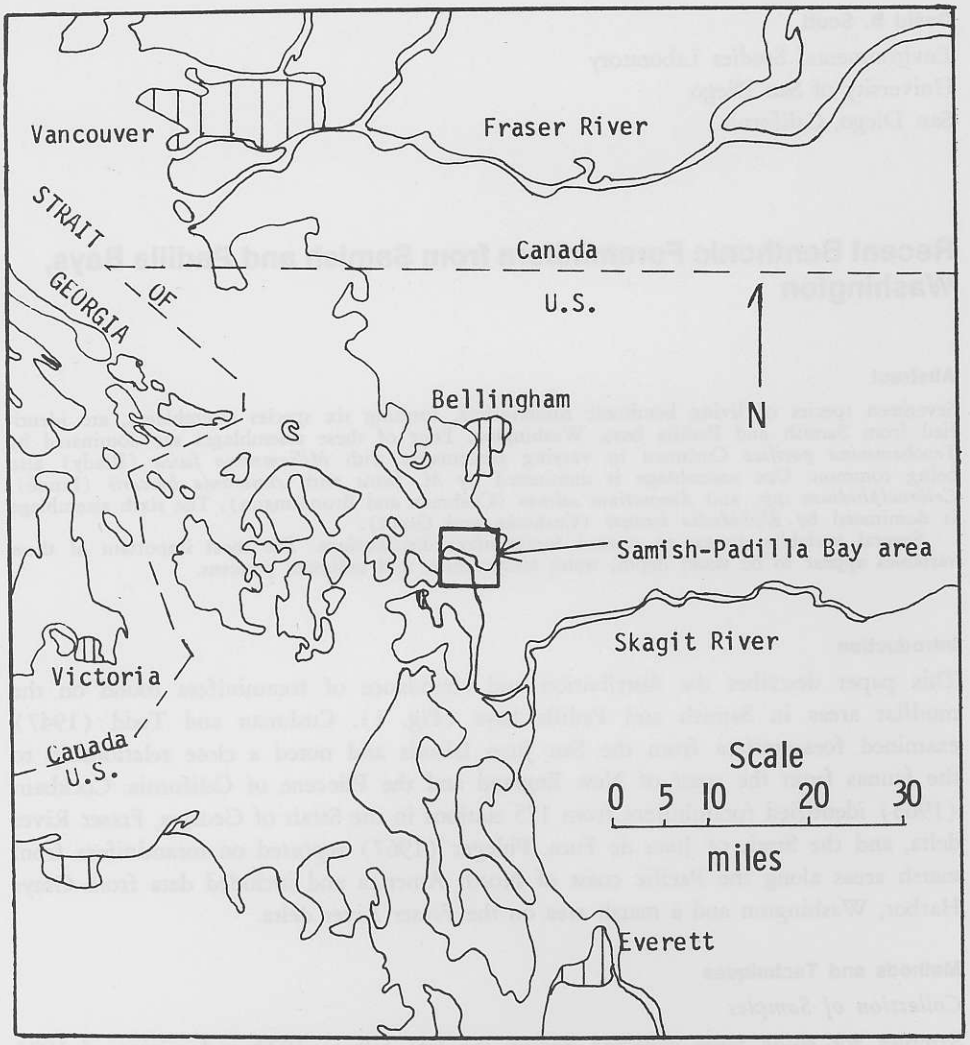


Figure 1. Regional map showing Samish-Padilla Bay (inset).

**Physical Data**

*Hydrography*

Hydrographic data collected during sampling and from Collias *et al.* (1966) indicate the entire Samish and Padilla Bay area to be estuarine; however, salinities rarely fall below 26 o/oo. Water temperatures at the time of sampling were cold (7°C-9°C), but Collias *et al.* (1966) reported temperatures during the summer months as high as 14°C in offshore portions of Samish Bay, and daytime temperatures presumably rise higher on small enclosed mudflats such as station 1.

