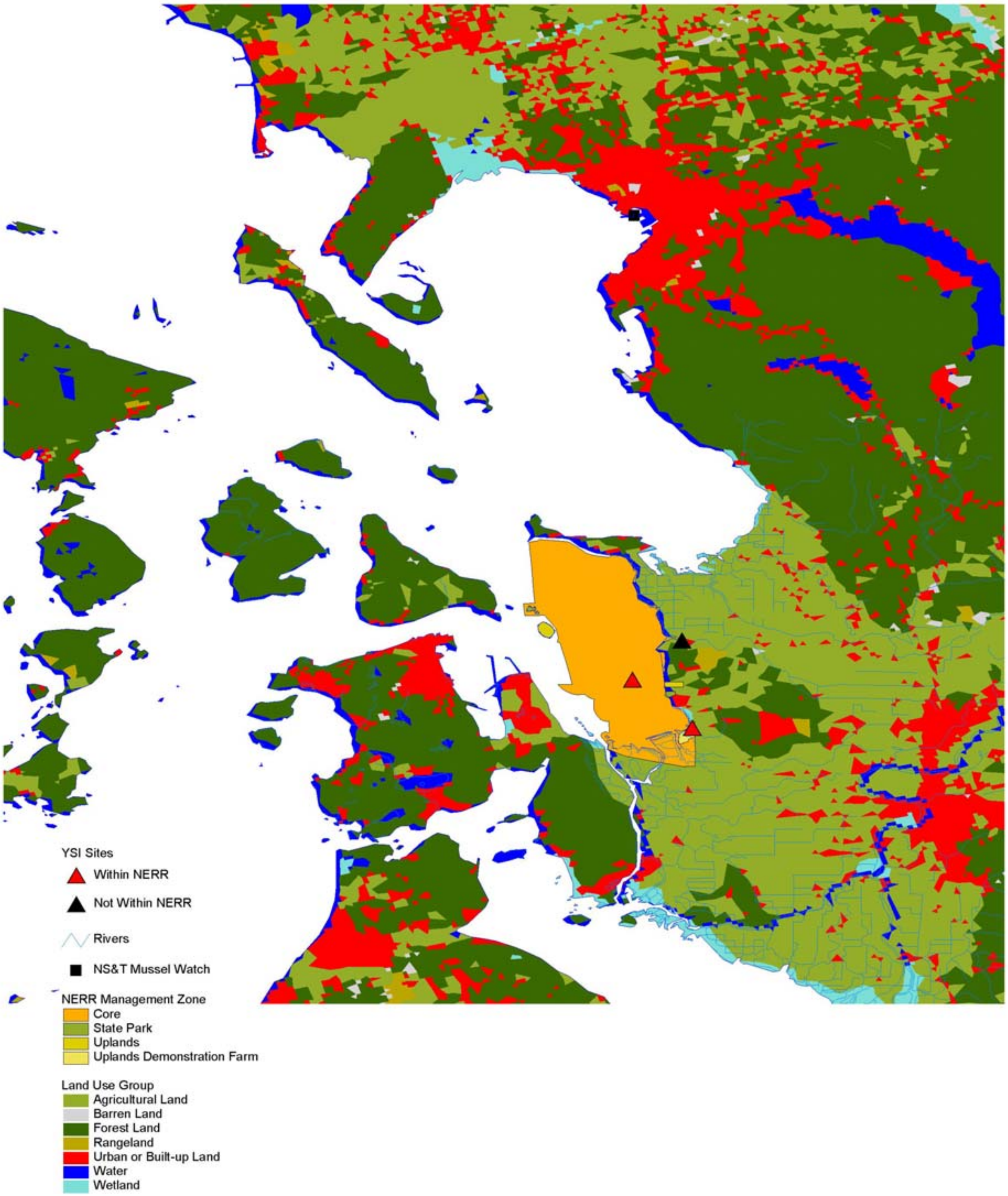
Padilla Bay


YSI Sites
Within NERR
Not Within NERR
Rivers
NS&T Mussel Watch
NERR Management Zone
Core
State Park
Uplands
Uplands Demonstration Farm
Land Use Group
Agricultural Land
Barren Land
Forest Land
Rangeland
Urban or Built-up Land
Water
Wetland

Padilla Bay, Bayview Channel (PDBBY)

