EXECUTIVE SUMMARY

Between 2012 and 2014, the Pacific Shellfish Institute (PSI) was awarded NEP funds to test nutrient bioextraction using native blue mussels as a way to address eutrophication in Budd Inlet. Nutrient bioextraction is the process of growing and harvesting shellfish or algae for the main purpose of removing nutrients from a watershed. This work demonstrated the effectiveness of cultivating, harvesting and composting Budd Inlet mussels, while simultaneously engaging the community in nutrient reduction efforts. This report expands on the 2012 "proof of concept" work by addressing the next step— establishing a connection between nutrient removal and the related impacts on water quality (i.e., pH, DO, Chl *a*, etc.) within and beneath the mussel installations.

The goal of this project was to evaluate nutrient bioextraction using mussels as a way to improve water quality in lower Budd Inlet. Project objectives were to: 1) maintain and expand the network of waterfront businesses, residents, marinas, and restaurants that implement mussel demonstration sites; 2) study how the mussel installations affect water quality via nutrient bioextraction, mussel filtration, and other processes; 3) harvest and compost the mussels growing on temporary nylon straps and permanent structures for terrestrial agricultural application; 4) provide opportunities for outreach and education via public presentations and classroom curriculum; and 5) make recommendations for innovative solutions to multi-parameter TMDLs.

During our pilot trials, over 5,000 lbs. of mussels were harvested removing 50 pounds of nitrogen, 2.75 pounds of phosphorus, and 225 pounds of carbon while generating over four cubic yards of organic compost. The mussel compost was incorporated into gardens and landscapes at The Evergreen State College's Organic Farm, Department of Corrections – Cedar Creek Facility, City of Olympia's Capitol Campus, and in backyards of Thurston County residents.

The impacts to water passing through the WB mussel installation was evaluated using two flow-through experiments. Results indicated that plankton cell counts, Chl *a*, and POC/PON decreased as the water moved through the system. This removal of phytoplankton via filter feeding resulted in slight increase in dissolved nutrients (i.e., nitrates, nitrites, silica) and decrease in pH moving through the system as fewer phytoplankton remained in the water column to assimilate nutrients and carbon dioxide. During peak growth rates, mussels also released the waste product ammonium, which was detected in concentrations above historic ambient conditions for lower Budd Inlet.

Mussel biodeposition at both sites was 3-5 time higher under the mussel installations when compared to control stations. During July and August, pH and DO were typically lower under mussels compared to the reference site, but the difference was slight and likely to have no

biological significance. By September, no difference was detected at either site due to changing weather patterns that improved water quality conditions considerably.

Nutrient bioextraction results in a net reduction of nutrients post-harvest due to the fact that shellfish growth requires no additional food supplementation. Instead, mussels obtain their nutrients directly from surrounding waters. Despite this benefit to water quality, care must be taken when siting larger mussel installations in locations characterized by poor water circulation. Circulation maps and models of Budd Inlet indicate that flow velocities and DO concentrations are historically lower at EB, approaching complete hypoxia in mid-summer. Based on this knowledge, EB would not be an ideal candidate for a larger scale nutrient bioextraction project. Nutrient bioextraction would be suitable, however, in a lower Budd Inlet location that experiences adequate water circulation. In such instances, nutrient removal would occur via physical harvest (measurable) and denitrification, although denitrification was not measured as part of this study.

Various, theoretical, scaled-up mussel farming scenarios are presented in this report – both of which would result in the harvesting of approximately 500,000 to 600,000 pounds of mussels and remove 5,000 pounds of nitrogen from Budd Inlet. Should future nutrient bioextraction projects be pursued, however, ongoing monitoring of biological communities within and beneath installations, mussel “drop-off” times, and water quality at depth is recommended.

Water quality trading (WQT) is a voluntary market-based approach that, if used in certain watersheds, might achieve water quality standards more efficiently and at lower cost than traditional approaches (EPA, 2004). WQT has been encouraged by various agencies as part of the 2014 Recommendations for Improving Water Quality Assessment and Total Maximum Daily Load Programs in Washington State (Interagency Project Team, 2014). Establishment of WQT in Budd Inlet should, however, be predicated by TMDL established load allocations. When PSI began the “Surf to Turf” research, we expected to correlate required nutrient reductions in the Deschutes Basin to confirmed nutrient reductions from our bioextraction efforts in Budd Inlet. Unfortunately, with the separation of the upper and lower Deschutes Basin TMDL process, work remains in developing load allocations for Budd Inlet.

These results demonstrate that nutrient bioextraction with shellfish can be a viable component toward improving Budd Inlet water quality. The shared ecosystem functions of nutrient remediation, water clarification, biodeposition, and habitat creation make suspension-feeding bivalves a valued provider of ecological services to the shallow-water ecosystems. In addition, nutrient bioextraction engages the public, encourages Puget Sound stewardship, and supports larger nutrient removal efforts being made by LOTT Clean Water Alliance, the TMDL advisory group, participating government agencies, non-profit organizations, and the community at large.