Although no data are available on seasonal variations in Padilla Bay, the physical parameters of water entering this bay are probably more stable than those of water entering Samish Bay. Water for Padilla Bay comes primarily from oceanic water to the west whereas water enters Samish Bay from estuarine-dominated Bellingham Bay,

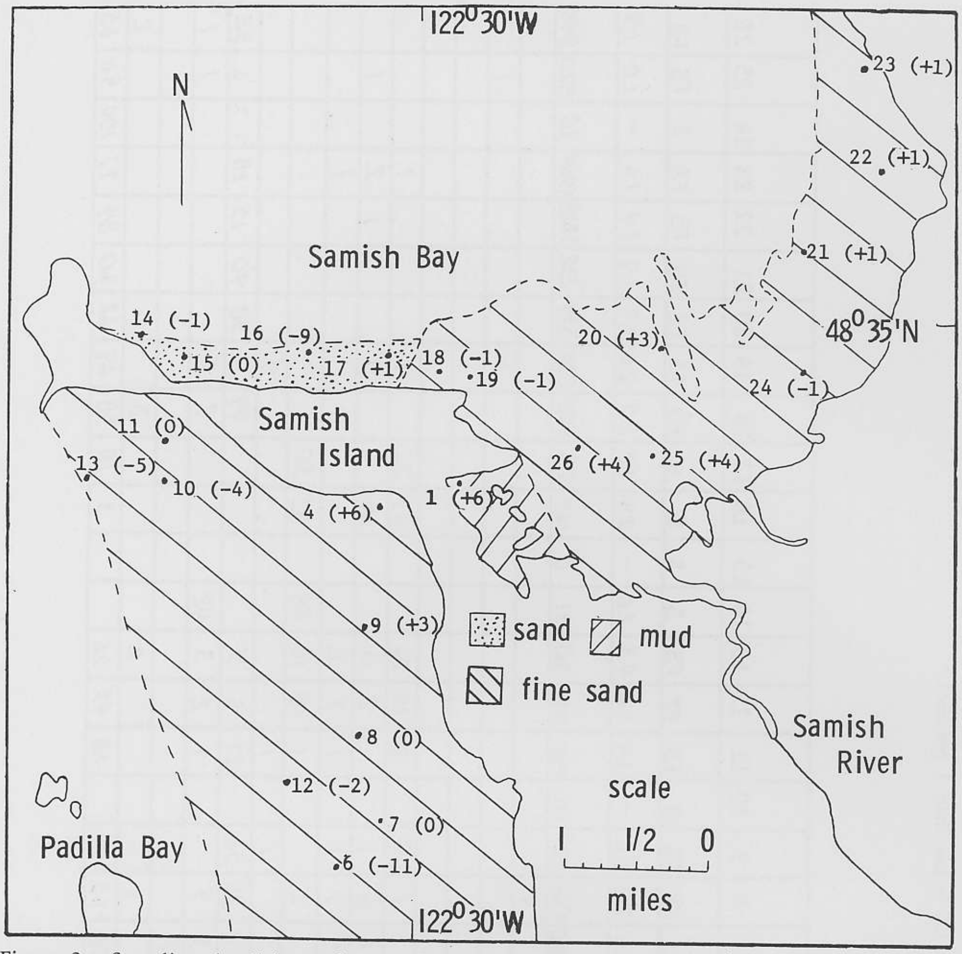


Figure 2. Sampling localities, sediment distribution, and water depths in feet (coastal mean low water equals zero) at each station.

and the Samish River and physical parameters vary considerably depending on river flow.

*Sediments*

Sedimentation in the region probably stopped 70 or more years ago with the last shift of the Skagit River (Sternberg, 1967). The Samish River presently flowing into the area contributes fine material, thereby maintaining a balance between marine erosion and deposition (Sternberg, 1967).

Three types of sediment are recognized in the area (Fig. 2): coarse sand occurs in tidal channels and off the leading edge of the delta; fine sand is found over most of the tidal flat area of Samish and Padilla bays; and silts and clays occur in small, sheltered mudflats close to the shoreline of Samish Bay.

**Results**

Seventeen species of foraminifera were identified. The distribution and population statistics of all species are shown in Table 1. There are six foraminiferal assemblages

TABLE 1. Foraminiferal species distributions in percent (X is less than 1 percent).

