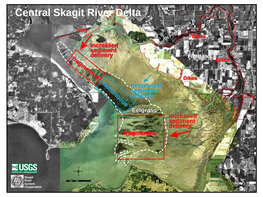
Nearshore habitats and hydrodynamic/sedimentary processes that affect habitat structure and connectivity in the Skagit Delta

Eric Grossman, Andrew Stevens, Yael Sagy, David Finlayson, Chris, Curran, Anthony Paulson, Doug George, Angela Lam (USGS)

Greg Hood, Aundrea McBride, Eric Beamer, Steve Hinton (SRSC)

Issue



Extensive channelization and diking along the Skagit River to foster agricultural and urban development has led to 70-80% loss of estuarine habitat in the Skagit Delta (Collins, 2000) which may be causing density-dependent mortality for ESA-listed Chinook salmon (Beamer et al. 2005) and other threatened species including bull trout (DOI Trust Species). Channelization has focused flow and sediment discharge to the nearshore, altering estuarine mixing and sedimentary processes that shape habitat structure and ecosystem function. The nearshore ecosystem faces increasing pressure from urban growth, flood mitigation, and habitat restoration, yet little is known about how these activities will alter hydrodynamic and sedimentary processes and impact the habitats and food web "downstream" (offshore) of the delta.

Scientific Questions:

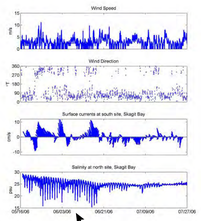
1) What is the distribution and connectivity of nearshore habitats in the Skagit Delta and how do hydrodynamic and sedimentary processes affect them?

2) How will the nearshore ecosystem respond to future land use (agriculture, urbanization, habitat restoration) and climate change?

Hydrodynamic Processes

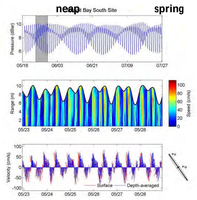
Time-series measurements show that the Skagit River plume delivers significant particulate and freshwater across Skagit Bay and that tidal circulation is dominated by a net northward flow. Habitats north of the delta are especially vulnerable to the fate of sediment and freshwater from the Skagit River.

Environmental conditions during deployment



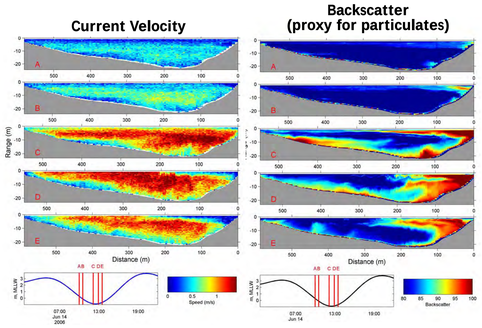
Freshwater mixing at -10 m (north site)

Representative Tides and currents



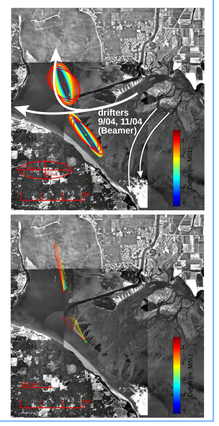
Skagit River plume during ebb tide

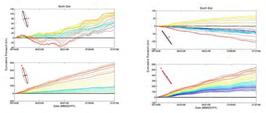
Despite strong alongshore current velocities (right), high sediment loads of the Skagit River plume can extend across Skagit Bay (far right). Freshwater also makes its way to Whidbey Island when discharge is >40,000 cfs and preliminary data indicate it is transported at least as far as Ala Spit during flood tides.



