

ECOLOGICAL CONSEQUENCES OF GEODUCK CLAM *Panope generosa* Gould, 1850 AQUACULTURE FOR BENTHIC COMMUNITIES OF INTERTIDAL SAND FLATS IN SOUTHERN PUGET SOUND, WASHINGTON USA: A SUMMARY OF FINDINGS, 2008-2012

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Geoduck clam (*Panope generosa* Gould, 1850) aquaculture is an expanding and profitable enterprise on intertidal beaches of southern Puget Sound, Washington USA. Aquaculture operations have engendered significant cultural conflict and management interest on a regional scale based on perceptions of potential associated ecological damage. From summer 2008 through summer 2012 our research group evaluated responses of intertidal benthic communities to the various stages of the geoduck aquaculture cycle, applying a before-after-control-impact approach across multiple study sites. Key disturbances associated with the geoduck culture cycle include: a) initial outplanting of juvenile clams from hatcheries, and coincident placement of predator exclusion structures to protect young clams; b) removal of predator exclusion structures at 1-2 years into the culture cycle; and c) harvest of market-sized adult clams using localized sediment liquefaction and manual extraction at 5-7 years after initial outplanting. We evaluated effects of the listed disturbances on patterns of abundance and diversity in benthic infauna (primarily amphipod crustaceans, polychaete annelids, minute bivalves, holothurians, and burrowing anemones) and mobile epibenthic macrofauna (primarily fish, crabs, sea stars, and snails), and have evaluated effects on abundance, size distributions, growth rate, diet, and stable isotope signatures on an abundant demersal fish (Pacific staghorn sculpin, *Leptocottus armatus* Girard, 1854) known to have high site fidelity in our study plots.

Studies of infaunal responses indicated only temporary and minor shifts in assemblage composition, and virtually no changes in diversity, associated with indicated disturbances. Variance in the data was driven by seasonal and spatial factors to a much greater degree than factors associated with aquaculture operations. Responses of mobile macrofauna to culture-

associated disturbances were also temporary. Placement of predator exclusion structures displaced species typical of sand beach habitats, particular small flatfishes and gastropods and favored increased abundances of *Cancer* and hermit crabs, sea stars, and staghorn sculpins in cultured plots. The macrofaunal assemblage quickly returned to pre-disturbance configuration following removal of predator exclusion structures. Mean size and rate of weight gain in tagged staghorn sculpins were higher in cultured plots than in reference plots, but stable isotope signatures did not vary by plot type, indicating that sculpins probably fed at the same trophic level in cultured plots as in open sand habitats, but consumed food at higher rates in the cultured plots. In aggregate, our findings indicate minor transient effects of geoduck aquaculture on resident benthic communities in southern Puget Sound.