| Station number | 1 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sediment type | M | FS | FS | FS | FS | FS | S | FS | FS | FS | S | S | S | S | FS | FS | FS | FS | FS | FS | S | FS | FS |
| Species diversity | 3.3 | 1.3 | 2.3 | 1.6 | 2.2 | 2.2 | – | 1.9 | 3.6 | 4.3 | 2.0 | – | 2.8 | 2.8 | 2.5 | 2.0 | 1.9 | 1.9 | 1.4 | 1.6 | – | 1.0 | 1.9 |
| Total number of specimens/25 ml. | 1190 | 9650 | 606 | 2260 | 3360 | 1567 | 0 | 2491 | 298 | 160 | 31 | 0 | 169 | 28 | 1824 | 800 | 354 | 232 | 3408 | 6464 | 28 | 1920 | 840 |
| Alveophragmium ? sp. | | | 1 | | x | | | | | | | | | | | | | | | | | | |
| Ammobaculities dilatatus | 1 | | | | | | | | | | | | | | | 1 | | | | | | 1 | |
| Ammonia beccarii | 23 | | | | | | | | | | | | | | 1 | | | | | | | | |
| Ammotium salsum | 7 | | | | | | | | | | | | | | | | | | | | | | |
| Buccella frigida | | | 3 | | 1 | 4 | | 2 | 19 | 36 | | | 41 | 32 | | 7 | | | | 1 | | | |
| Cribroelphidium spp (2) | 20 | | 1 | 1 | 6 | 1 | | | 2 | 8 | | | 18 | | | 5 | | | 1 | 2 | | 1 | |
| Eggerella advena | | | 6 | 1 | 1 | 1 | | 1 | 7 | 2 | | | | | 1 | | | | | 1 | | | |
| Elphidiella hannai | x | | 10 | | x | | | 1 | 18 | 18 | 58 | | 45 | 50 | 1 | | | | | | | | |
| Glabratella opercularis | | | | | | 1 | | 1 | | | | | | | | 4 | | | | | | | |
| Miliammina fusca | 46 | 12 | 12 | 19 | 20 | 36 | | 27 | 6 | 5 | | | | | 49 | 11 | 38 | 40 | 15 | 18 | | 1 | 32 |
| Quinqueloculina spp.(3) | | 2 | 1 | 3 | 9 | | | 1 | 2 | 3 | 42 | | | | 7 | 5 | | | | | | 1 | 1 |
| Spirillina vivipara | | | | 1 | | | | | | | | | | | | | | | | | | | |
| Trochammina inflata | 1 | x | 1 | | x | | | | | 2 | | | | | 3 | | | | | | | | 2 |
| T. pacifica | 2 | 86 | 64 | 76 | 63 | 56 | | 68 | 45 | 26 | | | 3 | 18 | 38 | 69 | 62 | 60 | 84 | 77 | 100 | 96 | 65 |

(Fig. 3). Assemblages south of Samish Island are more diverse and have higher average densities than those north of Samish Island.

Species diversities were calculated using the formula (Simpson, 1949)

$$D_E = N(N-1) \Big/ \sum_{i=1}^{S} ni(ni-1)$$

where $N$ is the total number of individuals, $S$ is the total number of species, and $ni$ is the number of individuals in the $i^{th}$ species.

*Assemblage 1*

This assemblage is characterized by *Trochammina pacifica, Miliammina fusca, Buccella frigida, Eggerella advena,* and *Elphidiella hannai,* occurs at stations 6, 12, and 13, and has the highest species diversity (3.4) of any assemblage.

