SPARTINA WORKSHOP REC…

SEATTLE, WASHINGTON · NOVEMBER 14-15, 1990

EDITORS · THOMAS F. MUMFORD, JR., PATRICIA PEYTON, JAMES R. SAYCE, AND STEVE HARBELL

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Editors
Thomas F. Mumford, Jr., Patricia Peyton, James R. Sayce, and Steve Harbell

Workshop Sponsors
Pacific County Department of Planning
Washington Department of Natural Resources, Division of Aquatic Lands
Washington Sea Grant Program

Washington Sea Grant Program
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Cover photo: Lawrence Way, British scientist, examining seed heads of *Spartina anglica* at Juniper Beach, Camano Island, Washington. (Photo: T. Mumford, Jr.)

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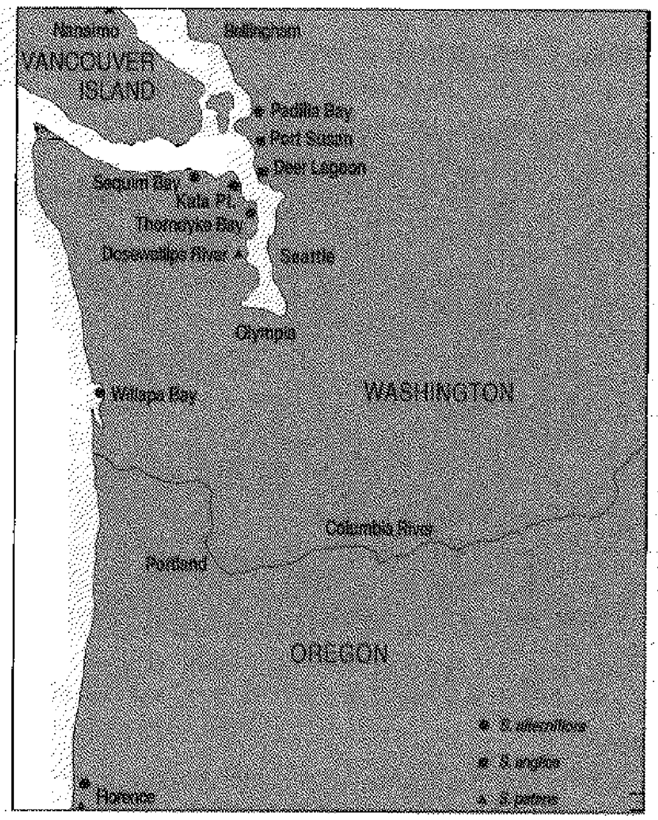
About the Spartina *Workshop*

Intertidal areas of Washington, Oregon, California, and British Columbia are currently being invaded by three exotic species of cordgrass: *Spartina alterniflora, S. patens,* and *S. anglica*. These plants form dense, monotypic stands that colonize bare tideflats and displace low intertidal salt marsh. If left uncontrolled, these areas will ultimately consist of broad marsh flats cut by narrow, deep channels. The result is massive habitat alteration, with ramifications for wildlife, fisheries, geology, native vegetation, and hydrology.

In Washington, *Spartina* is present in Willapa Bay and Puget Sound. The invasion is most advanced in Willapa Bay, where *S. alterniflora* was introduced in 1894 and now covers more than 2,000 acres. It is predicted to cover about 30,000 acres of the bay—most of the intertidal zone—by the year 2030.



Distribution of three species of Spartina *in British Columbia, Washington, and Oregon as of December 1989.*

Spartina was viewed as a threat in Willapa as early as 1942. Barbara Aberle in 1979 recommended to the Washington Department of Game that *S. anglica* be eradicated in the Port Susan area. Concern has been strongest in the Willapa Bay area, where U.S. Fish and Wildlife officials are concerned about loss of habitat on the Willapa Wildlife Refuge, and county officials and the oyster industry view the incursion as a threat to the local economy as well as to the environment.

In 1988 Jim Sayce, Pacific County planner, formed a working group consisting of representatives from resource agencies, tribes, environmental groups, and industry. The group, which meets every two months, has recommended research, control programs, and processes to carry them out.

In early 1990, Barbara Aberle was hired by the Department of Natural Resources to perform a literature search and talk with researchers around the world about *Spartina* biology, ecology, and control and eradication programs. Her report, still in the draft stage, has been widely circulated for review. She made many contacts and suggested speakers for this workshop.

