CONFLUENCE
ENVIRONMENTAL COMPANY

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cc: Diani Taylor, Bill Taylor, Bill Dewey, Taylor Shellfish Farms

From: Marlene Meaders, Chris Cziesla, and Ruth Park

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Date: February 13, 2015

Re: Field Methods and Results of Taylor Shellfish Foss Farm Visit: Sand Dollar Observations Associated with Geoduck Aquaculture

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This memorandum was requested by Taylor Shellfish Farms (Taylor Shellfish) related to existing conditions of Pacific sand dollar (*Dendraster excentricus*) populations associated with geoduck (*Panopea generosa*) aquaculture operations. The information presented below is based on observations at an existing geoduck farm in Case Inlet (Foss Farm), a proposed geoduck farm (Haley Beach), and broad observations within South Puget Sound. The Foss Farm is a 12-acre geoduck farm in various stages of the culture process. It has been an active farm since 2000, and has been through at least three planting cycles and two harvest cycles. The proposed Haley Beach farm site is located approximately 3.5 miles north of the Foss Farm (Figure 1). This memorandum is an addendum to the report titled *Sand Dollar Biology and Effects Related to Geoduck Aquaculture at Haley Beach* prepared for the Pierce County Hearing Examiner and dated September 8, 2014 (Meaders et al. 2014).

SAND DOLLAR DISTRIBUTION IN SOUTH PUGET SOUND

According to Dethier (2010), "Certain beaches in Puget Sound without eelgrass have beds of sand dollars (*Dendraster excentricus*), which live primarily subtidally but extend up into the low or even mid-shore." The intertidal distribution of sand dollars was monitored between 1994 and 2000 through the Washington State Department of Natural Resources (DNR 2001) as part of the Nearshore Habitat Program. Mapping in South Sound took place primarily in 1997 and 1999. Sand dollar distribution and coverage was one of the parameters identified in the inventory, which was characterized as absent, patchy, or continuous along the shoreline. The DNR (2001) dataset resulted in a basic distribution of sand dollars for the Puget Sound, with the highest occurrence in South Sound (Figure 2).