Characterization (Latitude = 48° 29' 47" N; Longitude = 122° 30' 07" W)
Tides at Bayview Channel are mixed semidiurnal and tidal range is 1.6 m (2.6 m tide range during spring tides). Padilla Bay is a shallow embayment with inter-tidal channels that drain and distribute tidal waters onto tidal flats. Bayview Channel is one of the major inter-tidal tributary/distributary channels within Padilla Bay, extending about 4.5 km from Swinomish Channel at its "mouth" to the inter-tidal flats. About 2.5 km from the intersection of Bayview Channel with Swinomish Channel, a small (900 m) inter-tidal tributary/distributary channel joins Bayview Channel. The monitoring site is located along the edge of this small channel, about 400 m from its intersection with Bayview Channel. The tributary/distributary channel does not exist as a channel at MHW. At MLW, the tributary/distributary channel is about 2 m deep where it joins Bayview Channel and 0 m deep where it begins draining the inter-tidal flats. Channel width is about 50 m where the monitoring site is located. At the monitoring site, the depth is about 4 m MHW. Creek bottom habitats are fine silt and clay over sand. No bottom vegetation is located at the monitoring site, but eelgrass (*Zostera marina*) is located nearby. The tributary/distributary drains/floods predominately eelgrass (*Zostera marina* and *Z. Japonica*) covered inter-tidal flats. Non-point source pollution has little affect on this site.

Descriptive Statistics
Thirty-four deployments were made at this site between Jan 1996 and Dec 1998, with equal coverage during all seasons except for winter 1997 (Figure 14). Mean deployment duration was 29.2 days. Only one deployment (Jan 1997) was less than 10 days.

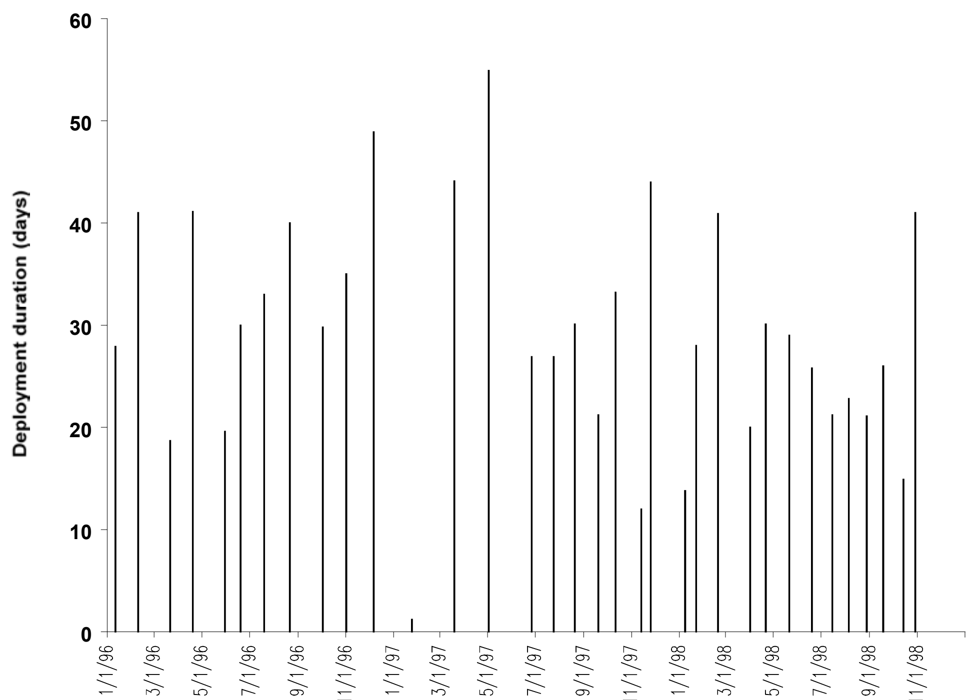


Figure 14. Padilla Bay, Bayview Channel deployments (1996-1998).

Eighty-five percent of annual depth data were included in analyses (85% in 1996, 77% in 1997, and 93% in 1998). Sensors were deployed at a mean depth of 2.3 m below the water surface and 0.8 m above the bottom sediment. Scatter plots suggest strong fluctuations (2-3 m) in daily and bi-weekly depth, with consistent amplitude throughout the data set. Harmonic regression analysis attributed 39% of depth variance to 24 hour cycles, 34% of depth variance to 12.42 hour cycles, and 28% of depth variance to interaction between 12.42 hour and 24 hour cycles.

Eighty-five percent of annual water temperature data were included in analyses (85% in 1996, 77% in 1997, and 93% in 1998). Water temperature followed a seasonal cycle, with mean water temperatures 7-8°C in winter and 13-15°C in summer (Figure 15). Minimum and maximum water temperatures between 1996-1998 were –1.5°C (Dec 1996) and 23.5°C (Jul 1996), respectively. Scatter plots suggest moderate fluctuations (1-2°C) in daily and bi-weekly water temperatures in winter and fall and strong fluctuations (5-10°C) in spring and summer. Harmonic regression analysis attributed 36% of temperature variance to interaction between 12.42 hour and 24 hour cycles, 32% of temperature variance to 12.42 hour cycles, and 32% of temperature variance to 24 hour cycles.

