Waterfowl foraging budget for *Zostera japonica* in Willapa Bay.

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Introduction:
Waterfowl hunters have asserted that management of *Z. japonica* would threaten waterfowl populations on the Pacific Flyway that utilize Z. *japonica* for refueling along this critical flyway. One approach to address this concern is to develop a foraging budget based on the amount of *Z. japonica* in Willapa Bay, the amount of *Z. japonica* consumed by waterfowl and the total waterfowl usage in Willapa Bay during peak migration. Foraging ecology budgets for waterfowl are complicated. They require a lot of assumptions and detailed data on waterfowl populations and consumptive use and eelgrass acreage. Two methods will be used in this model. One is based on data used in a study of eelgrass consumed by brant in Humboldt Bay (Moore, 2002) and the other is based on data used for a landscape budget for waterfowl developed in Puget Sound (Lovvorn J.R. & Baldwin, K.R. 1996).

Methods and Data:
Z. japonica area in Willapa Bay: Polygons were drawn around areas containing moderate to thick *Z. japonica* in Willapa Bay, based on the USDA 2006/2007 survey. They estimated ~ 12,000 acres of *Z. japonica*. This does not include any acres with thinly populated *Z. japonica* or any increase in acres since 2007. A more generous mapping of Z. *japonica* polygons suggests that there are ~ 18,000 acres of *Z. japonica* in Willapa Bay.

Z. japonica dry weight data: Top growth of *Z. japonica* was sampled monthly from September to November, in 1 ft^2 quadrats at 40 locations in Willapa Bay. Leaves were dried and recorded as grams dw/m^2. Moderate to thick density *Z. Japonica* averaged ~ 0.1 to 0.2 kg dry weight/m^2 (405 to 812 kg dry wt/ac). Based on these data, there are between 5 to 15 million kg dw of *Z. japonica* available for forage in Willapa Bay (0.1 kg dw/m^2 X 4,046 m^2/ac X 12,000 ac to 0.2 kg dw/m^2 X 4,046 m^2/ac X 18,000 ac).

Consumptive use model: This model uses brant as a surrogate for all waterfowl consuming eelgrass. It is based on a MS thesis by J. Moore, 2002, in Humboldt Bay. He determined that brant consume ~100 g dw of *Z. marina*/day. Since brant are ~ twice the body weight of dabbling duck (3.5 lbs vs. 1 to 1.75 lbs), the smaller dabbling duck species are assumed to eat ~ 50 g dw of eelgrass/day. Assuming waterfowl usage for Grays Harbor and Willapa Bay is approximately equivalent, there are ~ 20,000 dabbling ducks during October and November (Lovvorn & Baldwin 1994). These values can then be combined to obtain the eelgrass consumed in Willapa Bay during peak migration (20,000 ducks/day X 0.05 kg eelgrass/day X 60 days = 60,000 kg) This much forage can be obtained on ~75 to 150 acres of *Z. japonica*. If the number of foraging ducks is quadrupled to 80,000, and their foraging time doubled to 120 days (~9.6 million duck days), their consumptive requirement would be for ~ 1,000 acres of *Z. japonica* (80,000 ducks X 120 days X 0.05 grams/day = 480,000 kg *Z. japonica*).

Energy model: Lovvorn & Baldwin (1996), developed landscape models for waterfowl that included *Z. japonica*. They based their calculations on the energy requirements of dabbling ducks. Wigeon and other waterfowl use ~ 630 KJ/day of energy. 20,000 dabbling ducks for 60 days would need (630 MJ/day X 20,000 ducks X 60 days) = 756,000 MJ of energy from forage in Willapa Bay. They report that *Z. japonica* has 18,145 KJ/ g dw, but that only ~50% of that is utilized for energy. This equals a maximum of 7,200 MJ/ac for *Z. japonica* (0.5 X 18 MJ/g dw X 0.2 g dw/ m^2 X 4,046 m^2/ac). Because the density of *Z. Japonica* declines in the fall, there would be less energy later in the season. An average density across the migration season would be ~ 0.1 g dw/m^2 which reduces the energy value of *Z. japonica* to 3,614 MJ/ac. One acre of *Z. japonica* could therefore theoretically support ~ 100 ducks over 60 days of foraging (3614 MJ/ac ÷ (630 KJ/day/duck X 60 days)). To fulfill the energy required of 20,000 dabbling ducks would require 200 acres. If we quadruple the number of ducks (80,000 ducks feeding) and double their foraging days (120) then ~ 1600 acres would be required for the ~ 6,000,000 MJ of total energy required to feed those ducks.

Discussion: Both of the methods used above are very conservative. They assume that all food/energy for all ducks comes from *Z. japonica*. Based on the data presented in Lovvorn and Baldwin (1995), this is far from true. *Z. japonica* leaves provide 84, 8, 20 and 1% of the diet of wigeon, pintail, mallard and teal, respectively. It assumes that no *Z. japonica* root biomass is available for consumption and all the energy is derived from leaves. Dabbling ducks do eat rhizomes of *Z. japonica*, especially pintail and mallard (29% and 39% of diet, respectively). It assumes that there has been no increase in *Z. japonica* since 2007. Subsequent mapping, goggle earth satellites, and personal observations indicate significant increases in *Z. japonica* in several locations in the bay since 2007. Even if these budgets are conservative and greatly overestimate the amount of *Z japonica* consumed by dabbling ducks, that amount is several orders of magnitude less than what is available for consumption in Willapa Bay.

Historically, waterfowl forage in Willapa Bay did not include *Z. japonica*. It could be argued, therefore, that Z. *japonica* is not critical in their overall forage ecology. This inference could help to explain our recent survey results of esophagus + proventriculus content from 118 ducks in Willapa Bay in 2010. We found that wigeon (*A. americana)* was the only species that consumed significant amounts of *Z. japonica* (Patten and Norelius 2011). Obviously, more research on the forage ecology of waterfowl in Willapa Bay would be required to obtain more precise forage budget data. Until those studies are conducted, it is safe to assume the true usage of *Z. japonica* in Willapa Bay will range between ~ 100 to 200 acres on the low end to ~1,000 to 1,600 acres on the high end. In either case, management of a few hundred to a few thousand acres of *Z. japonica* on clam production ground is highly unlikely to have any impact on waterfowl populations.

References:

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