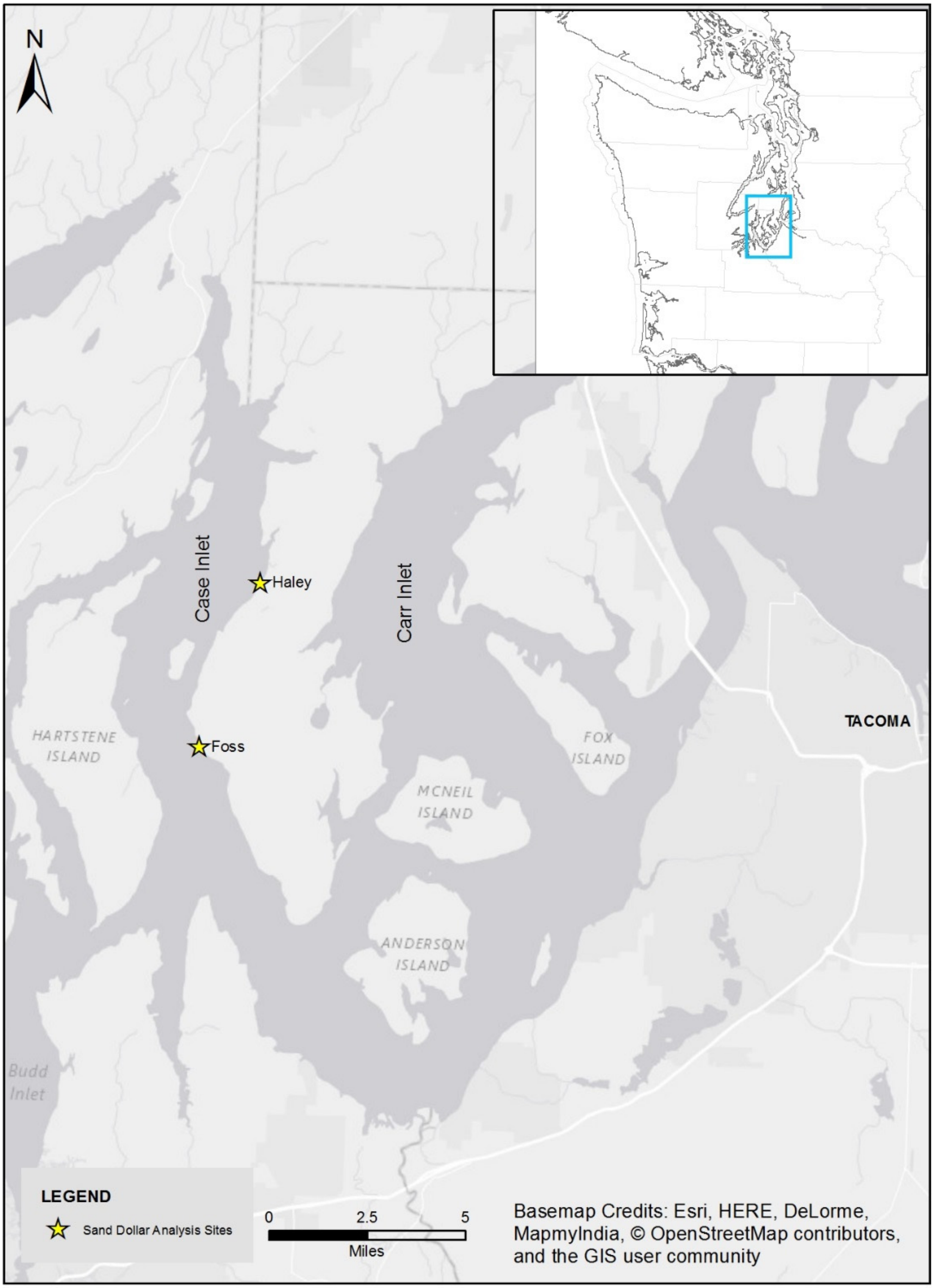

Figure 1 **Location of Foss Farm and the Proposed Haley Beach Farm Site**

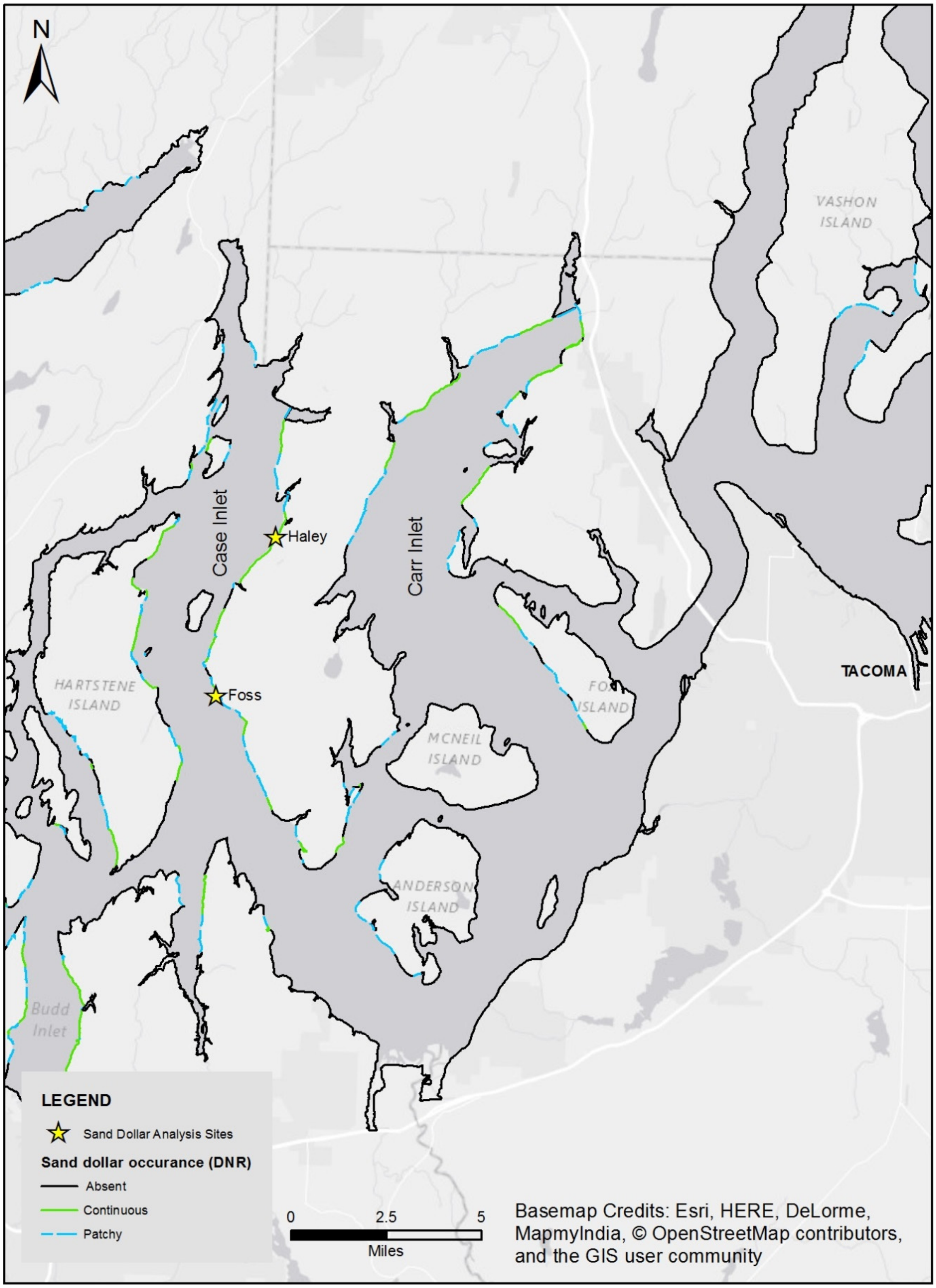

Figure 2 **Sand Dollar Distribution in Case Inlet**

Subsequent work in Puget Sound has provided a few more details on sand dollar distribution. The Spatial Classification and Landscape Extrapolation (SCALE) of intertidal biotic communities surveyed 45 beach segments in Central and South Sound using a nested sampling design (Dethier and Schoch 2005). Sampling was completed at each beach along 50 m (164 ft) horizontal transect lines established along the 0 ft MLLW tidal elevation. The authors reported that sand dollars show a patchy distribution, which is only increased because it settles in an "aggregative manner." Salinity may affect distribution patterns, and reduced or variable salinity appears to have a direct negative effect on species diversity in marine environments (Dethier, pers. comm., 2015).

Dr. Megan Dethier was one of the main researchers in both the DNR (2001) mapping and the SCALE survey work (Dethier and Schoch 2005). In 2007, Dr. Dethier was the lead author in a letter discussing concerns over the potential environmental effects of geoduck aquaculture. In that letter, the authors indicated that "sand dollar beds are uncommon and may be declining in Puget Sound, are a key ecological species controlling local communities, may serve as refuges for young Dungeness crabs, and do not return to beaches once lost" (Dethier et al. 2007). In a recent conversation with Dr. Dethier (pers. comm., 2015), she indicated that this comment was based on observations of sand dollar beds during her research. Although the observations are the best data available for Puget Sound, they do not represent a long-term trend analysis and it may be worth exploring patterns that could provide more understanding about sand dollar distribution.