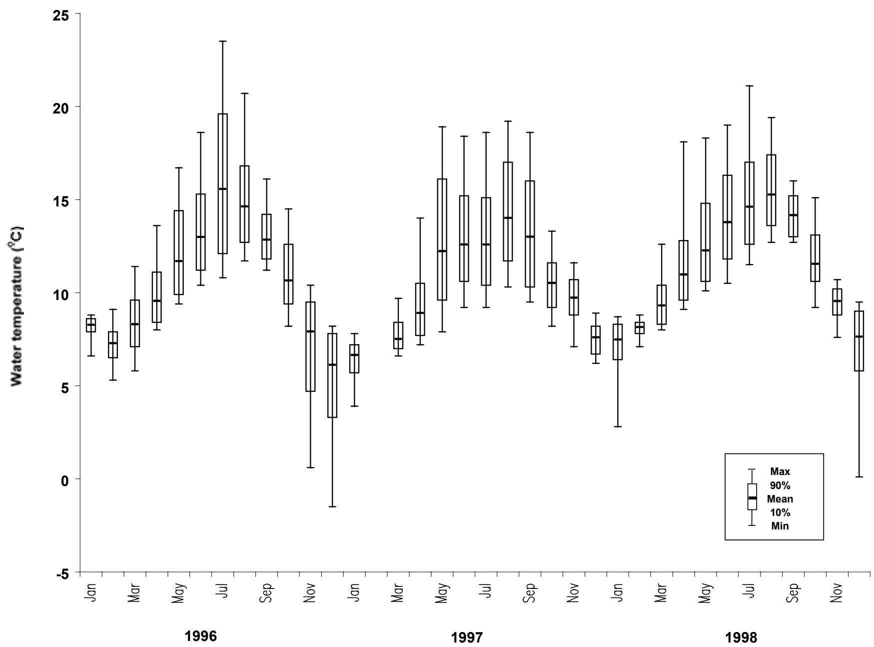


Figure 15. Water temperature statistics at Bayview Channel, 1996-1998.

Sixty-eight percent of annual salinity data were included in analyses (35% in 1996, 77% in 1997, and 91% in 1998). Mean salinity between Jan 1996 and Jun 1997 was 25-31 ppt, but was less variable (28-30 ppt) between Jul 1997 and Dec 1998 (Figure 16). Minimum and maximum salinity between 1996-1998 was 19.9 ppt (Mar 1997) and 32.2 (Mar-Apr 1996), respectively. Scatter plots suggest moderate fluctuations (1-3 ppt) in daily and bi-weekly salinity throughout the data set, with fluctuations equivalent to or in excess of annual variation (6 ppt) in mean salinity during episodic events in all three years. Harmonic regression analysis attributed 44% of salinity variance to interaction between 12.42 hour and 24 hour cycles, 36% of variance to 24 hour cycles, and 20% of variance to 12.42 hour cycles.

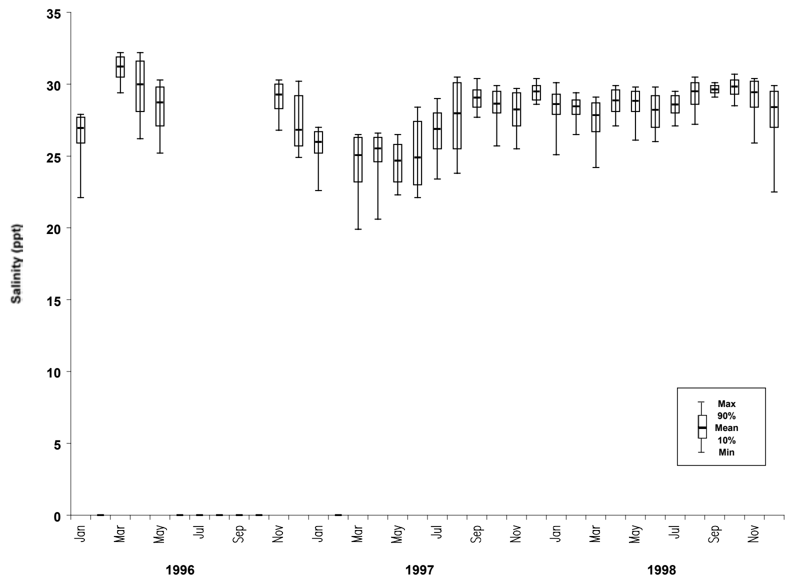


Figure 16. Salinity statistics at Bayview Channel, 1996-1998.

