DATE: **April 1, 2008**

TO: **Washington State Noxious Weed Control Board**
Noxious Weed Committee

FROM: **Pacific County Noxious Weed Control Board**
RE: **Addition of *Spartina alterniflora* to State Noxious Weed A List for 2009**

The Pacific County Noxious Weed Control Board requests the addition of smooth cordgrass (*Spartina alterniflora)* to the Washington State Noxious Weed List as a Class A noxious weed.

Common Names: Smooth Cordgrass
Latin Name: *Spartina alterniflora*
Native Range: *S. alterniflora* is native to the US East Coast and Gulf Coast where it is widely distributed.
Escaped/Naturalized: Western Washington's bay and estuaries (Willapa Bay, Grays Harbor, Puget Sound)

Background on the biology and properties of the species

Taxonomy and Distribution of Target Weed:

The taxonomic position of *Spartina alterniflora* is well accepted. It is consistently placed in the tribe Chlorideae in the subfamily Chloridoideae (Gould and Shaw 1983; Dahlgren et al. 1985; Watson and Dallwitz 1992).

<u>Taxonomic position of target weed</u>
Family: Poaceae
Subfamily: Chloridoideae
Supertribe: Chloridae
Tribe: Chlorideae
Genus: Spartina
Species: *S. alterniflora* (Loisel.)

S. alterniflora is native to intertidal salt marshes along the Atlantic Coast of North America from the Gulf of Mexico to Newfoundland (Mobberley 1956; Smart 1982). In these marshes it is often the dominant plant, forming dense and expansive monospecific stands that extend from upper to middle-lower tidal elevations. On the west coast, *S. alterniflora* has been introduced into San Francisco Bay, and nearby California estuaries, and into Willapa and Padilla Bays in Washington. It has been found occasionally in other Northwest estuaries but was eradicated promptly when found. *S. alterniflora* has also invaded and been environmentally detrimental in other areas of the world including Europe (Marchant 1967; Ranwell 1967), China (Chung 1990), and New Zealand (Asher 1990). In San Francisco Bay, a vigorous hybrid of *S. alterniflora* and the native *S. foliosa* is spreading rapidly and displacing *S. foliosa* (Ayres et al. 1999). These hybrids do not suffer from heavy infestations of *P. marginata* (Daehler and Strong 1996).

Taxonomy and Distribution of Related Plants:
The *Spartina* genus includes approximately 14 species worldwide (Mobberly 1956). Six of them, including the target species, are native to the Atlantic and Gulf Coasts of North America where the genus is believed to have arisen (Chapman 1977; Daehler and Strong 1996) (Table 1). Only *S. foliosa* is native to intertidal habitats of the Pacific coast of North America. It occurs in upper tidal elevations in estuaries from central California south to the tip of the Baja Peninsula (Mobberley 1956). This species is the only known host of California populations of *P. marginata*. Two species, *S. gracilus* and *S. pectinata*, occur in the central interior of North America, extending as far west as Eastern Washington and Eastern Oregon.

S. gracilus and *S. pectinata* do not occur west of the Cascade Mountain Range. No *Spartina* species are native to the coasts of Washington, Oregon, or British Columbia.

In addition to *S. alterniflora*, two other non-native *Spartina* spp.—*S. anglica* and *S. patens*---have been introduced into the state of Washington. Both are state listed noxious weeds and are invading Puget Sound, but do not occur in Willapa Bay or other outer coast estuaries. *S. anglica* was introduced from Britain where it arose during the 1800's as a result of hybidization of *S. alterniflora* and *S. maritima* followed by a doubling of chromosomes (Raybould et al. 1991). It has been invasive in numerous locations in Puget Sound. *S. patens* was established in one location near Hood Canal prior to 1968 (Frankel and Kunze 1984). Like *S. alterniflora*, these species are serious weeds of economic and environmental importance and are the targets of a mechanical and chemical control program that costs the state approximately $575,000 per year (Washington State Department of Agriculture 2006). With the exception of the introduced *Spartina*s, there are few chloridoid grasses that grow in the Pacific Northwest Coastal climate. The C-4 metabolism that is characteristic of the group restricts most of the subfamily to hotter and drier regions (Jacobs 1986; Shantz and Piemeisel 1927). Only one other species in the Chloridoideae is found in the Willapa Bay area. *Distichlis spicata* is a common saltmarsh grass that has recently been placed in the same supertribe as *Spartina*, but a different tribe, *Aleuropodeae* (Watson and Dallwitz 1992). Its distribution spans the North American continent. In Willapa Bay, it grows adjacent to *S. alterniflora* in the upper saltmarshes.