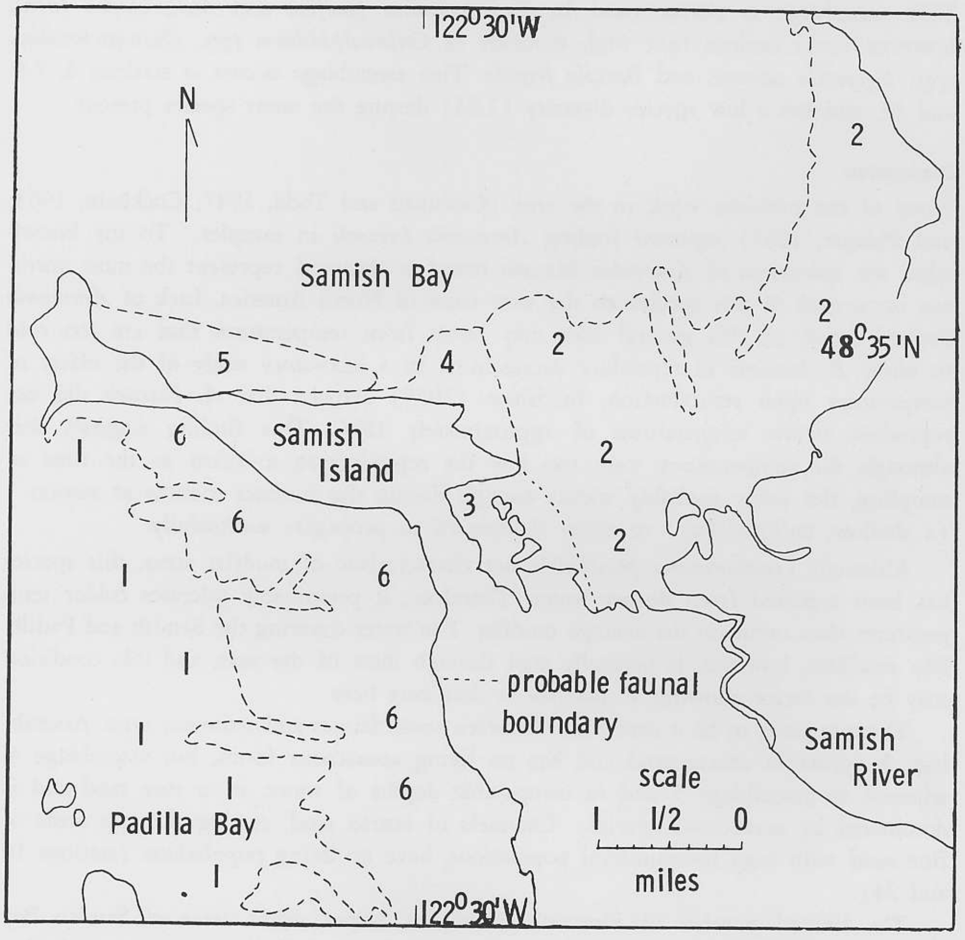


Figure 3. Faunal assemblages.

*Assemblage 2*
This assemblage is characterized by *Trochammina pacifica* and *Miliammina fusca* with some stations containing 90 percent *T. pacifica.* The assemblage occurs at stations 20-26 and has a low diversity of 1.6.

*Assemblage 3*
This assemblage is characterized by *Miliammina fusca, Cribroelphidium* spp., *Ammonia beccarii,* and *Ammotium salsum,* occurs at only one station (1), and has a high species diversity (3.3).

*Assemblage 4*
*Trochammina pacifica, Miliammina fusca,* and *Quinqueloculina* spp. characterize this assemblage, which occurs at stations 18 and 19 and has a species diversity of 2.2.

*Assemblage 5*
*Elphidiella hannai* and *Buccella frigida* characterize this assemblage, which occurs at stations 14-17 and has a species diversity of 2.5.

*Assemblage 6*
This assemblage is characterized by *Trochammina pacifica* and *Miliammina fusca;* however, some stations have high numbers of *Cribroelphidium* spp., *Quinqueloculina* spp., *Eggerella advena,* and *Bucella frigida.* This assemblage occurs at stations 4, 7-9, and 11, and has a low species diversity (1.84) despite the many species present.

## Discussion

None of the previous work in the area (Cushman and Todd, 1947; Cockbain, 1963; and Phleger, 1967) reported finding *Ammonia beccarii* in samples. To my knowledge, the specimens of *Ammonia beccarii* found at station 1 represent the most northern occurrence of this species on the west coast of North America. Lack of *Ammonia beccarii* north of this general area may result from temperatures that are too cold to allow *A. beccarii* to reproduce successfully. In a laboratory study of the effect of temperature upon reproduction, Bradshaw (1955) showed that *A. beccarii* did not reproduce below temperatures of approximately 18°C. This finding suggests that although the temperatures were too low for reproduction to occur at the time of sampling, the water probably warms enough during the summer months at station 1 (a shallow, enclosed bay) to allow *A. beccarii* to propagate successfully.

Although *Trochammina pacifica* is not characteristic of mudflat areas, this species has been reported from deeper water. Therefore, it presumably tolerates colder temperatures than occur on the average mudflat. The water covering the Samish and Padilla Bay mudflats, however, is normally cold through most of the year, and this condition may be the factor allowing *T. pacifica* to dominate here.

There appears to be a correlation between some faunas and sediment type. Assemblage 5 occurs in coarse sand and has no living arenaceous forms, but assemblage 4, adjacent to assemblage 5 and in comparable depths of water, is in fine sand and is dominated by arenaceous species. Channels of coarse sand, cutting through areas of fine sand with high foraminiferal populations, have no living populations (stations 10 and 24).

The limited number of foraminifera in the deeper water areas of Samish Bay caused difficulty in comparing species diversity of the shallow-water areas with that of deeper-water areas. In Padilla Bay, however, a limited number of samples suggests that species diversity increases with water depth with the result that mudflat areas exposed at spring low tides have a lower diversity than deeper, unexposed areas (Table 1).