A couple of key observations led to the thought by Dr. Dethier that sand dollars do not return to beaches once lost. In the San Juan Islands, sand dollar beds have disappeared from several locations (for unknown reasons) and have not returned even after decades. Additionally, in 2010, a geoduck operation moved a portion of the sand dollar bed from a harvest location and set them high up on the beach in gravel substrate (Gibbons 2010). The grower later toured the area with a marine biologist (Duane Fagergren) and described the sand dollar population at the site as "thriving." The 2010 incident was an isolated event and not a common practice of the aquaculture industry. The concern raised by Dr. Dethier was that a main cue for larval settlement is likely the presence of adults (Highsmith 1982), which may be a contributing factor for why populations in the San Juan Islands have not recovered.

Following the 2010 incident when sand dollars were moved to an area of the beach that was not suitable habitat (i.e., exposing them to desiccation), the growers critically considered the interactions between geoduck aquaculture and sand dollar beds. Taylor Shellfish used their own experiences with sand dollars on the Foss Farm to inform best management practices (BMPs) for other growers. They have found that geoduck clams and sand dollars co-exist. In fact, there appear to be benefits to both species. As deposit feeders (Chia 1969; Merrill and Hobson 1970; O'Neill 1978; Fodrie et al. 2007), sand dollars likely benefit from the increased amount of nutrients deposited in the substrate by geoducks (i.e., biodeposition) or during a harvest event when sediment disturbance moves nutrients to the surface (Dewey, pers. comm., 2015). Geoducks have been observed to grow faster in the presence of sand dollar beds (McKague, pers. comm., 2014), which may be a result of natural predator protection offered by the sand dollar aggregation or the changes to local hydrodynamics that may increase food for filter feeders. These observations were used to formally introduce BMPs to all growers through an update of the Environmental Codes of Practice in 2011 (PCSGA 2011). These BMPs were reviewed in detail in the Meaders et al. (2014) report.

