

**Nutrient Pollution and Effects on the Water, Sediment, and Ulvoid species creating  
Green Tides in False Bay, San Juan Island, WA**

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## **Abstract**

False Bay in San Juan Island, WA (N48.4865°, W123.0680°) is a biological preserve on the southwest side of San Juan Island. The watershed includes Trout Lake, the main supply of water for the town of Friday Harbor. Ulvoid blooms have been common which produces a stench as well as possibility for research into the cause. Sampling of the biomass, nitrate concentrations, oxygen saturation, salinity, and temperature at both high tide of August 14, 2012 and low tide on August 15, 2012 revealed small impact of creek or possible agricultural runoff than previously expected. Small amounts of nitrate did not appear to correlate with biomass readings and differences in oxygen saturation. It suggested possible uptake of ulvoids instead. This study provides a jumping off point for future research into causes of ulvoid blooms and nutrient cycling in the bay as well as the unique ecology of this system.

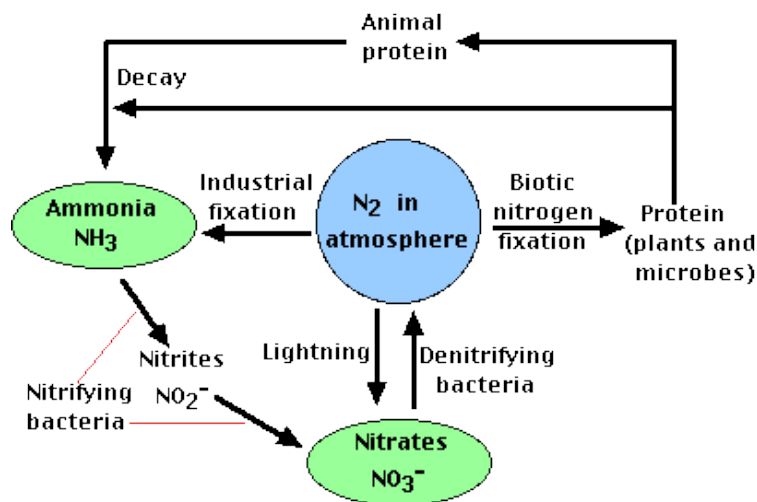
## **Introduction**

The False Bay Watershed located on San Juan Island is the largest watershed in the county and contains the most grassland and farmland acreage as well (Characterization Report). This 12,000-acre drainage basin, which contains a major source for water for the town of Friday Harbor, empties its water into San Juan Creek and then out into False Bay (Characterization Report). False Bay is a unique tidal flat that is home to an extensive collection of marine animals, plants, birds, and much other sea and intertidal species that rely on this ecosystem for survival (Personal Observation in field). The unique types of plants and animals that inhabit the area make False Bay a biological preserve (University of Washington). Agriculture covers large parts of the watershed and most is used for cattle ranching (Characterization Report). Over the past decade San Juan

County Health Services has performed the only real monitoring of the creek in 1998 (SJC Health and Community Services). Farmlands and cattle pastures can be major contributors to nitrogen pollution, a major limiting factor in seaweed growth and typical cause of eutrophication. Nitrogen can also be the limiting factor in seaweed growth (Frankenstein 2000, Nelson 2003). Large amounts of nitrogen have leached into Puget Sound through runoff into waterways in excess of the recommended 1.25 mg/L (Frankenstein 2000). This is based off of the definition of effluent limits of water-quality based determinates which takes into account the interactions of the effluent and receiving waters as well as the duration of the concentration in the area as determined by surveyors (EPA).

