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

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Introduction:
Waterfowl hunters have asserted that management of *Z. japonica* would threaten waterfowl populations that utilize Z. *japonica* for refueling along the critical Pacific Flyway. One approach to addressing 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 survey data on both waterfowl and eelgrass. Two methods will be used in this model. One is based on studies of eelgrass consumed by Brant in Humboldt Bay (Moore, 2002 and black swans in New Zealand (Dos Santos et al. 2012). The other is a landscape budget for waterfowl in Puget Sound (Lovvorn & Baldwin 1996).

Methods and Data:
Z. japonica area in Willapa: Polygons were drawn around areas containing moderate to thick *Z. japonica* in Willapa Bay, based on the USDA 2006/2007 survey. Acres within the polygons were calculated on ARC. There were ~ 18,000 acres of *Z japonica* in Willapa Bay based on the 2007 data layer.

Z. japonica dry weight data: Top growth of *Z. japonica* was sampled monthly in 1 ft^2 quadrats September to November 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 $dw.m^{-2}$. Based on these data, there are at least 14,565,000 kg dw of *Z. japonica* in Willapa (0.2 kg $dw.m^{-2}$ X 4046 $m^2.ac^{-1}$ X 18,000).

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 (1.6 kg vs. 0.45 to 0.8 kg), the smaller dabbling duck species are assumed to eat ~ 50 g dw of eelgrass/day (Dos Santos et al. 2012). Assuming waterfowl usage for Grays Harbor and Willapa Bay are 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 $eelgrass.day^{-1}$ X 60 days = 60,000 kg) This much forage can be obtained on ~30 acres of *Z. japonica*. If we quadruple the number of ducks (80,000 ducks feeding), double their foraging days (120 days) and double their foraging rate/day (0.1 $Kg.day^{-1}$), this increase the usage to 480 ha of *Z japonica* needed to support waterfowl in Willapa Bay

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 $kJ.day^{-1}$ of energy. This is very close to the values used for migrating shorebird by Kersten & Piersma (1987). Where the amount of daily energy (kJ) required by a shorebird to maintain its existence metabolic rate (EMR) was calculated following Kersten and Piersma (1987) as: EMR (kJ) = 912 • (body mass [kg])$^{0.704}$. For a 0.5 kg waterfowl this is 559 $kJ.day^{-1}$.

Twenty thousand dabbling ducks for 60 days would need 756000 MJ of energy from forage in Willapa Bay (630 kJ/day X 20,000 ducks X 60 days). If we quadruple the number of ducks (80,000 ducks feeding), and double their foraging days (120), then ~ 6,000,000 MJ of energy would be required. Lovvorn & Baldwin (1996) report that *Z. japonica* has ~18,000 kJ g^{-1} dw, but only ~50% of that is utilized for energy. This then means that *Z. japonica* at its peak in August provides ~ 18000 $kJ.m^{-2}$ (18000

kJ g^{-1} dw X 0.5 X 200 g $dw.m^{-2}$). Because the density of Z. *japonica* declines in the fall, a smaller value for dry weight should be used for September to October. If that value is 25%, we obtain 4.5 $MJ.m^{-2}$ or 4500 $MJ.ha^{-1}$. To provide for the 6,000,000 MJ of energy required by 80,000 ducks feeding for 120 days would require 1333 ha. For a more realistic number of foraging water (20,000 X 60 days) on 168 ha of *Z. japonica* would be required.

Discussion: Both of the methods used above are very conservative. They assume that all food/energy for all ducks comes from *Z. japonica* and the full complement of waterfowl (80,000) are feeding for four months solid on nothing but *Z. japonica* shoots. Even when these extreme assumptions are used in the calculations for foraging budgets only 400 to 1300 ha of *Z. japonica* are required to sustain the population of ducks. The real value is likely to be between 30 and 170 ha. Data provided by Lovvorn and Baldwin (1995), would support this lower use rate of *Z. japonica*. They calculate that *Z. japonica* leaves provide 84, 8, 20 and 1 % of the diet of wigeon, pintail, mallard and teal, respectively. We assume 100% for every species. Our data also did not use root biomass of *Z. japonica* for any consumption or energy values. Dabbling duck do eat rhizomes of *japonica*, especially pintail and mallard (29% and 39% of diet, respectively).

Based on these forage budget, what would be the impact of *Z. japonica* management in Willapa Bay on Waterfowl? Our estimates of ~18,000 acres (~ 7,000 ha) of *Z. japonica* in Willapa Bay are conservative since they assume no increase since 2007. Subsequent mapping, goggle earth satellites, and personal observation indicate significant increase in *Z. japonica* in several locations in the bay since 2007. Using the highest foraging require of ~1300 ha of Z. japonica, there is a net surplus of 5700 ha eelgrass. Using a more realistic foraging requirement of ~200 ha, would leave 6,800 ha of un-eaten *Z. japonica*. Control of a 1000 ha *Z. japonica* per year should have no impact on waterfowl populations.

References.

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