The successful implementation of these BMPs has been used at the Foss Farm for multiple planting and harvest cycles. Observations of the Foss Farm related to the sand dollar population, compared to the proposed Haley Beach farm site, are provided below.

FIELD OBSERVATIONS AT AN EXISTING AND PROPOSED GEODUCK FARM

Observations of sand dollars were collected by Confluence Environmental Company (Confluence) at the existing Foss Farm during three separate site visits: (1) August 12, 2014, (2) January 26, 2015, and (3) January 27, 2015. In addition, observations were collected at the proposed Haley Beach farm site on August 9, 2014, and August 12, 2014. The goal of these visits was to document the occurrence of sand dollars in relation to geoduck aquaculture gear or operations compared to a site without aquaculture present. The intention was not to track the sand dollar population at the Foss Farm, or to understand the overall areal extent or seasonal migration of sand dollars. The main question being addressed was whether there was a population-level change in sand dollars due to geoduck aquaculture operations.

In addition to the efforts above, the Haley Beach site was reviewed by ENVIRON (2013a,b) in May/June 2012 during baseline surveys for permitting purposes and on August 9, 2014, by Confluence and the Appellants prior to the Hearing Examiner appeal of the mitigated determination of non-significance (MDNS) for the Haley Beach proposed geoduck farm. Finally, the Foss Farm was reviewed by Confluence and the Appellants on January 27, 2014, to conduct an independent review of the sand dollar population at an existing geoduck farm.

The methods discussed below are in relation to the field visits by Confluence, but the results of these visits will be compared to observations made by other parties at both the proposed Haley Beach and existing Foss Farm site.

Methods

August 12, 2014 Site Visit: Both the existing Foss Farm and the proposed Haley Beach farm site were accessed by boat from 12:00 to 15:00 during a tidal elevation range from -1.3 feet (ft) to +5.5 ft mean lower low water (MLLW)[1]. Confluence biologists entered the water using snorkel gear and conducted a number of random counts for sand dollars within a variety of plots at different phases of the culture cycle. At each location, a random set of five 0.25-square meter (m^2) quadrat counts were collected. Table 1 provides a description of the locations where counts were conducted. These data were compared with data collected by the Appellants during an August 9, 2014, site visit. The Appellant site visit was conducted during a low tide when the beach was exposed.

[1] Tidal elevation range was based on the 6-minute tide data at Tacoma, WA (Station ID 9446484) compared to the predicted tide height at Vaughn, Case Inlet, WA (Station ID 9446366).

Table 1 Data Collection Locations during the August 12, 2014, Site Visit

Parameter	Foss Farm					Haley Beach
Number of Counts	5	5	5	5	5	5
Tidal Elevation	0 ft MLLW	+2 ft MLLW*	0 ft MLLW	0 ft MLLW	0 ft MLLW	0 ft MLLW
Gear Present	None	None	Mesh tubes	None	PVC tubes	none
Aquaculture Process	1 week post-harvest	Above harvest area (no culture)	Tubes present for 1 year (planted in 2013)	Geoduck clams planted in 2010	1 week post net removal	none

MLLW = mean lower low water
*Note that in order to find a location directly adjacent to the area that was just harvested, the data was collected at a higher tidal elevation, which affected the results of the sand dollar counts.

January 26, 2015 Site Visit: The Foss Farm was accessed by boat from 10:00 to 13:30 during a tidal elevation range from +9.0 ft to +16.0 ft MLLW. The site was surveyed using a combination of underwater video camera with differential global positioning system software (dGPS) and GoPro® underwater video camera technology. The underwater camera with dGPS was deployed from a boat. The dGPS collected the tract where the camera collected video footage within mesh tubes and polyvinyl chloride (PVC) tubes (Figure 3). As a supplement to the underwater camera footage from the boat, two divers entered the site with a GoPro camera to collect additional observations of sand dollars within a geoduck plot planted in mesh tubes and locations just outside of the geoduck plot close to an area that was harvested an hour prior to diving the site (Figure 3).

January 27, 2015 Site Visit: The Foss Farm was accessed by land from 16:15 to 17:10 during a tidal elevation range from +1.6 ft to +2.2 ft MLLW. The upper extent of the Foss Farm was surveyed along the low tide line and in inundated areas adjacent to the exposed portion of the beach (Figure 3). Photographs and observations were collected during the site visit. The Appellants were also present during this site visit, and collected observations within similar locations.