Table 1. Distributions and origins of *Spartina* species in North America. Compiled from (Daehler and Strong 1996; Brueggeman et al. 1992).

Species	Habitat	Native to	Introduced to
S. alterniflora	Intertidal	Atlantic/Gulf coasts	Willapa Bay, Padilla Bay, Grays Harbor*, WA; San Francisco Bay, Humbolt Bay, CA
S. anglica (*S. alterniflora* **x** *maritima* hybrid)	Intertidal	Britain	Puget Sound, WA; San Francisco Bay, CA
S. patens	Upper intertidal	Atlantic/Gulf coasts	Suislaw estuary, OR; Hood Canal, WA*
S. densiflora	Upper intertidal	Pacific coast of Southern South America	San Francisco Bay, Humbolt Bay, CA
S. foliosa x *alterniflora* hybrid	Intertidal		San Francisco Bay, CA
S. foliosa	Intertidal	Pacific coast (California to Baja Peninsula)	
S. pectinata	Brackish/terrestrial	Central Interior, Atlantic (not west of Cascade Range)	
S. cynosuroides	Brackish	Atlantic/Gulf coasts	
S. bakeri	Brackish and freshwater lakes	Florida/Georgia	
S. gracilus	Alkaline lakes, stream banks	Central Interior (not west of Cascade Range)	
S. spartinae	Beach, terrestrial	Gulf/Central America	

*populations recently eradicated.

Description and Life History:

S. alterniflora is a rhizomatous perennial grass that resprouts each year from a dense, persistent root mass. It spreads clonally through underground rhizomes and disperses longer distances by way of broken root fragments and floating seeds. The growing season for this plant spans from April to September. *S. alterniflora* often reaches heights of 2 m but this can vary greatly among years and clones. Each fall, the bulk of the above-ground foliage dies back and only the short young shoots remain green but dormant over the winter. The dead leaf tissue (wrack) accumulates in the upper tidal zones. Flowering occurs from August through October. Clones with medium to tall culms and medium to low shoot density are more likely to flower than the short, dense morphs (Sayce 1988). After 1995, there was a dramatic increase in flowering rates which contributed to a rapid population expansion in Willapa Bay.

Seed Bank

Viability of seeds tended to be low in Willapa Bay before 1995; Sayce (1988) reports 0.04% viability, but after 1995 samples showed increased viability (D. Strong, unpublished; Kim Patten, unpublished). Seeds are dispersed from September to November. *Spartina* spp. do ***not*** appear to have long-term seed banks. In the laboratory *S. alterniflora* seeds survive for approximately 8 months (Mooring et al. 1971) and in the field seeds of the closely related *S. anglica* have been found to survive only one growing season (Hill 1984).

Spartina spp. thrive in salty environments. One reason for this is their use of the C-4 photosynthetic pathway. In C-4 plants, the first product of carbon dioxide incorporation is a 4-carbon acid rather than the 3-carbon phosphoglyceric acid produced in the more common C-3 plants. With the C-4 pathway, less water is lost through evapotranspiration than in C-3 plants. *Spartina* spp. also have specialized organs on the leaves that secrete excess salt (Thompson 1991). Invasion by *S. alterniflora* takes on a characteristic pattern. Plants that survive the young seedling stage begin to send out rhizomes to form new shoots. The clone spreads radially outward as a circular patch at a rate of approximately 0.5 m per year (Sayce 1988). The mudflats become dotted with these circular clones of varying sizes (ages) until they eventually merge into a solid meadow.

Impacts of *S. alterniflora*:

State EIS and Federal EA

Washington State's official review of the impacts of the *S. alterniflora* invasion was carried out in 1992 and 1993 pursuant to the State Environmental Protection Act (SEPA). All of the state's natural resource agencies took part in that review. The Final Environmental Impact Statement (EIS) was issued in November 1993 by the following Co-leading Agencies: the Washington State Department of Ecology, the Washington State Department of Natural Resources, the Washington State Department of Agriculture, the Washington State Noxious Weed Control Board, the Washington State Parks Department, and the Washington State Department of Fish and Wildlife. The EIS concluded that invasive *Spartina* spp. would have significant deleterious impacts on the environment and economy of Washington and should be controlled. "Integrated weed management" (IWM) was identified as the preferred response. A parallel federal environmental review process conducted by U.S. Fish and Wildlife Service reached a similar conclusion. Completed in 1997, the Federal Environmental Assessment (EA) also adopted an "integrated pest management" strategy. The distribution, biology, and ecology of introduced *Spartina* species, their impacts on the environment and economy, and the impacts of various control methods have been reviewed in great detail in the EA and EIS. In the 1992 EIS, authors state that "*Spartina* is well known for its aggressive abilities as a colonizer and the absence of natural biological controls has contributed to its rapid spread in Washington."