Seventy-eight percent of annual dissolved oxygen (% saturation) data were included in analyses (76% in 1996, 69% in 1997, and 89% in 1998). Mean DO followed a seasonal cycle and was greatest (100-123% sat) in spring and least (76-88% sat) in summer. Minimum and maximum DO between 1996-1998 was 12.6% saturation (Mar 1996) and 225.5% (Jun 1997), respectively. Persistent hypoxia was never observed (Figure 17). Supersaturation was observed regularly in 1996 and 1998, but only in two months in 1997. When present, supersaturation persisted for 28.8% of the first 48 hours post-deployment on average. Scatter plots suggest minor fluctuation (20-40%) in DO over daily and bi-weekly intervals in winter and fall, but strong fluctuations (60-100%) in DO in spring and summer. Harmonic regression analysis attributed 43% of DO variance to interaction between 12.42 hour and 24 hour cycles, 36% of DO variance to 24 hour cycles, and 21% of DO variance to 12.42 hour cycles.

Photosynthesis/Respiration

Over two thirds (71%) of the data used to calculate the metabolic rates fit the basic assumption of the method (heterogeneity of water masses moving past the sensor) and were used to estimate net production, gross production, total respiration and net ecosystem metabolism (Table 13). Instrument drift during the duration of the deployments was not a significant problem at this site. Gross production slightly exceeded total respiration at Bayview Channel, although they were not significantly different from each other, the net ecosystem metabolism and P/R ratio indicated that this site is balanced. This was one of the few sites in the Reserve system that was not heterotrophic (Figure 18). Temperature was significantly ($p<0.05$) correlated with gross production and total respiration. Gross production and respiration increased as temperature increased. Salinity was significantly ($p<0.05$) correlated with gross production and net ecosystem metabolism. Gross production decreased as salinity increased, while net ecosystem metabolism became more heterotrophic as salinity increased. Thus, the metabolic rates generally followed a seasonal pattern with the lowest rates during the fall and winter when temperatures were low and the highest rates during spring and summer months, the peak growing period for eelgrass, *Zostera marina*, which covers the inter-tidal flats of Padilla Bay.

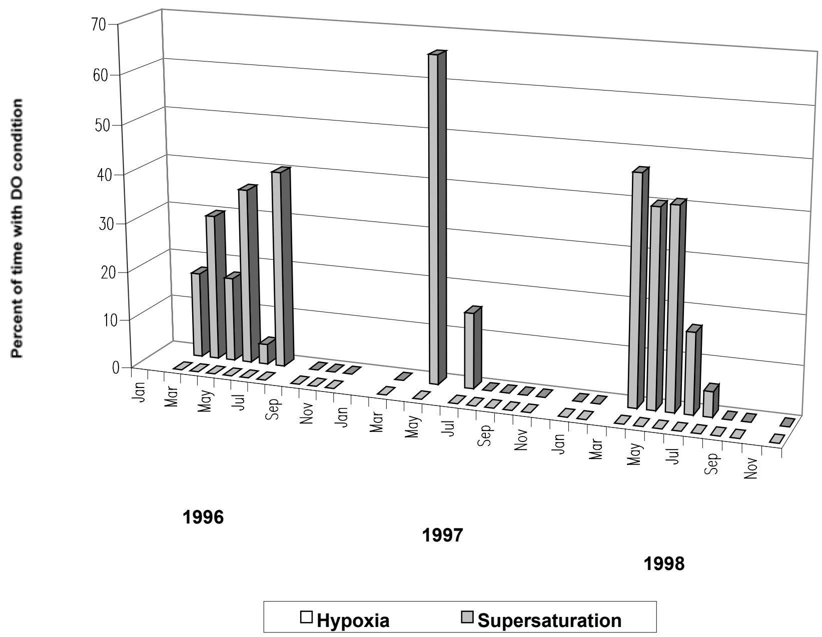


Figure 17. Dissolved oxygen extremes at Bayview Channel, 1996-1998.