Results

Sand dollars were found at similar tidal elevations at both the Foss Farm and proposed Haley Beach farm site. Based on observations during site visits in the spring and summer, sand dollars occurred at the proposed Haley Beach farm site from approximately -2 ft to +2 ft MLLW (ENVIRON 2013a,b; Meaders et al. 2014). The bottom edge of the bed was more distinct than the upper edge, and sand dollars appeared to be densest at the lower tidal elevations (i.e., ≤ 0 ft MLLW). The sand dollar bed, overall, was considered patchy in distribution. Observations at the Foss Farm were consistent with that of Haley Beach, in that sand dollars were primarily distributed within a similar tidal elevation, appeared to increase in density at and below 0 ft MLLW, and were patchy in distribution.

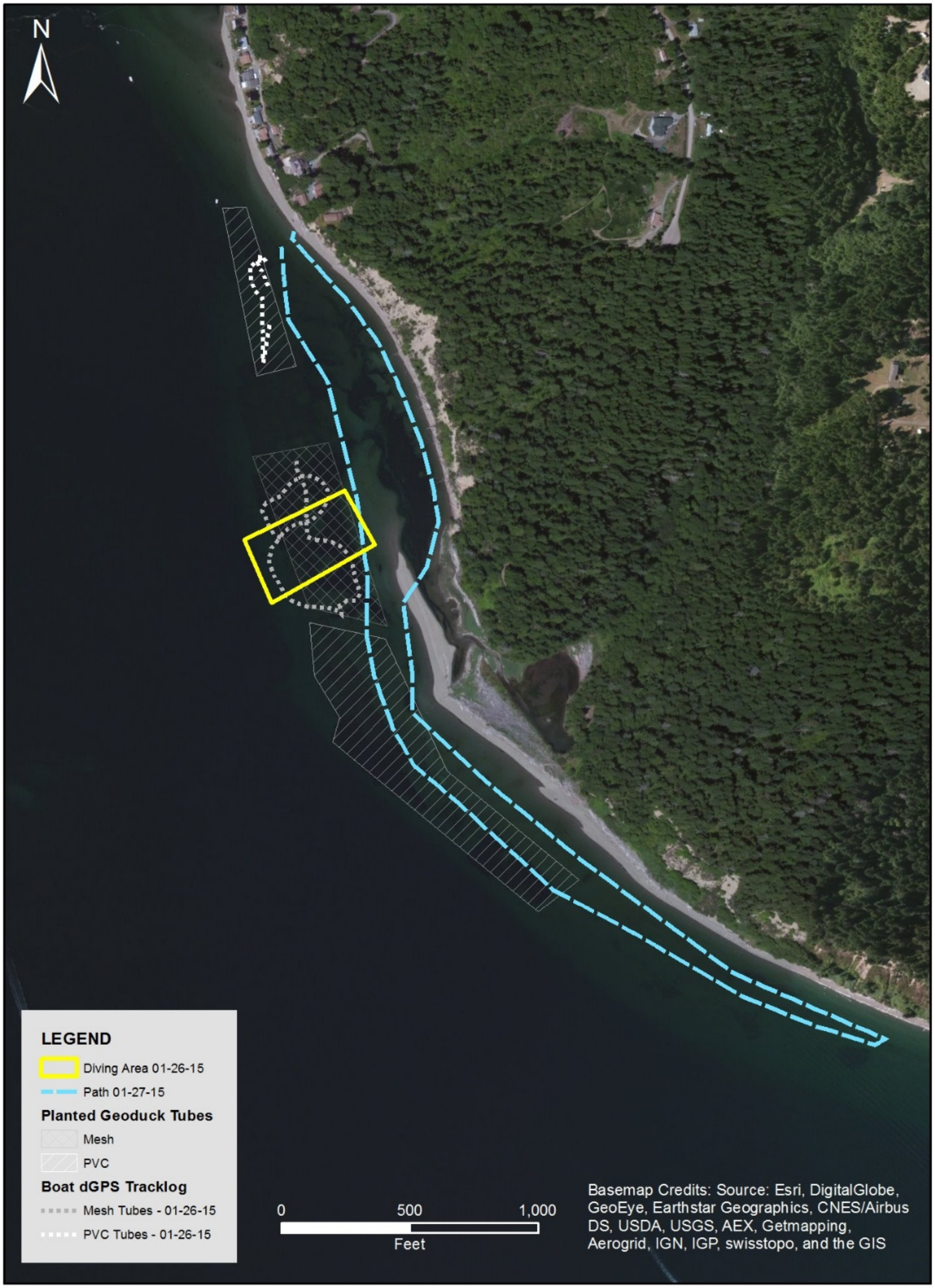

Figure 3 **Survey Tracts during the January 26 and January 27, 2015, Site Visits**