Faunas in Padilla Bay appear to have a higher diversity than those in Samish Bay (Table 1). This situation may reflect the more stable oceanic influence in Padilla Bay that is not present in Samish Bay.

*Alveophragmium* sp.

*Ammobaculites dilatatus* Cushman and Bronnimann
*Ammobaculites dilatatus* Cushman and Bronnimann, 1948, Cush. Lab. Foram. Research, v. 24, no. 2, p. 39.

*Ammonia beccarii* (Linné)
*Nautilus beccarii* Linné, 1758, Systema naturae ed. 10, v. 1, p. 710.
*Streblus beccarii* (Linné), Fischer de Waldheim, 1817, Soc. Imper. Nat. Moscow, Mem. v.s. p. 449, pl. 13.

*Ammotium salsum* (Cushman and Bronnimann)
*Ammobaculites salsus* Cushman and Bronnimann, 1948, Cush. Lab. Foram. Research, v. 24, p. 16, pl. 3, fig. 7-9.
*Ammotium salsum* (Cushman and Bronnimann) Parker, 1959, Jour. Paleo. v. 33, no. 2, p. 340, pl. 50, fig. 6, 13.

*Buccella frigida* (Cushman)
*Pulvinulina frigida* Cushman, 1922, Contr. Canadian Biol. v. 192, no. 9, p. 12.
*Eponides frigida* (Cushman), Cushman, 1931, U.S. Nat. Mus. Bull., v. 104, pt. 8, p. 45.
*Bucella frigida* (Cushman), Andersen, 1952, Wash. Acad. Sci., Jour., v. 42, no. 5, p. 144.

*Cribroelphidium selseyense* (Heron-Allen and Earland)
*Polystomella straitopunctata* Fichtel and Moll var. *selseyense,* Heron-Allen and Earland, 1901, Royal Micro. Soc. Journ., p. 448.
*Elphidium selseyense* (Heron-Allen and Earland), Cushman, 1939, USGS Prof. Paper 191, p. 66.

*Cribroelphidium frigidum* (Cushman)
*Elphidium frigidum* Cushman, 1933, Smithson. Inst. Misc. Coll., v. 89, no. 4, p. 5, pl. 1, fig. 8.

*Eggerella advena* Cushman
*Eggerella advena* Cushman, 1937, Cush. Lab. Foram. Research, Special Publ. 8, p. 51, pl. 5, fig. 12-15.

*Elphidiella hannai* (Cushman and Grant)
*Elphidium hannai* Cushman and Grant, 1927, San Diego Soc. Nat. Hist. Trans., v. 5, no. 6, p. 77, pl. 8, fig. 1, 2.
*Elphidiella hannai* (Cushman and Grant), Cushman 1939, USGS Prof. Paper 191, p. 66, pl. 19, fig. 1, 2.

*Glabratella opercularis* (d'Orbigny)
*Rosalina opercularis* d'Orbigny, 1839, Hist. Phys. Pol. Nat. Cuba, v. 8, p. 93, pl. 3, fig. 24, 25, pl. 4, fig. 1.

*Miliammina fusca* (Brady)
*Quinqueloculina fusca* Brady, 1870, Ann. and Mag. Nat. Hist., London, England, ser. 4, v. 6, p. 286, pl. 11, fig. 2a-c.
*Miliammina fusca* (Brady), Phleger and Walton, 1950, Am. Jour. Sci., v. 248, no. 4, p. 280, pl. 1, fig. 19.

*Quinqueloculina* spp.
At least three species.

*Spirillina vivipara* Ehrenberg
*Spirillina vivipara* Ehrenberg, 1843, Akad. Wis. Berlin, Phys. Abstr. Berlin, Deutschland, Teil 1, p. 422, pls. 3, 7.

*Trochammina inflata* (Montagu)
*Nautilus inflatus* Montagu, 1808, *Testacea Britannica,* Supplement, Exeter, England, S. Woolmer, p. 81.
*Trochammina inflata* (Montagu), Parker and Jones, 1859, Ann. and Mag. Nat. Hist., ser. 3, v. 4, p. 347.

*Trochammina pacifica* Cushman
*Trochammina pacifica* Cushman, 1925, Contr. Cush. Lab. Foram. Research, v. 1, pt. 2, p. 39, pl. 6, fig. 3a-c.

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