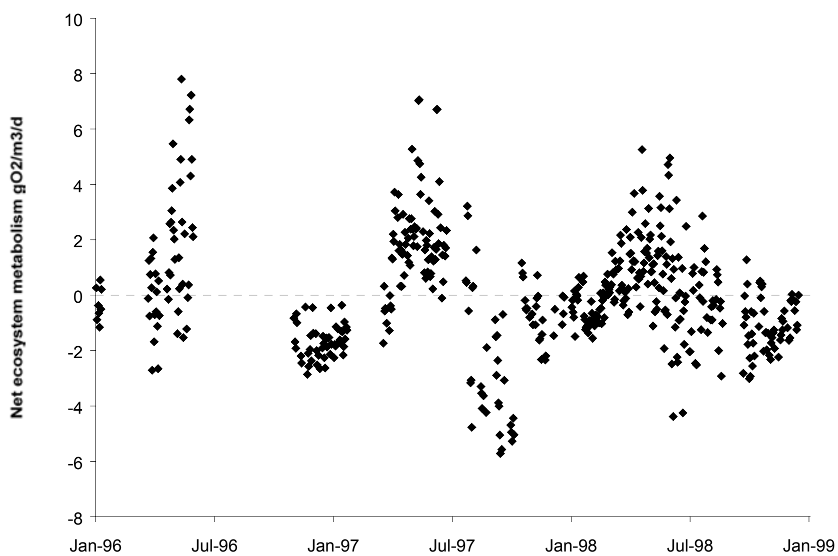


Figure 18. Net metabolism at Bayview Channel, 1996-1998.

Table 13. Summary of metabolism data and statistics at Bayview Channel, 1996-1998.

Bayview Channel	mean	s.e.
Water depth (m)	4.0	
Net production gO_2/m3/d	1.33	0.19
Gross production gO_2/m3/d	3.17	0.39
Total respiration gO_2/m3/d	3.23	0.37
Net ecosystem metabolism g O_2/m3/d	-0.06	0.12
Net ecosystem metabolism g C/m2/y	403	
P/R	0.98	
Statistical results		
Drift – paired t-test		
Gross production	ns	
Total respiration	ns	
Net ecosystem metabolism	ns	
Percent useable observations	71 %	
Paired t-test on gross production and total respiration	ns	
Correlation coefficient	Temperature	Salinity
Gross production	0.30	-0.11
Total respiration	0.30	ns
Net ecosystem metabolism	ns	-0.18

Padilla Bay, Joe Leary Slough (PDBJL)

Characterization (Latitude = 48° 31' 05" N; Longitude = 122° 28' 25" W)
This monitoring site is located near a dam at the mouth of Joe Leary Slough. The dam has twelve, 4' diameter outfall pipes with tide gates that allow freshwater to flow out of the slough, but prevents seawater from entering the slough; however, a small amount of saline water from Padilla Bay seeps through the tide gates during high tide. There are no tides on the "freshwater" side of the dam where the monitoring site is located, although freshwater accumulates behind the tide gates during high water when the tide gates are closed. Joe Leary Slough is 16 km long and drains a 4700 hectare watershed. Water depth varies from about 0.5 to 1.5 m deep and channel width varies from about 1 m to 10 m. At the monitoring site, located in a small holding basin on the freshwater side of the tide gates, water depth varies from 0.5 to 1.5 m during summer and up to 4 m depth during winter floods. Creek bottom habitats near the site are predominantly soft silt and clay without bottom vegetation. There is no marsh vegetation in the basin in which the monitoring site is located and the upland vegetation is agricultural. Land use in Joe Leary Slough includes agriculture (crops, berries, and orchards), pastures, dairy farms, and low-density housing. Activities that potentially impact the site include periodic dredging to provide better drainage from farm lands, low-density development, a closed landfill site, and runoff from farmlands. Joe Leary slough experiences high concentrations of fecal coliform bacteria, nutrients from agriculture, high turbidity, and low dissolved oxygen concentrations.

Descriptive Statistics
Sixty deployments were made at this site between Jan 1996 and Dec 1998, with equal coverage during all seasons (Figure 19). Mean deployment duration was 16.4 days. Two deployments in 1997 and seven deployments in 1998 were less than 10 days.