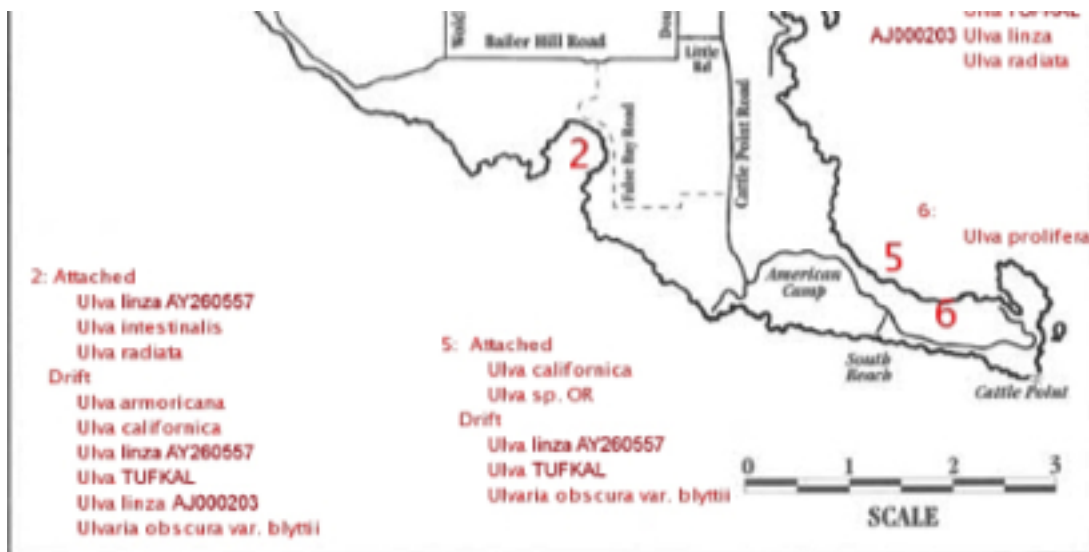
*Brief Description of the Nitrogen Cycle*

While nitrogen comprises 79% of the atmosphere it is not easy to harness. Lightning or other biota fix Nitrogen in the air into  $\text{NH}_3$  which is used by animals and for other agricultural purposes with then decays into nitrites which are in turn nitrified into nitrates which are commonly found in water as  $\text{NO}_3^-$ . This compound is the focus of this experiment and how its concentration can affect ulvoids.



Overview of the Nitrogen Cycle showing the path to the forming of nitrates (Fig. 2)  
*Green Tides*

Ulvoids are very responsive to nitrogen inputs and in eutrophic, shallow waters can grow rapidly given the right amount of nutrients (Taylor 2005). For years, there have been large “green tides” of species of *Ulva* blooming on the shore and in the water of False Bay. This species list includes *Ulva fenestrata* (Price and Hylleberg 1982), *Ulva linza*, *Ulva lactuca*, *Ulvaria Obscura* and various other Ulvoids of both *Ulva* and *Ulvaria* (O’Kelly, Strathman Observations).



(Fig. 1 Courtesy of Charley O’Kelly)

A green tide is a bloom of certain species of green algae that usually is caused by higher than normal nitrogen concentrations in both the water and sediment (Frankenstein 2000). Green tides are also referred to as Harmful Algal Bloom (HAB’s) due to their rapid growth and tendency to turn anaerobic (NOAA). In False Bay this occurs when the tide goes out, heats up the soft sand and as the tide comes in, the shallow water is warmed and with the increased nutrient load produces large algal blooms (Mumford Observation in field).

Rotting of algae produces a bad smell from hydrogen sulfide release, which can be harmful to humans (WA DOE). Not only does it produce smells from rotting, but as the algae decays, the dead material can deplete the dissolved oxygen content in the water which is harmful to fish, snails, anemones, mollusks and many other amphipods that live in the area (FHL Species List).

Signs of anaerobic environment can be blackened sediment, as well as white mats of the bacterium *Beggiatoa*, which is a small sulphur-oxidizing bacterium that anaerobically consumes large amounts of oxygen as well as nitrogen in intertidal areas (Jean-Pierre et al. 1990). More research is necessary to understand effects as well as where the added nitrogen is coming from or if this is a natural occurrence.