In late 1989 I began talking with Jim Sayce and Steve Harbell, Washington Sea Grant marine field agent, about logical steps for dealing with *Spartina*. We concluded that *Spartina* was a regional problem that could benefit from the experience of other countries. For that reason, Jim, Steve, and I sought and received funding from the Sea Grant Program to support a workshop under its special legislative budget appropriation for shellfish studies. We also received organizational help and support from Patricia Peyton, Washington Sea Grant communications manager, who became the fourth member of our workshop team.

The workshop, held November 14-15, 1990, in Seattle, featured an international array of *Spartina* experts who provided participants with information on the biology and ecology of cordgrass, its distribution and impacts, and control and eradication methods and programs. Abstracts of their presentations are included in this report.

At the close of the workshop, the assembly divided into smaller groups whose participants were asked to discuss and recommend, on both a local and a regional level, areas of research related to *Spartina* and *Spartina* control, approaches for dealing with *Spartina* invasions in western coastal states, and processes to implement proposals. The discussions and recommendations are presented elsewhere in the record, under "Regional Strategies." Their general conclusions are as follows:

- Top priority should be given to preventing the spread of *Spartina* to uninfested areas.
- A task force (for British Columbia, Washington, Oregon, and California) is needed to address the problem of *Spartina* invasions on the West Coast.
- Within Washington state, a position should be created to coordinate *Spartina* issues.
- An immediate inventory of *Spartina* infestation in Washington is critical.

Thomas F. Mumford, Jr.

Spartina *Working Group*

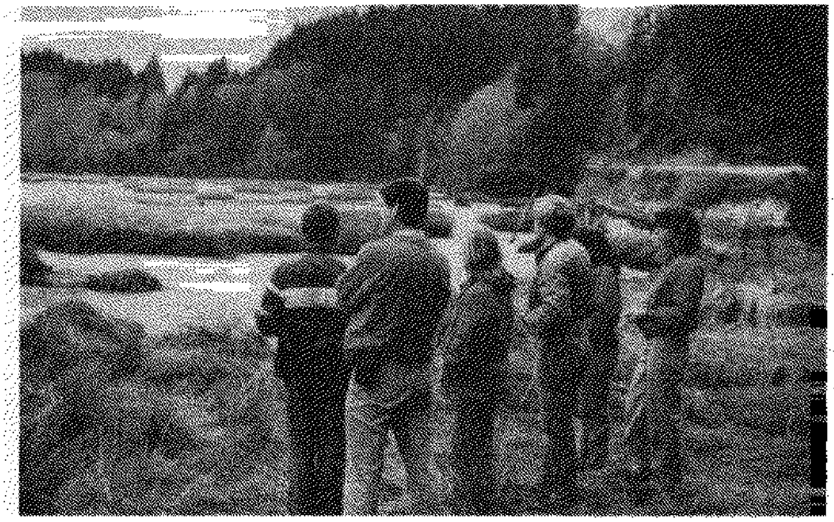
Barbara Aberle, Washington Department of Ecology
Ken Brunner, U.S. Army Corps of Engineers
Douglas A. Bulthuis, Washington Department of Ecology
Daniel P. Cheney, Willapa Aquaculture Council
Gary Dade, Pacific County Vegetation Management
Helen Engle, Tacoma, Washington
Janice Friebaum, Washington Department of Natural Resources
Steve Harbell, Washington Sea Grant/WSG Cooperative Extension
Jim Hidy, Willapa National Wildlife Refuge, U.S. Fish & Wildlife Service
Rick Johnson, Thurston County Noxious Weed Board
Fayette F. Krause, The Nature Conservancy, Washington
Michael McHenry, Northwest Indian Fisheries Commission
John Marshall, Washington Department of Ecology
David Minter, The Nature Conservancy, Oregon
Thomas F. Mumford, Jr., Washington Department of Natural Resources
Tom Northup, Washington Department of Fisheries
Ted Pankoski, Washington Environmental Council
John Pitts, Washington Department of Agriculture
Joanne Reynolds, Skagit County Weed Coordinator
Neil Rickard, Washington Department of Fisheries
James R. Sayce, Pacific County Planning Department
Dennis Tufts, Washington Department of Fisheries
Bob Zeigler, Washington Department of Wildlife

About the Speakers

Barbara Aberle, who is currently employed in the Wetlands Section of the Washington Department of Ecology's Shorelands Program, is pursuing a master's degree in environmental studies at The Evergreen State College. Her thesis is a study of the spread of *Spartina alterniflora* in Willapa Bay and is an outgrowth of a literature review she conducted for the Aquatic Lands and Natural Heritage Program at the Washington Department of Natural Resources in 1989. She holds a B.S. degree in ecosystems analysis from Huxley College of Environmental Studies, Bellingham, Washington

Rod Asher has worked at Cawthron Institute, Nelson, New Zealand, for fifteen years in microbial biochemistry, ecology of marine sediments, and more recently on environmental impact and monitoring contracts in marine, estuarine, and freshwater systems, e.g., *Spartina* eradication, fish and invertebrate surveys. His work-related interests include electric fishing, scientific photography, and SCUBA diving.