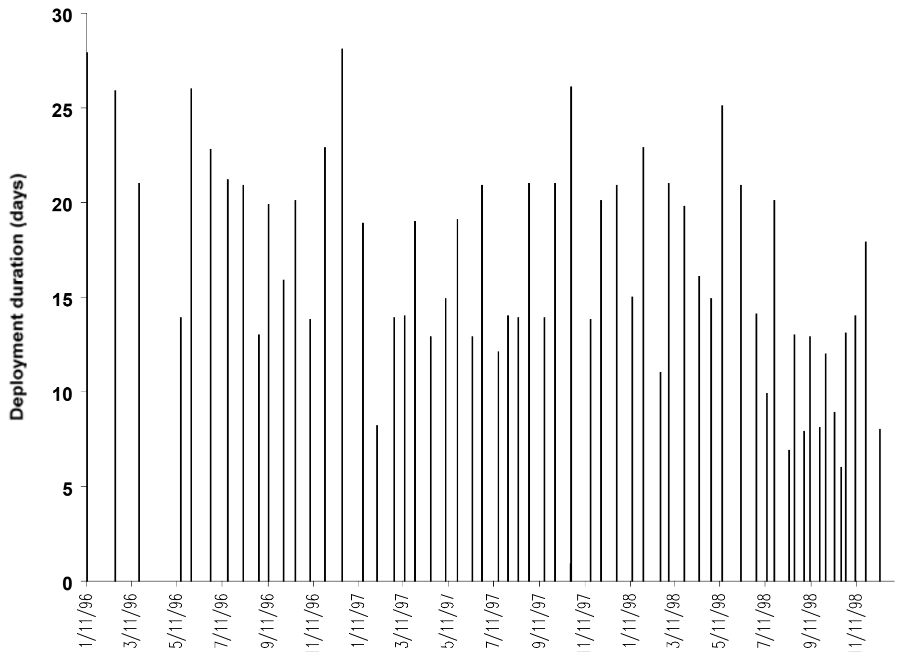


Figure 19. Padilla Bay, Joe Leary Slough deployments (1996-1998).

Eighty-nine percent of annual depth data were included in analyses (76% in 1996, 92% in 1997, and 99% in 1998). Sensors were deployed at mean depth of 0.7 m below the water surface and 0.3 m above the bottom sediment. Scatter plots suggest seasonal variation in daily and bi-weekly depth fluctuations. In summer, depth fluctuations were typically ≤ 1 m; however, between fall and spring depth fluctuations were typically ≥ 1.5 m. Harmonic regression analysis attributed 63% of depth variance to interaction between 12.42 hour and 24 hour cycles, 29% of depth variance to 24 hour cycles, and 8% of depth variance to 12.42 hour cycles.

Eighty-nine percent of annual water temperature data were included in analyses (76% in 1996, 92% in 1997, and 99% in 1998). Water temperature followed a seasonal cycle, with mean water temperatures 5-8°C in winter and 18-21°C in summer (Figure 20). Minimum and maximum water temperatures between 1996-1998 were –0.6°C (Dec 1998) and 28.2°C (Jul 1996), respectively. Scatter plots suggest strong fluctuations (≤ 5°C) in daily water temperature and even stronger fluctuations (≤ 8°C) in bi-weekly water temperatures, with strongest variation occurring in summer. Harmonic regression analysis attributed 52% of temperature variance to 24 hour cycles, 40% of temperature variance to interaction between 12.42 hour and 24 hour cycles, and 8% of temperature variance to 12.42 hour cycles.

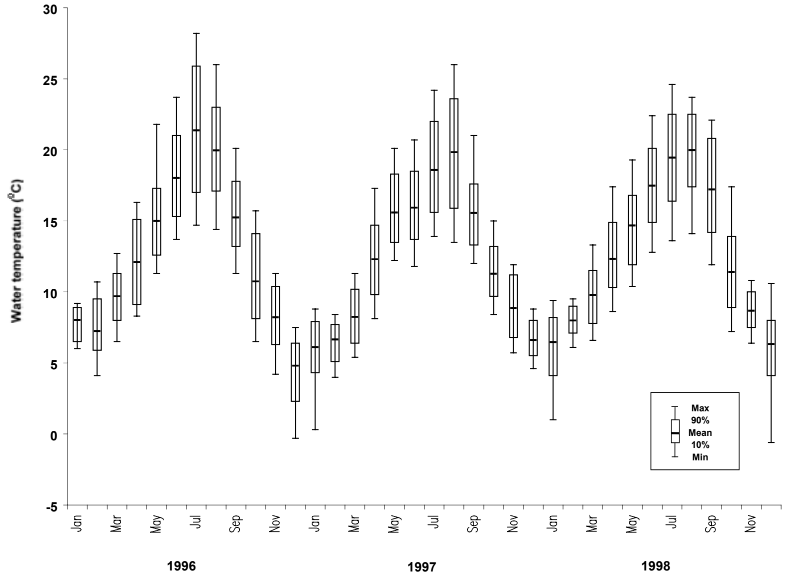


Figure 20. Water temperature statistics at Joe Leary Slough, 1996-1998.