Sand dollar densities were also similar between the Foss Farm and proposed Haley Beach farm site. Based on random counts collected during the August 2014 site visits, average densities appeared to be comparable between areas with gear and areas adjacent to the tube field (Table 2). Average densities were potentially higher in an area that was harvested one week prior to sampling, which was higher even than areas without aquaculture at the Haley Beach site (Table 2). Video observations at the Foss Farm site during the January 26, 2015, site visit (Appendix A) observed much broader numbers and confirmed the original observations made during the August 2014 site visit. There was evidence of effects to individual organisms from aquaculture activities and along freshwater seeps discharging from upland habitat (Figure 4A). However, the sand dollar population appeared to be robust in the presence of geoduck aquaculture operations (Figure 4B).

Table 2 Sand Dollar Densities at Foss Farm and Haley Beach in August 2014

	Foss Farm Sand Dollar Densities (animals/0.25 m^2)					Haley Beach Sand Dollar Densities (animals/0.25 m^2)	
	Harvest		Mesh Tubes		PVC Tubes and Netting	Confluence 2014	Appellant 2014***
	1 Week Post-Harvest	Above Harvest Area	Tube Field*	Adjacent to Tube Field**	1 Week Post Net Removal		
Tidal Elevation (MLLW)	**0 ft**	**+2 ft**	**0 ft**	**0 ft**	**0 ft**	**0 ft**	**-2 ft to +2 ft**
Count 1	105	47	65	47	65	105	96
Count 2	138	57	44	41	59	122	64
Count 3	110	45	43	55	67	94	11
Count 4	122	28	24	64	71	87	74
Count 5	117	38	99	76	110	66	62
Average	**118**	**43**	**55**	**57**	**74**	**95**	**61**
Standard Deviation	**13**	**11**	**29**	**14**	**20**	**21**	**31**

*Mesh tubes present. Crop planted in 2013.
**No tubes present, but in the culture area. Crop planted in 2010.
***Appellant data collected on August 9, 2014; as provided in Jim Brennan's PowerPoint presentation.

Other observations of sand dollars at the existing Foss Farm and proposed Haley Beach site were consistent in terms of the ecology of the organisms, as discussed in Meaders et al. (2014). For example, there were obvious signs of migration and aggregation at both sites. This was evident based on the patchy distribution that included areas of dead sand dollars in locations where the bed had likely migrated away from as the population accessed new feeding areas. In addition, sand dollars were buried in the sediment when the beach was exposed (Figure 5A) and standing on end (i.e., feeding in the water column) when the area was inundated (Figure 5B). Finally, a variety of size classes were evident in the sand dollar beds at both the Foss Farm and proposed Haley Beach farm site, representing both juvenile and adult life stages.