Circulation and Transport

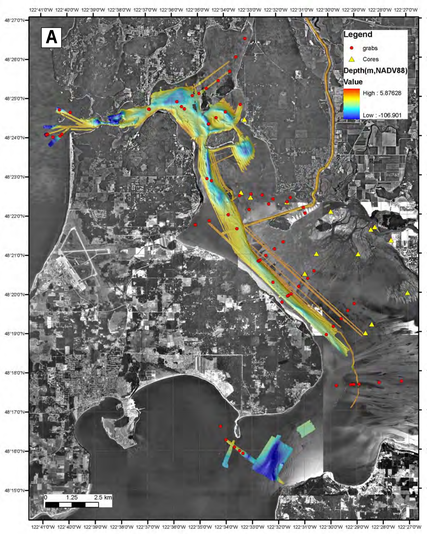
Skagit Bay is characterized by net northward transport; north of the jetty, surface water is directed shoreward (right). Circulation is sufficient to move freshwater and suspended sediment out of Skagit Bay and beyond Deception Pass (below). Uncertainty remains as the magnitude and spatial extent of sediment export and its ultimate fate upon deposition.

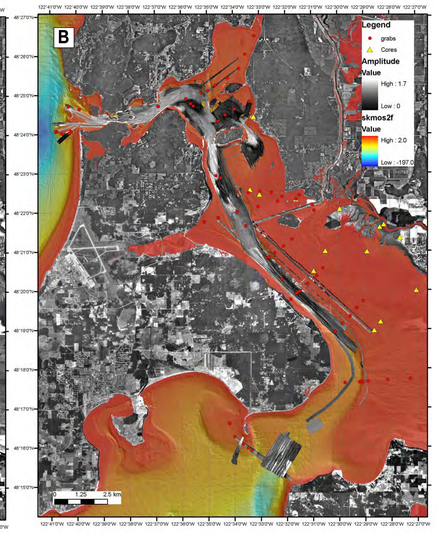




Nearshore Habitats of the Skagit River Delta

Analyses of substrate and water-column properties from geophysical, video, sediment grab and core sample, geochemical, and aerial photographic studies indicate that the Skagit Delta-Bay System is morphologically complex with significant habitat diversity varying by substrate type. The delta proper is dominated by sand while most of the Skagit Bay seafloor out through Deception Pass is rocky, cobble, or mixed, coarse sediment, implying that a significant fraction of the fines (silt and clay) from the Skagit River is exported, impacting nearshore habitats at considerable distances.





(A) Acoustic depth data shows the morphologic complexity of the Skagit Delta-Bay System, with bedforms and channels indicative of active progradation at the delta front and deep, passages encircling islands and mounds in north Skagit Bay controlled by strong currents.

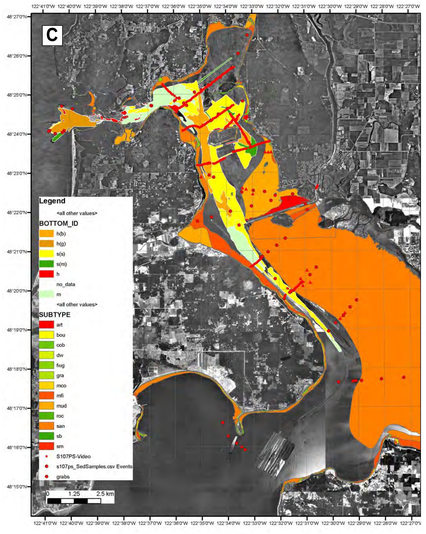
(B) Acoustic backscatter shows the substrate varies considerably from hard, rocky areas (bright) to soft, sediment-rich areas (dark).

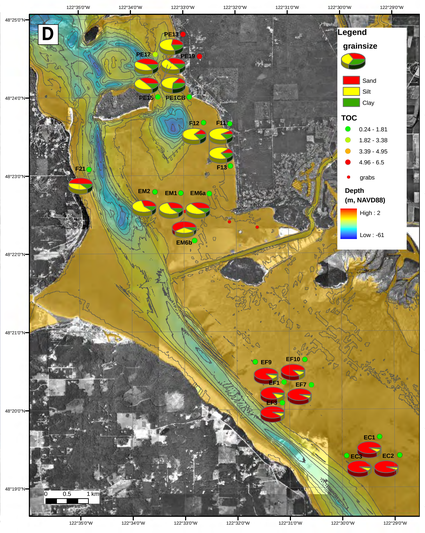
(C) Along with analyses of video, sediment, and aerial photographs, benthic substrate/habitat classification following Greene et al. (1999), show that sand dominates the shallows, while hard rock and cobble predominate in the deeps; mud is limited to Turners Bay and the deepest areas (south of Hope Island, outside Deception Pass).