Eighty-nine percent of annual salinity data were included in analyses (76% in 1996, 92% in 1997, and 99% in 1998). Mean salinity followed a pronounced seasonal cycle; however, very large variances (15-25 ppt) were associated with mean salinity readings throughout the data set (Figure 21). Mean salinity was greatest in summer and was 11-13 ppt. Mean salinity in winter 1997 was slightly lower (4-7 ppt) than mean salinity in winter 1996 and 1998 (6-8 ppt). Minimum salinity was always less than 1 ppt throughout the data set. Maximum salinity was almost always greater than 20 ppt between 1996-1998, with a notable exception in summer 1996. Scatter plots suggest daily and bi-weekly fluctuations in salinity were 1-3 times greater than the variation in annual mean salinity (9 ppt). Harmonic regression analysis attributed 53% of salinity variance to interaction between 12.42 hour and 24 hour cycles, 35% of variance to 24 hour cycles, and 12% of variance to 12.42 hour cycles.

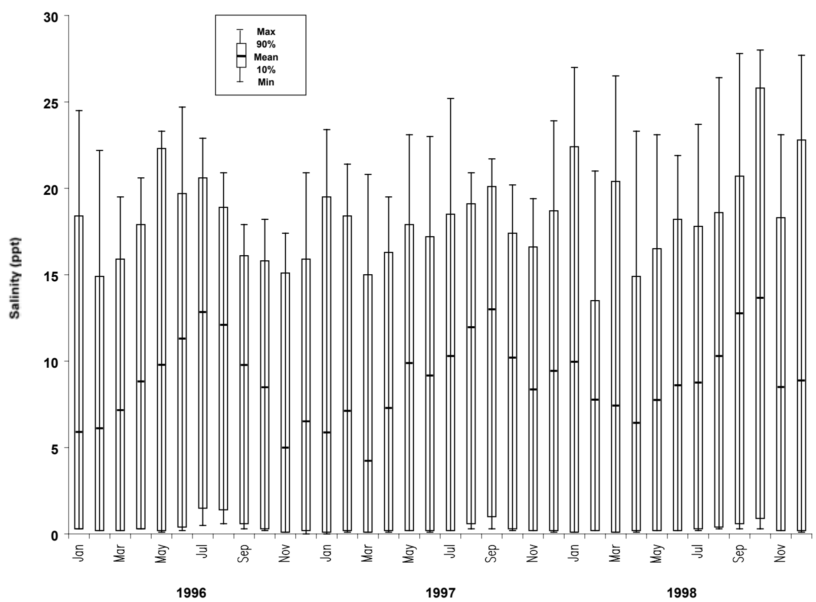


Figure 21. Salinity statistics at Joe Leary Slough, 1996-1998.

Seventy-seven percent of annual dissolved oxygen (% saturation) data were included in analyses (51% in 1996, 80% in 1997, and 99% in 1998). Mean DO followed a seasonal cycle, with lowest percent saturation between Sep-Nov (16-55%) and greatest percent saturation in spring (1996, 1997) or summer (1998). Mean percent saturation in spring 1996 was greater (51% in Apr, 94-107% in May-Jun) than mean percent saturation in spring 1997 (59-61%), which was comparable to mean percent saturation in summer 1998 (54-67%). Hypoxia was regularly observed between 1996-1998 and, when present, hypoxia persisted for 22% of the first 48 hours post-deployment on average (Figure 22). Supersaturation was regularly observed in spring/summer 1996 and sporadically in 1997 and 1998 and, when present, supersaturation persisted for 21% of the first 48 hours post-deployment on average. Scatter plots suggest strong fluctuations (60-100%) in percent saturation throughout the data set, with very strong fluctuations (≥ 120%) in summer. Harmonic regression analysis attributed 49% of DO variance to 24 hour cycles, 40% of DO variance to interaction between 12.42 hour and 24 hour cycles, and 11% of DO variance to 12.42 hour cycles.