As sediment is trapped in dense *S. alterniflora* clones, expanses of flat open intertidal mud are transformed into emergent monotypic marshes (Sayce 1988). Rigorous analysis of the impacts of *S. alterniflora* on the benthic invertebrate assemblages that form the basis of the food web revealed a marked alteration in diversity as “terrestrially associated” invertebates replaced the native assemblage associated with tidal mudflats (Zipperer 1996). Other studies showed that *S. alterniflora* invades and aggressively displaces the native shoreline plant species and the eelgrass and algal communities. Additional concerns have not been well studied, but are widely regarded as plausible. Among the possible long-term effects are those resulting from sediment trapping, and fundamental changes in the benthic profile. Such fundamental alteration of the hydrology of the watershed could lead to increased winter flooding, already a costly and chronic problem for lowland coastal communities. Another fear concerns the likely increase in summer mosquito populations as *Spartina* marshes spread. Increasingly dependent on tourism, Washington coastal areas are presently free of nuisance levels of biting insects.

Washington’s open mudflats are important wintering and fueling areas of the Pacific Flyway for migratory shorebirds and waterfowl. In addition, the state’s estuaries are “critical habitat” for salmon populations making their transition from freshwater to saltwater and their return to freshwater spawning grounds. Besides the multitude of ecological values, Washington’s threatened estuaries are home to economically important commercial marine enterprises. The present day aquaculture industry is one of the leading private sector employers and contributes an estimated $20 million per year to the local economy.

State Statute Announced Eradication as Policy

The Washington Legislature in 1995 declared that the *Spartina* infestation had become an environmental emergency, and directed all state agencies to assign a high priority to the eradication program. (RCW 17.26.006).The Legislature also specifically exempted *Spartina* control activities from review under the State’s Shoreline Management Act, making it clear that the threat was exceptional and control activities should not be hampered by time consuming regulatory procedures.

Location and infestation information – where, when, and how much

Willapa Bay

WSDA Estimates for 2009

In his testimony before to the State Weed Board in November 2007, WSDA Pest Program Manager Brad White stated that somewhat over 2,250 net acres of Spartina were treated during the 2007 treatment season. Further he described the 2007 season as the first season in which all live spartina in Willapa was fully treated. Mr White reported that WSDA had decided to use an overall baywide efficacy prediction of 50% to develop their estimation for re-growth in 2008. The following table shows the results if a 50% reduction/efficacy rate is used again to predict the acreage regrowing in 2009.

WSDA Predictions for Baywide Regrowth	
2007 Actual Net Acreage Treated	**2254 ac**
*2008 predicted***	1150 ac
*2009 predicted***	575 ac

** predictions based on 50% reduction rate used by WSDA

In its reports to the Legislature, WSDA has presented tables with efficacy rates quantifying the site-by-site reductions in net acres. Those tables showed reduction rates from a low of 58% to a high of 99%.

US Fish and Wildlife Service Estimates for 2009

During the 2007 season, the US Fish and Wildlife Service’s Willapa National Wildlife Refuge was assigned responsibility for treating Spartina in an area that encompassed slightly more than 80% of the geographic scope of the peak infestation. Much of that ground is now free of Spartina or only lightly infested. Nevertheless, the whole area must be revisited each year to pick up on any re-growth or re-infestation with seedlings produced elsewhere in the Bay. At the end of 2007, Refuge staff developed re-growth predictions for 2008 based on empirical observations of treated acreage in each area of their operation. The following is a table of US Fish and Wildlife Service re-growth predictions, based on what the Service describes as the “minimum” expected reduction rate of roughly 66%. Applying this conservative reduction rate to each area again, the Refuge would predict 168 net acres left in 2009 *within areas treated by the Refuge*.