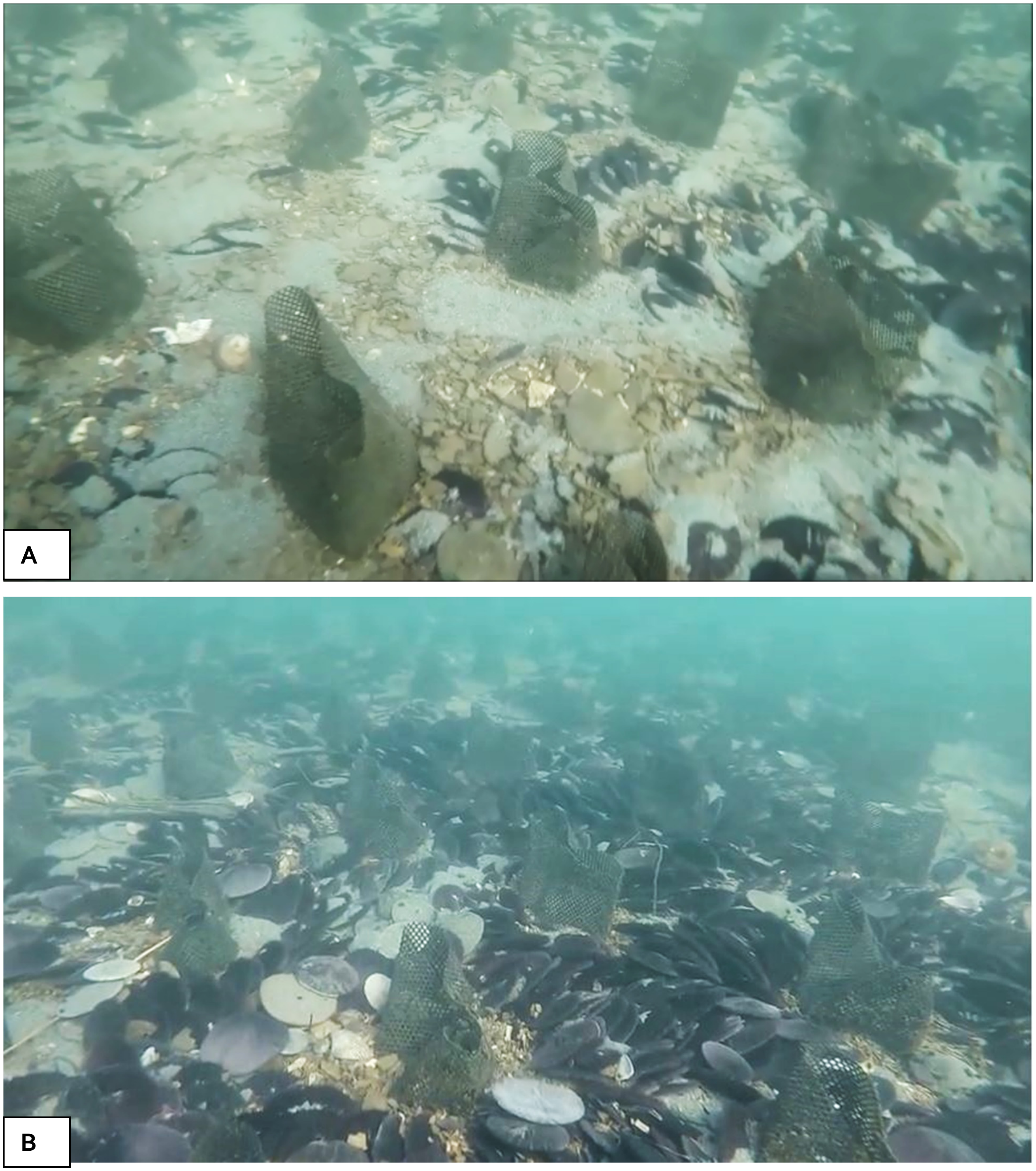

Figure 4 Sand Dollars within Culture Tubes at Foss Farm, Case Inlet
A = Patchy distribution of sand dollars; B = Aggregations within the culture tubes.

Conclusions

Based on the observations between the existing Foss Farm and proposed Haley Beach site, the sand dollar population, overall, was not significantly affected by the presence of geoduck aquaculture. Dense sand dollar aggregations still occurred in and amongst the tubes. When gear was not present, which is the majority of the culture cycle, there did not appear to be a difference between areas planted with geoducks and areas that have not experienced geoduck aquaculture. In fact, an area that was harvested a week prior to sampling had higher densities of sand dollars compared to an unaltered beach. While this is based on a limited sample size, it makes sense in terms of the ecology of the organism. Sand dollars are both mobile organisms and deposit feeders (Chia 1969; Merrill and Hobson 1970; O'Neill 1978; Fodrie et al. 2007). A harvest event would disturb organics in the sediment, providing additional food resources for these organisms.

SUMMARY

Sand dollars appear to be ubiquitous in Puget Sound, especially in South Sound. Patchy sand dollar beds occur throughout South Sound with no apparent distribution pattern that can be discerned from the available data (DNR 2001; Dethier and Schoch 2005). Reduced or variable salinity may be a natural stressor on marine species (Dethier, pers. comm., 2015), and mortality associated with freshwater seeps along the Foss Farm site was observed during the January 26, 2015, site visit. Presence of adults may be an important determinant in the persistence of a sand dollar bed, and ensuring that BMPs retain adult sand dollars on a beach encourages larval settlement to the area.

The main question being addressed by this effort was whether there was a population-level change in sand dollar beds as a result of the geoduck aquaculture operation at an existing farm, which has included at least three planting cycles and two harvest cycles. While there were limited changes, and some individual mortality of organisms, the population was stable and robust in the presence of geoduck aquaculture. There were a variety of size classes present (e.g., both juvenile and adult life stages), which indicates that larvae are attracted to the area and settle within the existing sand dollar beds. According to Highsmith (1982), larval settlement and metamorphosis is sometimes triggered by chemical cues provided by adults. Based on an understanding of the distribution, life history, and ecology of sand dollar populations (literature reviewed in Meaders et al. 2014), geoduck aquaculture and sand dollar beds can be mutually sustainable. There are even potential benefits for both organisms. Sand dollar presence can increase the growth of geoduck clams and geoduck biodeposition or a geoduck harvest event can provide a new food resource for sand dollars.

