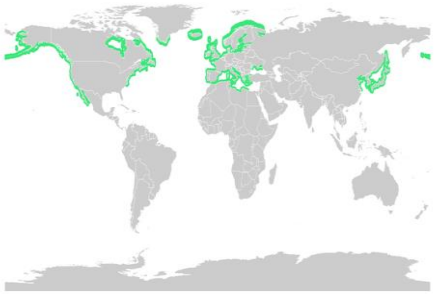
Plant Propagation Protocol for *Zostera marina*
ESRM 412 – Native Plant Production
Protocol URL: https://courses.washington.edu/esrm412/protocols/*zoma.pdf*



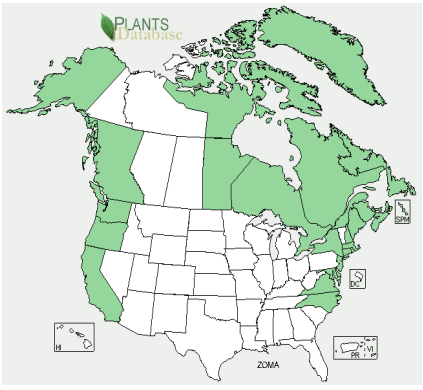


Photo Source: (Marine) http://www.marinebio.ca/hd/eelgrass.php
Map #1 Source: (Short) http://maps.iucnredlist.org/map.html?id=153538
Map #2 Source: (USDA) https://plants.usda.gov/core/profile?symbol=ZOMA

TAXONOMY	
Plant Family	
Scientific Name	Zosteraceae
Common Name	Seagrass
Species Scientific Name	
Scientific Name	*Zostera marina*
Varieties	
Sub-species	
Cultivar	
Common Synonym(s)	ZOPA *Zostera pacifica* L. ZOMAS *Zostera marina* L. var. *stenophylla* Asch. & Graebn. ZOMAL *Zostera marina* L. var. *latifolia* Morong
Common Name(s)	Eelgrass, Seawrack
Species Code (as per USDA Plants database)	ZOMA
GENERAL INFORMATION	
Geographical range	Circumglobal in northern latitudes. Found throughout the north Atlantic into Canada, Greenland, and northern Europe into the Mediterranean and Black Seas. Found in the north Pacific, extending into the Arctic in Alaska, and across the ocean into eastern Asia. Southern reaches into Baja California, Mexico. (Marine)
Ecological distribution	Forms perennial meadows in protected saltwater lagoons, bays, and coastal inlets. Tolerates a wide range of salinity: 18-40psu. Requires a muddy sand, muddy gravel or mud substrate to root in. Does not tolerate strong wave action, and seeks protected or semi-protected bays.
Climate and elevation range	Low intertidal zone, subtidal zone to -4m.

Local habitat and abundance	In the Pacific northwest it is the dominant native sub-tidal plant. Wasting disease, coastal development, propeller damage and water pollution are reasons for its decline. Considered of 'Least Concern' on Red List of Threatened Species by the International Union for Conservation of Nature and Natural Resources. (Short IUCN)
Plant strategy type / successional stage	The plant is monoecious. Pollen and seed dispersal are aided by ocean currents. Seeds can float attached to gas bubbles to further their distribution. They are also dispersed by wildfowl attachment or ingestion. (Marine). Sub-surface rhizomatous propagation occurs as well. Rhizomes float, allowing widespread distribution by currents, until it roots in an accommodating substrate. It does not resist attaching organisms (like marine algae), which makes it excellent habitat for small organisms and epiphytic algae. It stabilizes marine sediments and thus provides protective habitat for rearing fish, shellfish and other marine life. (LBJ) It is a perennial plant, but if heavily stressed, it will reproduce in an annual cycle.
Plant characteristics	Eelgrass appears like a seaweed but is in fact a grass-like seed plant. Thin, long leaves (20 to 50cm, occasionally up to 200cm) containing lacunae (air spaces) allow it to stream with the current. Neither a seaweed nor an algae, Eelgrass is a true seed plant. (LBJ)
PROPAGATION DETAILS	
Ecotype	As few studies on *Zostera marina* have been conducted in the Pacific northwest, most of the "Propagation Details" refer to studies completed in the Chesapeake Bay, a focal point for eelgrass restoration. Local Washington state attempts to restore eelgrass in Puget Sound have drawn off of this information stemming from the Chesapeake. Eelgrass adapts to diverse conditions within its habitat type, and so these propagation protocols can be adapted to local waters.
Propagation Goal	Plants
Propagation Method	Seed
Product Type	Propagules- seeds
Stock Type	
Time to Grow	89-90 days
Target Specifications	shoots at least 12.25 cm tall, with a rhizome at least 2.25 cm long
Propagule Collection Instructions	Flowering shoots with seeds in various stages of maturation collected in the late spring from donor beds by hand or with a mechanical harvester, suspended in tanks with flowing, aerated, estuarine water until the seeds shed.