#### *Possible Sources*

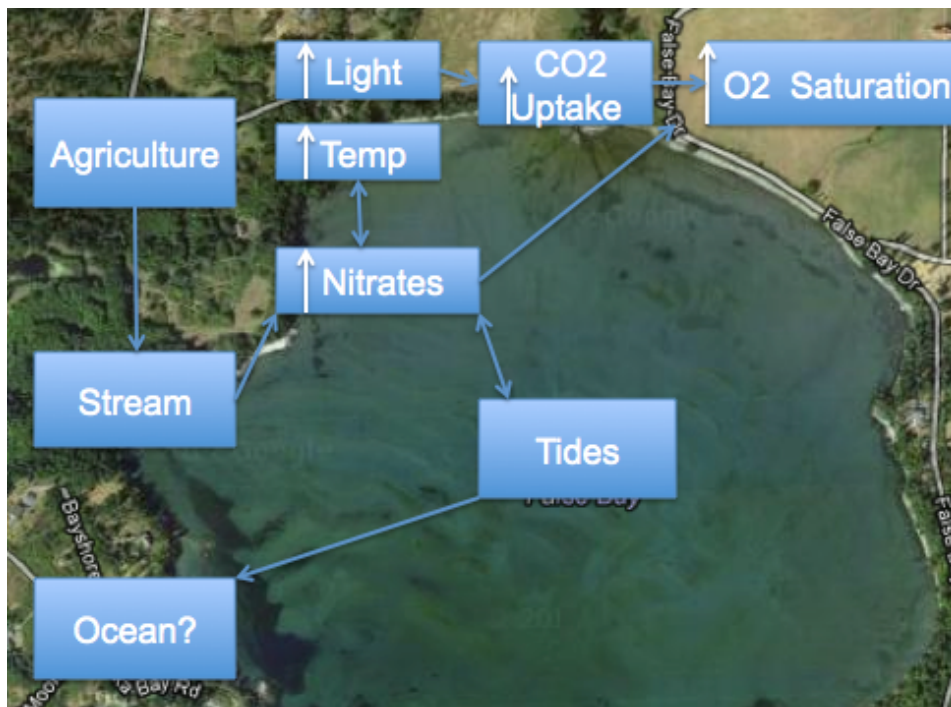
Due to the extensive cattle ranching in the watershed, there is a good chance extra nitrogen is flowing in through the San Juan Creek. Studies in the past on the water quality have shown that fecal coliform amounts are high for False Bay (1997 Monitoring). 30% of land use in the Watershed is set aside for agriculture and as a non point source polluter it is difficult to track all runoff (Action Plan 2001).

It is possible that leeching due to farming practices in the upper parts of the basin have run down the San Juan Creek and flowed into False Bay. As the extra nitrogen combines with warm water in the shallow tidal flats, the added nutrients create an explosion of Ulvoid growth. Nitrogen may also leech into the sediment where it can then continue the cycle of rapid algal growth. Residents of this area have seen algal blooms for decades that even predate some of the agricultural practices in San Juan Island. This

will help further understanding whether this problem is natural or is increasingly becoming man made.

### *Study Goals*

The major goal of this study is to understand if the nitrogen is entering through the San Juan Creek and then increasing the nitrate amounts in the water and sediment. The other goal of this study is to understand how the nitrates are feeding this bloom. If there is increased nitrate in the water they could feed an algal bloom. This will be more of a descriptive study in nature.



(Fig. 3 Detailing dynamics of False Bay Interactions)

### **Methods**

Sampling sites were randomly selected in a sweep of the shore in an arc that begins at the western side of the Bay and moves eastward in random intervals. Sampling began at a random site and moved in a south to north direction moving further away from

site 1 in both directions towards and away from the delta of the creek. The first visit revealed an extensive amount green scum on the surface. The study sites from an aerial view resemble that of an inverted umbrella.

Latitude	Longitude
48.490326	-123.06639
48.490366	-123.06656
48.490067	-123.06531
48.489528	-123.06392
48.490632	-123.06725
48.490923	-123.06852
48.490467	-123.06825
48.490589	-123.06833
48.490653	-123.0687

(Table 1 Detailing Lat and Long of site locations)

### *Biomass Collection*

Ulvoids were collected at high tide to monitor biomass. A 0.5m x 0.5m quadrat was laid out to read out abundance and then each site was bagged. Due to the frequency of some of the ulvoids different amounts were taken at some quadrates. During biomass these amounts were multiplied correctly to scale for differences size of plots. Site six was not used due to lack of algae at that location. Samples were individually placed on aluminum foil holders and oven dried for over 5 days then weighed out to obtain dry weight.

Samples were taken from either 0.25m<sup>2</sup> or 0.04m<sup>2</sup> area and multiplied to normalize the data in units of grams per 1m<sup>2</sup>. These were then used to calculate a rough area of the entire sampling area to determine total dry and wet biomass for False Bay.

### *Nitrate Sampling*

Water samples were taken from each site at both high and low tides. At high tide all except two sites were taken from the water column and the other two taken from digging in the sediment. At low tide all samples were taken in sediment holes except for

site five which had enough water to take straight from the column. At each site a YSI meter (YSI Incorporated - Yellow Springs, Ohio 45387) was used to determine oxygen content (in both percent saturation and concentration of mg/L), salinity (in parts per thousand), and temperature (in degrees Celsius).