Predictions for Regrowth in USFWS Treatment Sites					
Regrowth	Township 10/11	Township 12	Township 13	Township 14	Total
2007 actual	**464 ac**	**235 ac**	**251 ac**	**562 ac**	**1512 ac**
*2008 predicted**	154 ac	94 ac	100 ac	148 ac	496 ac
*2009 predicted**	52 ac	32 ac	34 ac	50 ac	168 ac

* predictions based on 66% reduction rate used by USFWS

Net acres left on the 20% of Willapa Bay assigned to State agencies are not included in the Refuge's predictions shown above. The State agencies reported treating a total of 742 net acres by the end of 2007 and also indicated that they expected differing overall efficacy rates. In the table below, the respective state reduction predictions are applied to the relevant state-assigned areas to generate predictions for 2008 and for 2009. The Refuge predictions are added to the State predictions to generate baywide predictions for 2008 and for 2009.

Baywide Predictions of Regrowth Using Each Agency's Efficacy Predictions						
Regrowth	WSDA area **	DNR area **	WDFW Area ***	Total state Areas	USFWS areas*	Total Baywide
2007 actual	**202 ac**	**100 ac**	**448 ac**	**742 ac**	**1512 ac**	**2254 acs**
2008 predicted	101 ac	50 ac	170 ac	321 ac	496 ac*	817 ac
2009 predicted	50 ac	25 ac	64 ac	139 ac	168 ac*	353 ac

* predictions based on 66% reduction rate used by USFWS
** predictions based on 50% reduction rate used by WSDA
*** predictions based on 62% reduction rate used by WDFW

WSU Regrowth Predictions
Since the beginning of the eradication efforts in 1995, Washington State University researchers have been monitoring the efficacy of various treatments. Mapping services provided by the UW Olympic Natural Resources Center have formed the basis for evaluating the scale of the infestation baywide and tracking reductions. Dr. Kim Patten projected re-growth based on his visual evaluation of treatment sites in each township throughout the Bay at the end of the 2007 season. The following table presents his prediction of the acreage that will re-grow in 2008 and 2009.

WSU Predictions for Regrowth Baywide**						
Regrowth	USFWS Township 10/11	USFWS Township 12	USFWS Township 13	USFWS Township 14	State assigned areas	Total Baywide Regrowth
2007 actual	**464 ac**	**235 ac**	**251 ac**	**562 ac**	**742 ac**	**2254 ac**
2008 predicted	10 ac	40 ac	25 ac	116 ac	325 ac	516 ac
2009 predicted	2 ac	8 ac	5 ac	23 ac	143 ac	181 ac

**** Reduction rates based on visual inspections.

The three analyses are displayed below for the purpose of comparison of predictions for 2008 and 2009 and what the remaining acreage represents as a percentage of the peak infestation of 8,000 net acres.

Totals Baywide For Willapa Bay	WSDA Prediction	Each agency predicts regrowth on its assigned area	WSU Prediction	Range of predictions **% of peak infestation remaining** (8,000 net acres)	Range of predictions **% of peak infestation eliminated to date**
2008 prediction for this season	1150 ac	817 ac	516 ac	High estimate of 14% to low estimate of 6%	Low estimate of 86% to high estimate of 94%
2009 prediction when Class A would go into effect	575 ac	353 ac	181 ac	High estimate of 7% to low estimate of 2%	Low estimate of 93% to high estimate of 98%

Grays Harbor

WSDA estimates that in Grays Harbor and the Copalis River, there were less than 2 net acres of alterniflora remaining in total and all were treated in 2007. (Personal Communication from Chad Phillips 3/6/08)

Puget Sound

WSDA estimates that in Puget Sound the following small amounts of S. alterniflora remained to treat: in Skagit County/Padilla Bay, 30 sq meters or .0075 net acres; and in Jefferson County approximately 5 sq meters or .00126 net acres. All were treated in 2007. (Personal Communication from Chad Phillips 3/6/08)

Control Methods:

The Legislature mandated using an Integrated Pest Management (IPM) approach to Spartina eradication. This was defined by state agencies as a "coordinated decision-making and action process that uses the most appropriate pest control methods and strategy in an environmentally and economically sound manner to meet pest management objectives." While a range of tools have been evaluated, not all were practical to use on an infestation of the scale of the Spartina infestation in Willapa Bay. Over the past 5 years, the dramatic reduction in net infested acres has been accomplished through the use of ground and aerial herbicide applications of imazapyr. Biological control using the insect *Prokelisia marginata* was pursued since 2000, but to date showed very limited or no impacts on the Spartina. State agencies have continued to apply mechanical treatments to mudflats in the winter when no other operations are feasible. These applications have not been demonstrated to be effective. Several landowners who are opposed to the use of chemicals have conducted repeated mowing in order to prevent seed viability. This control application was required by the Pacific County Weed Board for compliance with Class B designation during 2007. Repeated mowing is not viewed as an eradication strategy, but rather only a means to prevent the production and dissemination of viable seeds. Rototilling or dredging is considered a practical but relatively expensive eradication approach which may be used in small areas. Crews and private citizens also may conduct manual seedling pulls to remove shallow-rooted seedlings in areas where an infestation has not yet taken hold.

