5. PRIMARY PRODUCTIVITY DYNAMICS AND RATES

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BENTHIC PRIMARY PRODUCTIVITY

There has been relatively little research conducted on benthic primary production in Puget Sound, particularly in recent years. Puget Sound receives nutrients from rivers, streams, banks, bluffs, sewage discharges, and the ocean, and productivity in the Sound is generally regarded as being moderate to high relative to other estuarine systems (Strickland 1983). In shallow waters down to -10 m MLLW, benthic primary production is considered high (Thom 1987). In a study conducted in the mid-1980s as part of work carried out during the Seahurst Baseline Studies, nutrient limitation, primary productivity, and eutrophication issues were examined at several nearshore sites (Thom et al. 1988). Drift macroalgae contained the highest biomass during the summer maxima (August) among all autotrophs, followed by eelgrass, sediment-associated algae, and phytoplankton. Net primary productivity for all nearshore autotrophs combined at Seahurst Beach (reach 7) was greatest in spring (May). This was followed by a buildup of biomass in summer. Nitrate concentration at Seahurst Beach showed a steady decline in spring from high winter concentrations and a buildup during the period of declining productivity (fall-winter). Depleted nitrate concentration during times of high net primary productivity and algal biomass coupled with N:P ratios falling below growth-limiting levels provide strong evidence that nutrient limitation occurs under certain conditions in nearshore areas of central Puget Sound (Thom et al. 1988). In general, nutrient limitation in shallow estuaries is common, especially where benthic and water column photic zone coupling is strong. The nearshore zone in Puget Sound represents an area of relatively strong benthic-water column coupling. In areas where benthic plants are abundant, high levels of productivity during spring and summer are responsible for depleting inorganic nutrients that wash over beaches during flood tides.

WATER COLUMN PRIMARY PRODUCTIVITY

Primary productivity rates in Puget Sound are generally considered to be very high relative to other temperate estuaries; however, most estimates are based on relatively few measurements. Measurements taken in the Central Basin in 1964 and 1965 were 460 and 470 g C m^{-2} $year^{-1}$ (Winter et al. 1975). Primary factors affecting primary productivity in the Central Basin are sunlight, stratification, and residence time. Freshwater entering the Sound from the Skagit and Snohomish Rivers via the Whidbey Basin, with additional inputs from Lake Washington and the Duwamish and Puyallup Rivers, brings about stratification. Runoff is lowest in late summer and peaks in the winter and spring (Strickland 1983). Increased sunlight caused by long days, clear skies, and a high sun angle coincides with stratification at the surface, making May to July the peak growing season in the Central Basin (Dexter et al. 1981; Ebbesmeyer and Helseth 1977). River flow, tides, and winds govern the residence time in the Central Basin.

All of these influences are highly variable in time and space, producing extreme temporal patches of primary productivity and abundance, which are usually characterized by phytoplankton blooms. For example, primary productivity south of WRIAs 8 and 9 a passage near the mouth of Case Inlet is less than 60 percent of that in the Main Basin. This area, located near a sill, has strong mixing and short residence time. There is little seasonal variation in the

stability or nutrient content of the water. Annual production is estimated to be around 270 g C m^{-2} $year^{-1}$. Compared with the Main Basin, stability and phytoplankton biomass change very little at this location, either on a seasonal scale or shorter scale of blooms. Production also begins about two months earlier than in the Main Basin, probably because shallow water limits the depth of mixing. This mixing eventually restrains photosynthesis later in the season, causing the lower estimated primary production.

Primary production was first measured in January 1960 in Elliott Bay (reach 4) by (1966), although the data were never analyzed. Numerous productivity experiments have since been performed in the Duwamish River. Welch and Isaac (1967) showed that gross primary production varied inversely with tidal height. Turnover rates for phytoplankton were calculated to be 2.2/day over an interval of 0 to 4 meters (Prych et al. 1976), 0.6/day for depths of 0 to 1 meter, and 0.3/day for 0 to 4 meters (Welch 1968). Harper-Owes (1983) demonstrated that low oxygen levels in the Duwamish were due to salt-wedge water residence time and benthic oxygen demand. Welch (1969) noted a correlation between gross production and retention time as determined by freshwater discharge. Annual primary productivity over the photic zone was significantly lower than that of the Main Basin of Puget Sound, primarily because of reduced light penetration caused by the silt load in the Duwamish River (Ebbesmeyer and Helseth 1977).

As part of the MOSS program, a relatively long-term water quality sampling program has been instituted to collect a variety of data from selected offshore and nearshore stations on a regular basis. Nutrients, DO, PAR, salinity, suspended solids, temperature, turbidity, and primary productivity are included in the sampling. Preliminary data analysis of Central Basin stations suggests that primary productivity is limited by light in the winter and by nutrients in the summer at certain stations (S. Mickelson, pers. comm.). This is accompanied by seasonal variations in nutrient levels and spatial and temporal variations in primary production.

DATA GAPS

Primary productivity estimates available for benthic and water column components are lacking in any great detail with the exception of early studies done in the Duwamish River and estuary (Table 4). Production estimates are a critical component in understanding the links between phytoplankton, zooplankton, and higher trophic levels in the food chain. In addition, no systematic, standardized sampling has been conducted over the years to allow a comprehensive examination of long-term changes in productivity. Most research to date has been conducted with agency-specific goals in mind. While the collected data are very useful within a specific context, they do not address the larger questions of spatial and temporal variation or long-term distributional change.

Table 4: Data gaps for primary productivity

Gaps	WRIA 8	WRIA 9
Primary productivity estimates for both benthic and water column components	All reaches	All reaches
Time-series data to allow assessment in changes over time, including spatial, temporal, and long-term distributional changes	All reaches	All reaches

Key Findings

- The nearshore zone in Puget Sound represents an area of relatively strong benthic-water column coupling, and nutrient limitation may occur under conditions of limited vertical mixing during the spring and summer.
- Preliminary data indicates primary productivity is limited by light in winter and nutrients in summer at some areas.
- Puget Sound is a relatively productive temperate estuary.