Propagule Processing/Propagule Characteristics	Seeds are stored at constant 21C, salinity 18psu, in tanks. Holding seeds indoors in filtered, UV-sterilized, recirculating, temperature-controlled water or disturbance produced high rates of seed survival (Marion). There are conflicting reports about the benefits of using aeration in the holding tanks. Viability is indicated by intact seed coats, firmness when squeezed, and sinking rapidly in seawater. Soft, damaged or slow sinking seeds are discarded. (Tanner) (Marion) Seeds remain dormant through the summer and early fall with germination beginning in the fall, when temperature drops to 15◦C or below, and continuing through the winter. Seed storage recommended for 1 year maximum. Viability for seeds after one year of storage was shown to be 77%. It dropped to 71% after two years, and then to 37% and 31% after year three and four. Germination rates were 68% after one year of storage, but dropped to 37% after two years. (Dooley)
Pre-Planting Propagule Treatments	Separate seeds from grass wrack in water- the seeds will sink faster than chaff. (Marion) Sieves can also be used as necessary. Eelgrass demonstrates both physiological and physical dormancy. Warmer temperatures generally inhibit germination. Cold storage temperatures (4C for 32-90 days), lower oxygen levels (typical of estuarine sediments), and slightly reduced salinities, complemented by scarification are methods that have been known to promote it. Scarification is done by rubbing between layers of 400 grit wet/dry sandpaper. (Tanner)
Growing Area Preparation / Annual Practices for Perennial Crops	Growth rates can be increased with higher nutrient enriched estuarine sediments: Osmocote slow-release fertilizer that enriched the soil nutrient concentration by 2 g N/m2 and 0.88 g P/m2. In a 2002 fertilization experiment, shoot height, leaf width, rhizome length, and the number of lateral shoots per rhizome were significantly enhanced by fertilizers. Media high in sand (and high oxygen) leads to low germination. This is partially due to the favorable hypoxic conditions of the siltier estuarine sediments, compared to the less-preferable oxygen rich sandy sediments. (Tanner) 34×24×8–cm deep plastic trays seeded with the goal of 100 germinants per tray (1000 seeds with assumed 10% germination rate). (Tanner)
Establishment Phase Details	Seeds in soil-less culture germinated in the summer when held at 14◦C (Tanner). Lower salinities can increase germination rates. Establishment is largely dependent on seeds quickly rooting into the substrate without being carried away by currents. Optimal