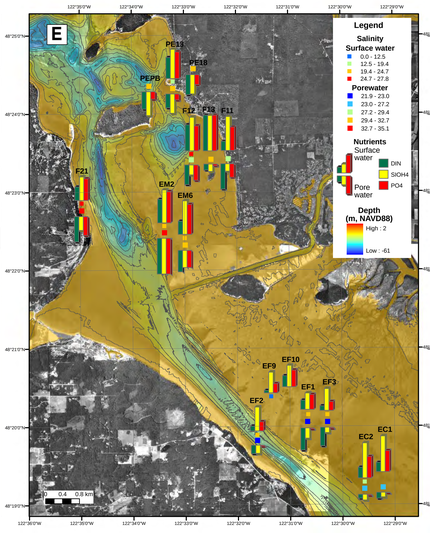
(D) Grainsize analyses show that sediment is coarse on the Skagit tide flats and delta front and finer north of the jetty and in the pocket estuary and fringe of Lone Tree Point. Total organic carbon is generally low but highest in the pocket estuary.

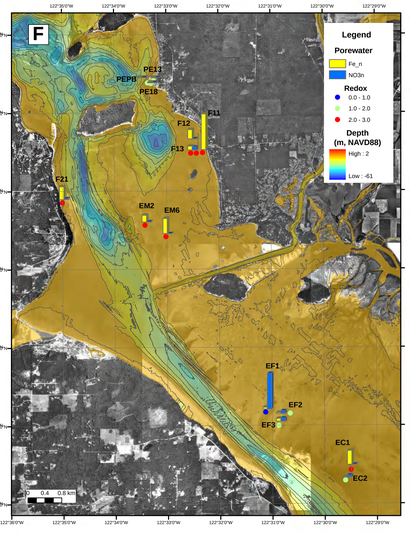
(E) Pore water salinity was generally higher than surface water salinities in all settings, even on the Skagit tide flats that are bathed by high rates of fresh Skagit River runoff, implying that high evapotranspiration during low tide dessication dominates over exchange of pore waters with the water column (even despite coarse sediment), allowing constituents produced by biogeochemical processes to accumulate in porewaters. Total nitrogen (DIN) and PO4 in surface waters was highest away from the Skagit River, while SiOH4 was greater close to the river. Porewaters were greatly enriched in all nutrients, especially DIN in muddy eelgrass and pocket estuary sediments.

(F) Pore water geochemistry of surface sediment was generally related to grain-size patterns and total organic carbon content. The coarse and low-carbon (<0.3 wt. pct) sediments of continuous and fragmented eelgrass were moderately oxidizing with oxidizing nitrate present and generally low concentrations of reduced Fe. In contrast, moderately rich carbon (0.9 – 1.1 wt. pct.) sediments of the muddy eelgrass and muddy fringe regions were more reducing and contained high concentrations of reduced Fe. Sediments of the pocket estuary differ from the trend of more reducing conditions with high carbon content. Even though these sediment were organic-rich (2 - 6 wt. ptc. C), very little reduced Fe was measured. Perhaps, the penetration of oxygen from the water column through these moderately sandy (20% – 40% wt. ptc.) surface sediments maintained a moderately oxidizing porewater environment.