Based on the observations at the existing Foss Farm site compared to conditions at the proposed Haley Beach farm site, it does not appear that a geoduck aquaculture operation would significantly alter sand dollar populations in South Sound.

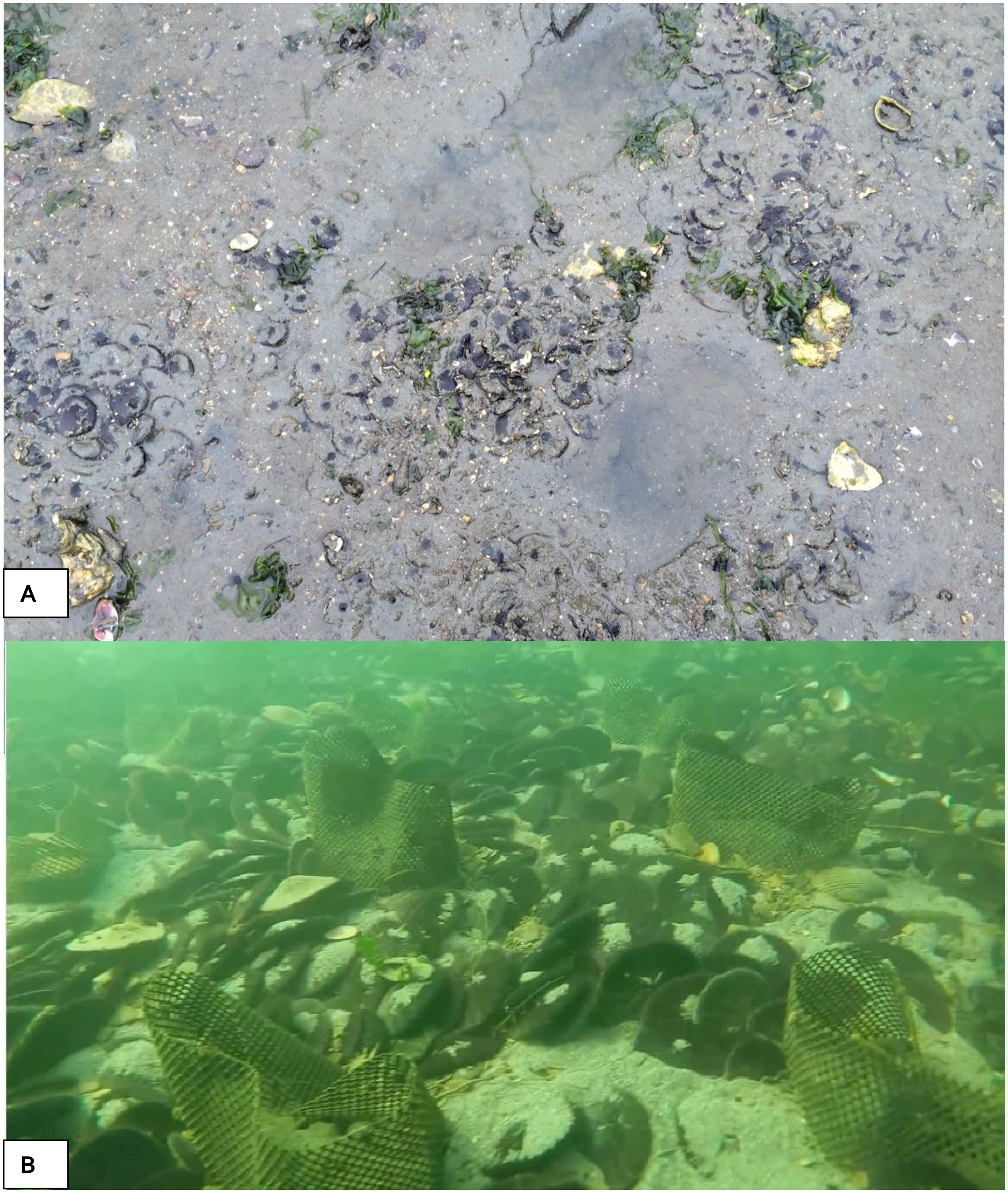

Figure 5 Sand Dollars Buried in the Sediment during a Low Tide versus Standing Vertically in the Water Column during a High Tide

A = Low tide with buried sand dollars; B = High tide with vertically-oriented sand dollars.

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