Brian Boyle, Commissioner of Public Lands, is serving his third term as the constitutional officer heading the Washington State Department of Natural Resources. Since election in 1980, Boyle has emphasized the department's role as "natural resource steward" and has worked to balance the income needs of Washington's public schools, universities, counties, and other trust recipients with the raw material needs of the state's resource-based industries and with the overriding need to protect its natural resources for future generations. As manager of more than five million acres of forest, agricultural and aquatic trust lands, his accomplishments include: stabilizing public timber supplies, diversifying trust income, forming the Old Growth Commission on Alternatives for Washington's Forest Trust Lands, negotiating the landmark Timber-Fish-Wildlife Agreement, establishing Natural Resource Conservation Areas, transferring more than 8,000 acres to state parks, and creating the Aquatic Lands Enhancement Account. As State Land Commissioner, Boyle chairs Washington's Board of Natural Resources, Harbor Line Commission, and Forest Practices Board. He holds a degree in metallurgical engineering from the Montana School of Mines and an MBA from the University of Chicago.



Spartina alternifolia, *Willapa National Wildlife Refuge.* Left to right: *Rod Asher, Keith Crothers, Kathleen Sayce, Jim Sayce, Barb Aberle, Janice Friebaum. (Photo: T. Mumford, Jr.)*

John Callaway recently completed his M.A. in biology at San Francisco State University. At that institution he studied the spread of *Spartina alterniflora* in San Francisco Bay and evaluated some of the possible impacts of *S. alterniflora* as an introduced species. He holds a double B.A. degree in marine biology and Slavic languages and literature from the University of California, Berkeley. At present, he is working on his Ph.D. in wetland ecology at Louisiana State University.

Daniel E. Campbell received his Ph.D. from the University of Florida in 1984 under the supervision of H. T. Odum. During his years at the university he studied native salt marshes on the Gulf coast of Florida and invading *Spartina* marsh in the Marlborough Sounds region of New Zealand. In 1984, he became a postdoctoral fellow at the University of Maine, working at the Maine Department of Marine Resources in Boothbay Harbor. There he was exposed to New England salt marshes, and on several trips in the Canadian Maritimes he observed the fantastic scale of marsh physiography in the macrotidal region of the Bay of Fundy. At present he is at the University of Rhode Island Graduate School of Oceanography in Narragansett.

Campbell's co-authors are **H. T. Odum,** a professor in the Department of Environmental Engineering Sciences, University of Florida, Gainesville, and **G. A. Knox,** a faculty member of the University of Canterbury, Christchurch, New Zealand.

Ron P. Crockett is a product development associate for Monsanto Agricultural Company. His duties include aquatic, forestry, and other non-crop related field research and development in Washington, Oregon, and California. He joined Monsanto in 1979 after completing a Ph.D. at the University of Minnesota. His current work on *Spartina* includes research on timing and methods of applications, herbicide rates, and a systems approach using Rodeo® herbicide, a commercial formulation of the isopropylamine salt of glyphosate.

Keith J. Crothers was appointed senior noxious plants officer by the Southland (NZ) District Council in late 1980 and was elected *Spartina* coordinator in 1989. At present he is on contract to the Regional Council. In 1985, he won the Du Pont Award for New Zealand Noxious Plants Officers recognizing his work to initiate an exchange program with professional counterparts in Australia. Currently, he serves as vice president of the New Zealand Institute of Noxious Plants Officers, Inc.

Robert E. Frenkel received a Ph.D. in geography from the University of California, Berkeley, in 1967 and has been with the geography department at Oregon State University since 1965. He regularly teaches undergraduate and graduate courses in biogeography, natural resource conservation, and wetlands ecology. Together with graduate students he has been conducting research on Pacific Northwest wetlands since the early 1970s, with projects ranging from salt marshes to subalpine mires. In connection with management activities for The Nature Conservancy, Dr. Frenkel studied the introduction of *Spartina patens* on Cox Island, a Nature Conservancy preserve in Siuslaw Estuary. His current research is on restoration of the Salmon River salt marshes.

Janice Friebaum is a conservation biologist with the Washington Department of Natural Resources' Natural Area Preserve Program. Since February, 1990, she has taken the lead in planning and implementing a joint project with the Willapa National Wildlife Refuge to test two control methods for *Spartina alterniflora* in Willapa Bay. She will use the information resulting from the study to develop a control/eradication program for two preserves in the Willapa Bay area. Her academic background includes earning a bachelor's degree in environmental studies from Eisenhower College, New York, and a master's degree in plant ecology from the University of Tennessee.