Samples were frozen overnight, thawed and then analyzed in lab to determine the nitrate (NO<sub>3</sub><sup>-</sup>) concentration in mg/L. A DR 5000 spectrophotometer was used to analyze each individual water sample. 10mL were pipetted into 25mL total of solution (mixture of 15mL Ro water and seawater) and shaken up. 15mL of this solution were added with Nitraver 6 reagent, shaken by hand then mixed with Nitraver 3 reagent. This reagent contained cadmium and potassium pyrosulfate to highlight nitrates in the water.

Afterwards the samples were run through a spectrophotometer to determine overall concentrations.

## Results

Results varied but were not what was expected. For the most part high tide experienced much higher values than at low tide with the exception of site five which showed differences in certain data.

Site	1	2	3	4	5	6	7	8	9
O2%	97,14	167,20.3	107.5,7	104,8	130,211	33,2	126,16	2.5,6	2,7
Salinity(ppt)	32,0.3	31.6,0	31.9,0.1	31.9,0	32.8,0.1	1.8,2	30.9,0.1	4.6,0	14.5,0
Temp (°C)	27,21.1	25.7,21.5	26.6,26.5	27,27	28.4,26.8	25.6,24.4	22.2,26.1	24.7,25.8	23.1,26.4
NO3-	0,0	0.025, 0	0.025,0.025	0,0.025	0,0	0.025,0	0.025,0.025	0,0	0.025,0.025
Dry weight/m2	287.5908	4.7036	839.0964	611.4775	210.0575	0	28.316	48.8924	53.6204

Table 2 Results of YSI readings, spectrophotometer and biomass

There were several points of interest on this chart. Data for high tide was much different from low tides and temperature was extremely warm. The seawater at Friday Harbor Labs is only about 10 to 11 degrees Celsius (FHL weather reports), which makes this ecosystem very different. Unlike the seawater in the labs, the nitrates in this water

were extremely low almost to zero. In fact the highest value of the 18 samples recorded was the seawater taken from the lab area.

Nitrates did not increase or decrease in any marked way along the shoreline which show no correlation between the major changes in biomass observed all along the shoreline. Salinity varied greatly over the two days as low tide produced mostly freshwater into the system. Oxygen readings showed complete saturation or even higher values for high tide while low tide was almost completely anaerobic. The differences in oxygen, temperature and biomass growth seem to be independent of nitrates taken from water or sediments.

## **Discussion**

Results of this experiment produced surprising results but offer much to improve on and look into in the future. While the nitrate samples remained right around zero for all sites, the biomass remained high in most areas and oxygen seemed to change independent of this. These results show there is very little nitrate if any in the water column or in the sediments at this time. This begs the question what is causing the ulvoids to bloom so rapidly and persist? A study by Bracken in 2004 suggested that nutrients were found in varying amounts at low tides due to isolation of tide pools. This theory could play into this study as well as many locations were not sampled in the bay and by moving further out from the high tide line and how high and low tides different results could have occurred.

Low oxygen at low tide suggests anaerobic conditions. Both tide-sampling trips were made during the day in bright sunlight but oxygen in the water is much more likely

than in the sediments but it is odd to find almost no trace of oxygen in the sediment at low tide.

This research suggests that the nutrients are also not locked up in the water but more that the ulvoids are acting as ecological protectors to lock up excess nitrate that has leached into the bay either from the creek or from the ocean at high tides. A study by Timothy Nelson in 2003 showed that ulva species exhibit high uptake of nitrogen and can hold it for a very long time. However, due to desiccation stress and decay during the night, many species of algae and other animals can be adversely affected in growth and development. Another question to ask is where this bloom is coming from. Merceron 2007 studied the range limits of ulvoids in a bay in France and discovered a wide range of areas that ulvoids can survive. Since these species of algae can live in many places and are constantly breaking off of each other and colonizing through drift, it is hard to determine the exact amount that is growing versus what has come in with the tide.

*Beggiatoa* found in the delta suggested very anaerobic conditions but also a possible overload of nitrates. *Beggiatoa* works in the Denitrification process and could have some effect on the amount coming out of the creek. Very black sediments in this area support a need to further understand the role of *Beggiatoa* in this green tide cycle.

Much more data is needed to determine if there is nutrient overloading in this system as well as much more time to study it. Further study of the seaweed growing along the shores may indicate how high the amounts of nitrates are in this bay and may shed light on future work. More work out in the bay at high tide and along the ocean may also be needed as well as monitoring of the creek at different seasons when stream flow increases and produces larger inputs of water into the delta area.

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