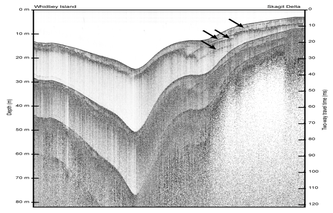






Sedimentary Processes

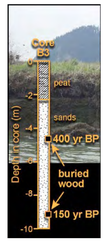
Seismic reflection profile data and studies of core samples indicate that the Skagit tide flats are a sediment-bypassing system comprised of a 1-6 m unit of medium to coarse sand overlying muds. The transition is abrupt and preliminary ^{210}Pb and ^{14}C ages of core materials indicate the depositional environment changed about 1850, likely associated with logging and channelization.

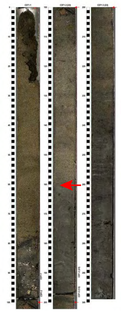


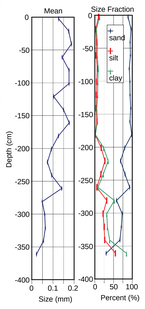
CHIRP profile (left) from Skagit delta front (see map below) showing 4-6 m thick upper unit of sand facies (see core photo below) with near uniform thickness across tide flats indicative of sediment bypassing.

Sediments in cores from Skagit Delta show:

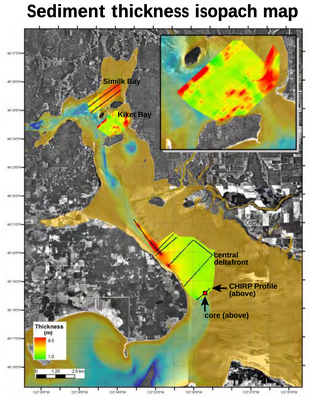
1) marked transition from silty to sandy environment, and
2) >10X increase in accumulation rate beginning ~1850







Sediment thickness isopach map



Analyses of surface sediment thickness and age (above) in 3 areas, Skagit delta-sand, Kiket Bay-sand/silt and Similk Bay-mud) show that the fate of Skagit R. sediment has been high accumulation across Skagit Bay with partitioning of sands to the delta tide flats and front, and fines exported to calm areas and outside the study area.

Preliminary Sediment Budget

Sources	Estimate	Annual Load (Mv^3/y)	Annual Load (Mm^3/y)	Historical Load (Mm^3)
Skagit R. Sediment	low (Ericksen 2006)	1.3	0.994	156,045,647
	high (USGS CHIPS)	10.2	7.798	1,224,358,154
LittoralDrift		?	?	?

Sinks	Area (m^2)	Thickness mean (m)	Volume (m^3)	% of Region	Total Area (m^2)	Pot. Total Sink Volume (m^3)
Skagit Delta-flats	10,623,850	3.9	41,447,888	0.167	63,743,100	248,687,330
Skagit Delta-front	718,625	6.6	4,762,673	0.2	3,593,125	23,813,364
Similk Bay	1,878,800	5.9	11,139,217	0.2	9,394,000	55,696,087
Kiket Bay	2,189,875	4.7	10,201,314	0.2	10,949,375	51,006,569
Total	15,411,150		67,551,092		87,679,600	379,203,350

Sink/Source		
Low Qs	243.01%	not enough supply for deposits
High Qs	30.97%	allows for deposition in other subregions and loss from study area

Other sinks	Vol (m^3)	Other Questions-Uncertainties	
Firlsland-overwash areas	?	Fraction of sand vs. fines in sources/sinks	?
Skagit Floodplain overwash areas	?	Spatial extent of sediment export	?

An evolving sediment budget analysis (above) suggests:

1) sediment inputs exceed accumulation in the study area.
2) prior estimates of sediment load from the Skagit River are low.
3) Additional sinks exist within Skagit lowlands and throughout the Skagit-Whidbey Basin.

Conclusions

1) Nearshore habitats including the last continuous stand of eelgrass in central Skagit Bay are impacted by high sediment delivery, however, little is known of the impact on overall ecosystem function.
2) Focused freshwater input strongly controls habitat availability for juvenile salmonids, yet its spatial-temporal variability remains uncertain and how it controls nutrient cycling and habitat connectivity.
3) Understanding watershed-nearshore connectivity is essential for successsful ecosystem recovery.