Mary Landin is a research biologist with the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Dr. Landin has thirty-one years' experience in private industry, with the USDA Agricultural Research Service, and with the U.S. Army Corps of Engineers. She received her Ph.D. in biological sciences at Mississippi State University. Dr. Landin has worked in wetlands (including salt marshes) restoration/establishment and habitat development for the past sixteen years, and is manager of the Corps's Wetland Research Program restoration and establishment task throughout the nation. Her other work involves endangered species, reclamation of disturbed soils, beneficial uses of dredged material, and island habitat creation/management. She has authored or co-authored more than two hundred technical reports, manuals, papers, and other documents, including guidelines for wetland restoration/creation for mitigation. She is a member of the National Research Council's Task Committee on the role of technology and engineering in coastal habitats protection and enhancement.

Terence M. McNabb is the owner of Aquatics Unlimited, an aquatic plant management firm based in Kent, Washington, that provides chemical, mechanical, cultural, and biological control services for nuisance aquatic weed problems. In addition, he is a principal in EnviroScan, Inc., an environmental remote sensing firm based in Kent. EnviroScan has developed a video image collection and processing system that is used extensively for delineation, false coloring, and mapping of aquatic and wetland plant communities. McNabb has a B.S. degree from Michigan State University in water resource management and has completed the course in jurisdictional delineation of wetlands conducted by the National Wetland Sciences Training Cooperative. He is a past president of the Western Aquatic Plant Management Society and is currently on the board of directors of the Washington Weed Association and Aquatic Plant Management Society.

Thomas F. Mumford, Jr., received his Ph.D. from the University of Washington in 1973 in marine botany. He spent three years as a postdoctoral fellow at the University of British Columbia continuing his research in the taxonomy and ecology of seaweeds. In 1976, he joined the Washington Department of Natural Resources heading a program for seaweed aquaculture development. He has been with DNR since then, involved in seaweed aquaculture, marine plant management, nearshore habitat inventory, and GIS development for state-owned aquatic lands.

James R. Sayce, senior planner for Pacific County, has helped chart *Spartina* growth in Willapa Bay and has spearheaded the county's efforts to stem the spread of cordgrass into recreational and commercial clam and oyster beds surrounding the bay. Unlike *Spartina*, Sayce is a native of the area and a 1977 graduate of The Evergreen State College, Olympia. In 1983, he received a master's degree in biological sciences from the University of California, Irvine, where his research focused on the reproductive ecology of the western gull and the relationship between seabird reproductive success and standing stocks of the northern anchovy.

Kathleen Sayce, botanist, lives on Willapa Bay in Pacific County, Washington. Her academic credentials include a B.S in biology from Fairhaven College at Western Washington University, Bellingham (1975), an M.S. in botany from Washington State University, Pullman (1978), and graduate study in botany at Arizona State University, Tempe (1979-1980). Current research projects on Willapa Bay: floral species list for the lowlands of the estuary, and the ecology of several "weed" species, including *Spartina*.

Donald R. Strong received his Ph.D. from the University of Oregon in 1971 with a specialty in aquatic ecology and population biology. Since 1974 he has been in the Department of Biological Science at Florida State University, Tallahassee, where he is now a professor. His research focuses upon the insect herbivores of *Spartina alterniflora*, their effects upon the plant, and their natural enemies. He has had an interest in the ecology of introduced *Spartina* species on the west coast of North America for several years and is investigating the possibilities for biological control of this plant.

Lawrence Way is a government scientist at the Nature Conservancy Council which has responsibilities for the implementation of nature conservation in Great Britain. He studied for a degree in biology at Bristol University, with further studies in museum science at Leicester University. His first work at Bristol Museum involved the provision of a county ecological information service. Subsequent employment by the NCC led to a study in 1987 of U.K. *Spartina* control in the context of an estuarine barrage development proposal. More recent work has involved conservation issues associated with developments on estuaries and participation in a review of the conservation of British estuaries. He is currently responsible for the computer management of ornithological census data which are used in international site designation within Great Britain, wilder countryside and site casework issues.

Policy Considerations

Spartina and Washington State

Brian J. Boyle, Commissioner of Public Lands, State of Washington

Spartina alterniflora, *Long Island Slough, Willapa Bay, July 1990. (Photo: T. Mumford, Jr.)*

The people at this workshop have embarked on a project that is important both to Pacific County and to the state of Washington. I will explain our department's interest and outline some of the political aspects involved in solving the *Spartina* problem.