	depth for germination is 1-2 cm. Deeper than 2cm can lead to seed decomposition, and shallower than 1cm will lead to failure because there is too much oxygen near the surface. (Short 2002)
Length of Establishment Phase	3-29 days
Active Growth Phase	Seedlings grow rapidly, and some thinning might be necessary. New lateral shoots are produced from rhizomes. Entire shoot must remain submerged. The water level can be maintained just above the top of the shoot- this reduces the volume of water to be cooled, increases amount of light reaching the plant blades. Keep plants clean of epiphytic growth by gently dragging a net amongst the blades to wipe off growths. Keep tanks clean of algae by scrubbing. (Tanner)
Length of Active Growth Phase	65-95 days
Hardening Phase	At the time of harvesting, 89–90 days after planting, approximately 60% of seedlings met growth requirements for direct out-planting without a hardening phase. (Tanner)
Length of Hardening Phase	None
Harvesting, Storage and Shipping	Must be stored or shipped in saline tanks. Minimal disturbance required, as this directly affects mortality.
Length of Storage	This is unknown, but it is recommended to outplant as soon as possible to allow plants to begin rooting strongly in the substrate.
Guidelines for Outplanting / Performance on Typical Sites	Plant is buried in substrate from above the surface using a bamboo skewer, or hand planted by scuba divers. Outplanting performance is dependent on substrate type, disturbance factors (storm surges, current strength), and water quality. Optimal substrates: fine gravel, sand or mud. Elevation: Low water spring tides down to depths of 4m. It is rarely found in estuaries. It cannot grow in the shade. It is obligate and must grow in saltwater. (PFAF) Summer water temps above 25C will cause mortality. (Tanner) It is in flower from June to September, and the seeds ripen from Aug to October. (PFAF) Hand broadcasting the collected seeds is also a common restoration practice. Of note- currents are the primary mechanism for locally redistributing seeds short distances on un-vegetated shoals. In calm areas with minimal winter storms, hand broadcasting is preferable and minimal redistribution takes place once seeds are covered with sediment. In high energy areas with unconsolidated sandy sediments, physically burying

	the seeds will help establishment. (Marion)
Other Comments	Manual or mechanical transplanting from sods, cores or bare root (not growing from seed) can have higher survival rates, but harvesting and planting have higher cost and time demands, as well as higher disturbance impacts on the recipient substrate. Transplants have low genetic diversity.
INFORMATION SOURCES	
References	Churchill, A.C., A.E. Cok, and M.I. Riner. 1978. "*Stabilization of subtidal sediments by the transplantation of the seagrass* Zostera marina*"*. New York Sea Grant Report, NYSSGR-RS-78-15, Albany, New York. Dooley, F., Wyllie-Echeverriab, S., Van Volkenburgha, E. "*Long-term seed storage and viability of Zostera marina"* Aquatic Botany 111 (2013) 130–134. Fonseca, M.S., W.J. Kenworthy, and G.W. Thayer. 1998. "*Guidelines for the conservation and restoration of seagrasses in the United States and adjacent waters*". NOAA Coastal Ocean Program Decision Analysis Series No. 12. NOAA Coastal Ocean Office, Silver Spring, Maryland. Golden, R., et al. "*Large-Scale Zostera marina (eelgrass) Restoration in Chesapeake Bay, Maryland, USA. Part II: A Comparison of Restoration Methods in the Patuxent and Potomac Rivers".* July 2010 Restoration Ecology Vol. 18, No. 4, pp. 501–513. LadyBird Johnson Wildflower Center. Native Plant Database. *Search: Zostera marina.* <http://www.wildflower.org/plants/result.php?id_plant=ZOMA> (accessed 5 May 2014). Marine Biology Resource Network. *Search: Zostera marina*. http://www.marinebio.ca/hd/eelgrass.php. (accessed May 3, 2014). Plants For A Future. *Database Search Results: Zostera marina*. 1 May, 2006. <http://pfaf.org/user/Plant.aspx?LatinName=Zostera+marina> (accessed May 3, 2014). Short, F.T., Carruthers, T.J.R., Waycott, M., Kendrick, G.A., Fourqurean, J.W., Callabine, A., Kenworthy, W.J. & Dennison, W.C. 2010. *Zostera marina*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>.

	(downloaded on 12 May 2014). Short, F.T., R.C. Davis, B.S. Kopp, C.A. Short and D.M. Burdick. 2002. "*Site selection model for optimal restoration of eelgrass, Zostera marina L".* Marine Ecology Progress Series 227: 253-267. http://nre.unh.edu/faculty/short#sthash.0IHuf24t.dpuf Tanner, C., "Parham, T. 2010. "Growing Zostera marina (eelgrass) from Seeds in Land-Based Culture Systems for Use in Restoration Projects". Restoration Ecology. Volume 18, Issue 4, pages 527–537, July 2010. USDA Plants Database. *Search: Zostera marina*. <https://plants.usda.gov/core/profile?symbol=ZOMA> (accessed 28 April 2014)
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