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MEMORANDUM

December 5, 1985

To: Tom Eaton

From: Will Kendra and Tim Determan WK DaD

Subject: Summary of Information Concerning "Red Tide" Dinoflagellate Blooms

The Water Quality Investigations Section recently completed a receiving water study for three small sewage treatment facilities which discharge into Budd Inlet (Kendra and Determan, 1985). During the field survey, a red-colored algal bloom was observed in the vicinity of Seashore Villa. In response to public interest and your recent queries regarding the nature and potential toxicity of red tides in southern Puget Sound, we concluded further study of the bloom was in order.

The red tide was predominantly a monoculture of the dinoflagellate *Ceratium fusus*. Dissolved oxygen levels in the bloom exceeded 200 percent of saturation. Secchi disc transparency was 2.2 m, compared to 7.5 m in adjacent waters. Although cell densities were not estimated, field observations and cell counts for species composition indicated that cell concentrations were highest at a depth of 2 m. This finding is consistent with literature reports that *C. fusus* is negatively phototaxic--that is, it tends to avoid zones of intense light (Cardwell, *et al*., 1979).

Most red tides are caused by pigmented dinoflagellates. In marine waters, these organisms are second in abundance only to diatoms (Quayle, 1969). Because they possess both plant and animal characteristics, dinoflagellates have been placed in the division Pyrrhophyta by botanists and in the phylum Protozoa by zoologists. Many dinoflagellates, like plants, have chloroplasts and are photosynthetic. Others, more animal-like, are heterotrophic; i.e., they must feed on other plants and animals to obtain the organic compounds required for growth, maintenance, and reproduction. In general, most dinoflagellate species are free-living unicells which are capable of locomotion through the use of whip-like projections called flagella.

Red tides occur world-wide. Common dinoflagellate genera in Puget Sound include *Amphidinium*, *Ceratium*, *Dinophysis*, *Gonyaulax*, *Noctiluca*, *Peridinium*, and *Prorocentrum* (Dexter *et al*., 1981; Figure 1). Under optimal environmental conditions (typically in summer), dinoflagellates reproduce at high rates. Resultant blooms are variously colored, depending on the predominant species. Reds are most common, hence the term "red tide." Organisms first become visible when densities approach one million cells per liter (Magoon and Vining, 1981). Bloom densities as high as 20 million cells per liter have been reported (Bold and Wynne, 1978).

The initiation of red tides may be associated with the germination of dinoflagellate cysts. These cysts are a predominantly benthic resting form assumed by some dinoflagellates when environmental conditions become unfavorable. Steidinger and Haddad (1981) believe almost all nearshore and estuarine bloom species produce resting cysts even though cysts have not yet been identified for many dinoflagellate species. Periodic resuspension and excystment of these dormant cells produce vigorous populations which may ultimately attain bloom proportions.

Several environmental factors are believed to promote the onset of red tides, but at present causal mechanisms are not clearly understood (Prakash, 1974; Cardwell, et al., 1979; Steidinger and Haddad, 1981). Dinoflagellate population growth may be stimulated by minimal water column turbulence, reduced salinity, increased temperature and light intensity, high levels of organic and inorganic nutrients, and presence of chelators (chemical compounds that complex with metals to reduce their toxicity or increase their availability to plants as trace elements). Protected estuaries like inlets found in Southern Puget Sound provide such an environment. Investigators are unsure if water pollution encourages dinoflagellate blooms. Strickland (1983) noted that red tides occur naturally but may be intensified by human activities. Thus while discharges of treated sewage effluent may not cause red tides, they may create conditions that favor the development of more severe blooms.

Living dinoflagellate cells produce more oxygen by day in photosynthesis than they consume at night in respiration (Sweeney, 1976). Daytime oxygen levels of nearly 20 mg/L (>200 percent saturation) were observed in the C. fusus bloom in Budd Inlet. When organisms comprising a red tide die, bacterial decomposition of dead cells can deplete seawater oxygen concentrations. In extreme situations, low oxygen levels (and possibly the subsequent production of hydrogen sulfide) have caused extensive mortalities in fish and shellfish populations (Sweeney, 1976; Mahoney and Steimle, 1979). This effect is most pronounced in shallow bays where the volume of water is small and tidal flushing is poor.

Some dinoflagellates produce toxins that are capable of killing marine invertebrates and fish, sea birds, and shore mammals (LoCicero, 1974; Taylor and Seliger, 1979). Of more than 1,200 described species of dinoflagellates, fewer than 20 produce toxins (Steidinger, 1979). In Puget Sound, Gonyaulax catenella produces saxitoxin, a neurotoxin that is 100,000 times more potent than cocaine (Bold and Wynne, 1978; Magoon and Vining, 1981). Saxitoxin is accumulated and concentrated in the siphons or digestive glands of filter-feeding bivalve molluscs (clams, mussels, oysters, scallops, etc.). The toxin does not harm these molluscs but can cause "paralytic shellfish poisoning" (PSP) in mammals, including humans, that consume them. PSP is initially characterized by tingling of the lips and tongue, followed by numbness and paralysis, and in severe cases, death.