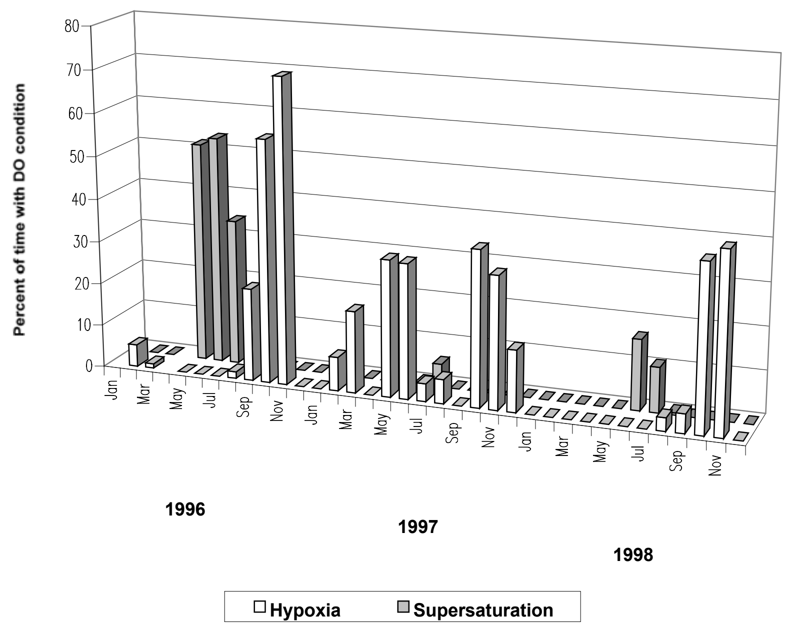


Figure 22. Dissolved oxygen extremes at Joe Leary Slough, 1996-1998.

Photosynthesis/Respiration

Over half (57%) of the data were used to calculate metabolic rates for net production, gross production, total respiration and net ecosystem metabolism (Table 14, Figure 23). Instrument drift during the duration of the deployments was not a significant problem at this site. However, harmonic analyses of the oxygen and salinity data suggested that dissolved oxygen concentrations were controlled by the exchange between Padilla Bay and Joe Leary Slough, not biological processes. It appears likely that some of these rate calculations reflect times when the tidal cycle coincided with the diurnal cycle, for example, a high tide at mid-day bringing in oxygen-rich, high salinity water into the low oxygen, fresh water normally present in the Slough. Thus, the values below should be treated with some skepticism until further analyses can be conducted.

Table 14. Summary of metabolism data and statistics at Joe Leary Slough, 1996-1998.

Joe Leary Slough	mean	s.e.
Water depth (m)	1.0	
Net production $gO_2/m3/d$	-1.24	0.10
Gross production $gO_2/m3/d$	3.31	0.13
Total respiration $gO_2/m3/d$	9.05	0.20
Net ecosystem metabolism g $O_2/m3/d$	-5.76	0.16
Net ecosystem metabolism g C/m2/y	-674	
P/R	0.37	
Statistical results		
Drift – paired t-test		
Gross production	ns	
Total respiration	ns	
Net ecosystem metabolism	ns	
Percent useable observations	57 %	
Paired t-test on gross production and total respiration	$p < 0.001$	
Correlation coefficient	Temperature	Salinity
Gross production	-0.18	-0.09
Total respiration	0.30	0.27
Net ecosystem metabolism	0.46	0.33

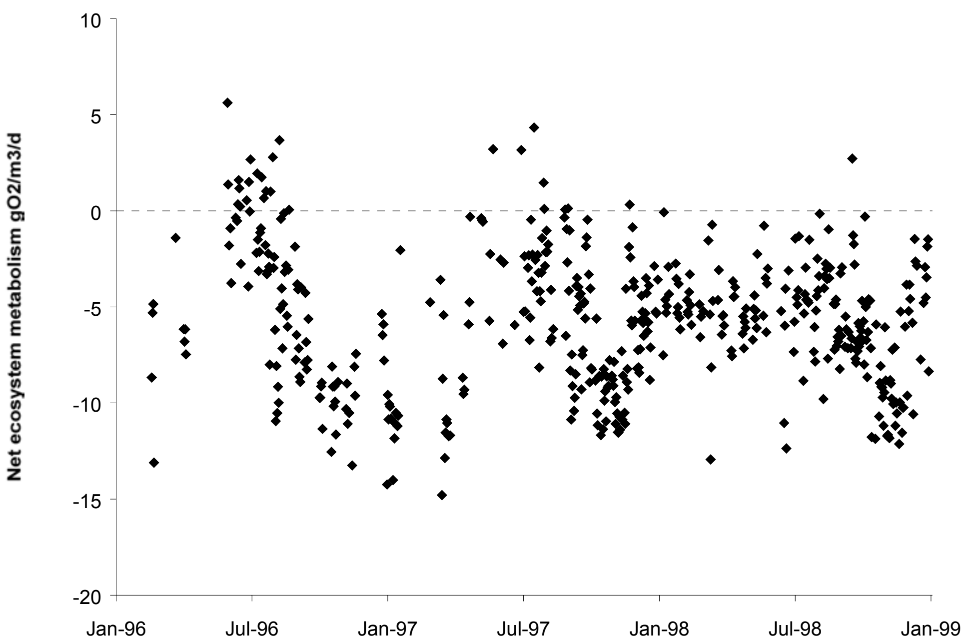


Figure 23. Net metabolism at Joe Leary Slough, 1996-1998.