Specific change requested

The Pacific County Noxious Weed Control Board requests that the State Weed Board add *S. alterniflora* to the Washington State Class A Weed List for 2009.

Reasons for the request

With a conservative estimate of 95% of the S. alterniflora eliminated, we have clearly reached the final phase of the eradication program. All live plants can and must be treated with the intent to eradicate. Listing this plant as a Class A noxious weed would impose a clear mandate on all land owners to kill *S. alterniflora* rather than merely control seed and vegetative spread. If limited to Class B designation, the County Weed Board has no authority to prevent landowners from harboring infestations on their property. Since 1994, roughly $25 million dollars have been spent by federal, state and local agencies in the effort to eradicate *S. alterniflora.* Enormous progress has been made eliminating *S. alterniflora* from thousands of acres of mudflats that serve as critical habitat for wildlife. This progress can be lost in a very short time, if the eradication program is not completed. Even small amounts of live *S. alterniflora* plants harbored by recalcitrant landowners will pose a serious, unnecessary and permanent risk of re-infestation to areas in which it has been eliminated through costly and difficult work.

Class B designation offers to no means to bring the eradication program to a successful completion. One resistant landowner can block completion of a program supported by the vast majority of citizens, deemed vital by the experts to protection of our natural resources, and nearing completion at a cost of tens of millions of dollars and decades of labor. Class A designation was created to address this situation.

Feasibility of Eradication

No Long-term Seed Bank

Studies have demonstrated that the spartina species do not develop long-term seed banks. The vast majority of spartina seeds are not viable past the first year. Studies have also demonstrated that pollination is not prevalent in widely dispersed plants. In 2007, viability studies conducted by Dr. Kim Patten of WSU showed that in all but one area of the Bay (on the north end of the Long Beach Peninsula), there was a low rate of seed viability.

Inexpensive Eradication Tool

The most effective tool in eradicating spartina--the herbicide imazapyr, is the least expensive approach.

Political Support for Eradication

In the area of heaviest infestation--Willapa Bay, the support for the eradication effort continues to be extremely strong. Landowners are encouraged by the progress they have seen throughout Willapa Bay. Only 1 landowner with infested tidelands remains opposed to eradication based on her opposition to the use of all herbicides. Because the net acreage on that property is small, mechanical removal is practical. However, an eradication approach will only be pursued by that landowner if it is legally mandated.

Sufficient Funding for Complete Treatment of All S. alterniflora

Sufficient funding has been provided for the past 5 years to allow complete treatment of all S. alterniflora plants. In 2008, the Washington Legislature appropriated an additional $100,000 for the Pacific County Noxious Weed Control Board to undertake eradication activities. The vision for the next 4 years calls for stable state funding levels increasingly shifted to local leadership to complete the Legislature’s mandate to eradicate all Spartina. With the dramatic reduction in the net acreage of S. alterniflora in Willapa Bay, the total statewide infestation in 2009 will be less than 600 acres. In most areas, there are only scattered outliers left. No large meadows or large clone fields exist. Mop up operations in 2009 will involve searching and treating small patches over thousands of acres and miles of tidal sloughes. This can be accomplished faster and with less funding than large-scale treatments required.

The commitment to finishing the job by the Governor’s office, the Legislature, and the Congressional delegation is strong. Even with reductions in the federal funding, state funding is expected to remain sufficient to accomplish the final elimination of S. alterniflora. County officials should not be limited to seed and vegetative control through a Class B designation. All S. alterniflora must be treated to kill, not merely suppress expansion.

Eradication programs often require years of mop-up, followed by years of careful and methodical scouting to search for hard to find outliers. Pacific County plans to continue thorough scouting and mop-up operations until 5 consecutive years of careful searching reveal no remaining plants. The hydrilla eradication program is example of a multi-year eradication effort. It began in 1995 and was believed to be successful in 2007, when no hydrilla plants were detected in either lake. Follow-up treatment continues and surveying is planned through 2012.

Bibliography

Asher, R. 1990. *Spartina* introduction in New Zealand. Pp. 23-24 in T.F. Mumford, P. Peyton, J.R. Sayce and S. Harbell (eds.) Spartina Workshop Record. Washington Sea Grant Program, University of Washington.