Cardwell, et al. (1977, 1979) reported that waters in several enclosed inlets of south Puget Sound periodically become highly toxic to some species of bivalve molluscs in late summer. They observed that extensive red tide blooms of C. fusus coincided with the periods of toxicity. Further, they demonstrated a significant causal relationship between C. fusus densities and oyster larvae mortalities. Because test waters were rendered nontoxic when dinoflagellate cells were ground up or removed entirely, mortalities were attributed to a physical mechanism rather than to a toxin. Strickland (1983) proposed that C. fusus may kill oyster larvae by impaling them on its long spine. Cardwell, et al. (1979) found that seawater toxicity in the southern Sound was markedly reduced in well-mixed areas of open water.

WK:TAD:cp

Attachments

cc: Dick Cunningham
Lynn Singleton

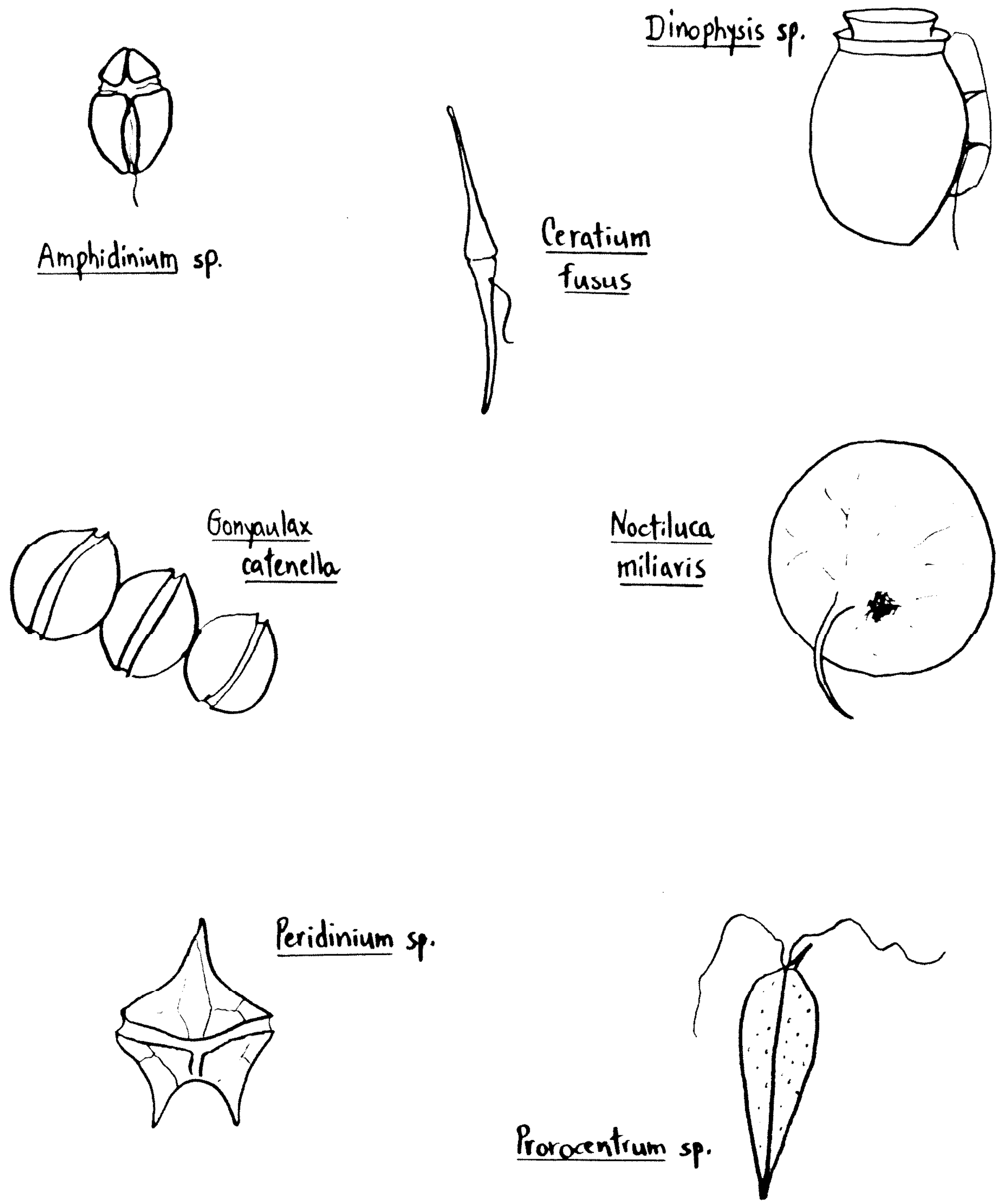

Figure 1. Common dinoflagellate genera in Puget Sound (adapted from the drawings and photographs of Newell and Newell [1967], Smith [1977], Bold and Wynne [1978], and Strickland [1983]). Organisms range in size from 10 um to 2 mm.

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