Ayres, D.R., D. Garcia-Rossi, H.G. Davis, and D.R. Strong. 1999. Extent and degree of hybridization between exotic (Spartina alterniflora) and native (S. foliosa) cordgrass (Poaceae) in California, USA determined by random amplified polymorphic DNA (RAPDs). Molecular Ecology 8: 1179-1186.

Brueggeman, J., M. Harenda, and S. Sundberg. 1992. Element A—Spartina: distribution, biology, and ecology. Final report submitted to Washington State Department of Ecology. Ebasco Environmental.

Chung, C.H. 1990. Twenty-five years of introduced Spartina anglica in China. Pp. 72-76 in A.J. Gray and P.E.M. Benham (eds.) *Spartina anglica*---A Research Review. Institure of Terrestrial Ecology, Natural Environment Research Council.

Daehler, C.C. and D.R. Strong. 1996. Status, prediction and prevention of introduced cordgrass Spartina spp. invasions in Pacific estuaries, USA. Biological Conservation 78: 51-58.

Dahlgren, R.M.T., H.T. Clifford, and P.F. Yeo. 1985. The Families of the Monocotyledons. Springer-Verlag, New York.

Frenkle, R.E. and L. M. Kunze. 1984. Introduction and spread of three *Spartina* species in the Pacific Northwest. Association of American Geographers 4: 22-25.

Gould, F.W., and R.B. Shaw. 1983. Grass Systematics. Texas A and M University Press.

Hill, M.I. 1984. Population studies on the Dee Estuary. Pp. 53-58 in P. Doody (ed.) Spartina anglica in Great Britain. Nature Conservancy Council.

Hitchcock, C. L. and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle.

Jacobs, S. W. L. 1986. Systematics of the Chloridoid Grasses. Pp. 277-286 in Soderstrom, T.R., K. W. Hilu, C.S. Cambell, and M. E. Barkworth (eds.) Grass Systematics and Evolution: an international symposium held at the Smithsonian Institution, Washington, D.C. July 27-31, 1986. Smithsonian Institution Press, Washington, D.C.

Marchant, C.J. 1967. Evolution in Spartina (Graminae) I. The history and morphology of the genus in Britain. Botanical Journal of the Linnean Society 60: 1-24.

Mobberley, D. J. 1956. Taxonomy and distribution of the genus Spartina. Iowa State Colleg J. Sci. 30: 471-574.

Mooring, M.T., A.W. Cooper and E.D. Seneca. 1971. Seed germination response and evidence of height ecophenes in *Spartina alterniflora* from North Carolina. American Journal of Botany 58: 48-55.

Phillips, Chad. 2008. Personal email with estimates of remaining net acres of Spartina alterniflora in Washington State. (3/6/2008 11:31am)

Ranwell, D.S. 1967. World resources of *Spartina townsendii* (sensu lato) and economic use of Spartina marshland. Journal of Applied Ecology 4: 239-256.

Raybould, A.F., A..J. Gray, M.J. Lawrence, and D.F. Marshall. 1991. The evolution of *Spartina anglica* C.E. Hubbard (Gramineae): the origin and genetic variability. Biological Journal of the Linnean Society 43: 111-126.

Sayce, K. 1988. Introduced cordgrass, Spartina alterniflora Loisel., in salt marshes and tidelands of Willapa Bay, Washington. Willapa National Wildlife Refuge Report, Ilwaca, Washington.

Schantz and Piemeisel. 1927. The water requirements of plants at Akron, Colorado. Journal of Agricultural Research 34: 1093-1190.

Smart, M. R. 1982. Contributions to the ecology of halophytes. Journal for Vegetation Science. Volume 2. Dr. W. Junk Publishers, Boston/London.

Thompson, J.D. 1991. The biology of an invasive plant: What makes *Spartina anglica* so successful? Bioscience 41: 393-401.

United States Fish and Wildlife Department. 1997. Control of smooth cordgrass (*Spartina alterniflora*) on Willapa National Wildlife Refuge, Environmental Assessment. Willapa National Wildlife Refuge, Ilwaco, Washington.

Watson, L. and M.J. Dallwitz. 1992. Grass Genera of the World. CAB International, Wallingford, UK.

Zipperer, V. 1996. Ecological effects of the introduced cordgrass, Spartina alterniflora, on the benthic community structure of Willapa Bay, Washington. MS Thesis, University of Washington, Seattle.