The Department of Natural Resources is the steward of the state lands, including the two million acres of land ordinarily under water. We take stewardship seriously. To us it means not only managing resources to generate revenue for the state, but also maintaining and improving those resources for both present and future generations. We believe the best way to do this is to concentrate our efforts first on maintaining or restoring native ecological systems, and then on harvesting these systems in a sustainable way.

Thus we plant and harvest so as to retain forest lands that function ecologically as much as possible like the native forests of the Northwest. The products of these forests are not only wood but also wildlife, fish, pure water, and recreation. We also manage our submerged lands to try to retain the aquatic heritage of Washington.

The *Spartina* invasion is a serious barrier to that goal. It threatens to change the tideflat environment that constitutes the primary habitat for oysters, hardshell crabs, and many fish species and that provides the nursery grounds for valuable fisheries. *Spartina* has already affected the oyster fisheries in Willapa Bay, from which half of Washington's oysters come, and has interfered with recreational use of beaches and waterfronts. It has the potential of causing further dramatic changes in the marine ecosystems of Puget Sound.

It is significant, in this regard, to recall one view of how *Spartina* got to Washington's waters in the first place. By the 1890s the native oyster population of Willapa Bay had become so depleted that oyster growers imported oysters from the East Coast. *Spartina* was in the packing material for those oysters. It is yet another example of how unsustainable use of natural resources may produce unpredictable effects. That is part of what our aquatic stewardship programs are designed to prevent.

The Department of Natural Resources has actively studied the *Spartina* issue for some time. Now it is time to act, and that is why the department, along with Pacific County and Washington Sea Grant, has sponsored this workshop.

Such broad-based sponsorship is significant. It is strongly reminiscent of the way DNR has begun to carry out one of its primary functions, the prevention and suppression of forest fire. For the past several years we have been sponsoring workshops and cooperative arrangements that link federal, state, and local efforts. We encourage this for two reasons. The first is obvious: coordination conserves scarce resources and enables different units of government to work together smoothly during an emergency.

The second reason is more subtle but no less vital to success. Stewardship is ultimately a political process. It means making public choices about how we use our natural resources: where we invest, what we use, what we preserve.

What I do mean is that eradicating *Spartina* will probably require some significant intrusions into our coastal ecosystem, using chemical, physical, or biological means. During this workshop, you will hear advice from some of the world's leading technical experts on those means. This advice is invaluable, but I would remind you that an effective control program is not entirely a technical issue. People, perhaps many people, will have to do some things and refrain from doing others. The control program may have effects on county and state budgets. All these inevitably involve politics.

Politics has been called the art of the possible. I hope it will be found possible to control *Spartina*, but I would urge you, as you proceed in your discussions of the science, to keep that art in mind.

Natural Area Preserves and Spartina

Janice Friebaum, Washington Department of Natural Resources

Public funds have provided an indispensable tool for acquiring and setting aside natural area preserves (NAPs) in Washington. State law (RCW 79.70) defines these areas as

> lands and water dedicated for preservation and protection in their natural condition . . . valuable for the purposes of scientific research, teaching, as habitats of rare and vanishing species, as places of historic and natural interest and scenic beauty, and as living museums of the original heritage of the state.

In the Willapa Bay area, the Niawiakum River has been designated and the Bone River proposed for inclusion in the state's NAP system. These two intact estuaries were selected because of their relatively undisturbed conditions; they include many types of intertidal salt marsh identified in the Washington Natural Heritage Plan as significant ecological elements in need of priority acquisition and protection.

The presence and spread of *S. alterniflora* on both these preserves poses a serious management problem. Cordgrass, if left unchecked, may alter key ecological processes as well as the structure and composition of existing estuarine communities. Possible scenarios include sediment buildup, altered hydrologic regimes and flow patterns, and displacement of native saltmarsh species.

If these preserves are to be maintained in their natural condition to represent the original heritage of the state (as state law directs), then a highly invasive, exotic plant such as cordgrass, with its system-altering potential, must be controlled, if not eradicated. At present, *Spartina* is probably of manageable size on these two preserves. Therefore, to protect the public's investment in them, the eradication of cordgrass must be a management priority.

Biology and Ecology

Identifying the *Spartina* Species

Kathleen Sayce, Shoalwater Botanical, Nahcotta, Washington
Thomas F. Mumford, Jr., Washington Department of Natural Resources

The genus *Spartina* belongs to the large family of grasses (Gramineae). *Spartina* species are perennial; that is, they produce plants that live for several to many years and can set seed each year. The culms (stems) are hollow.

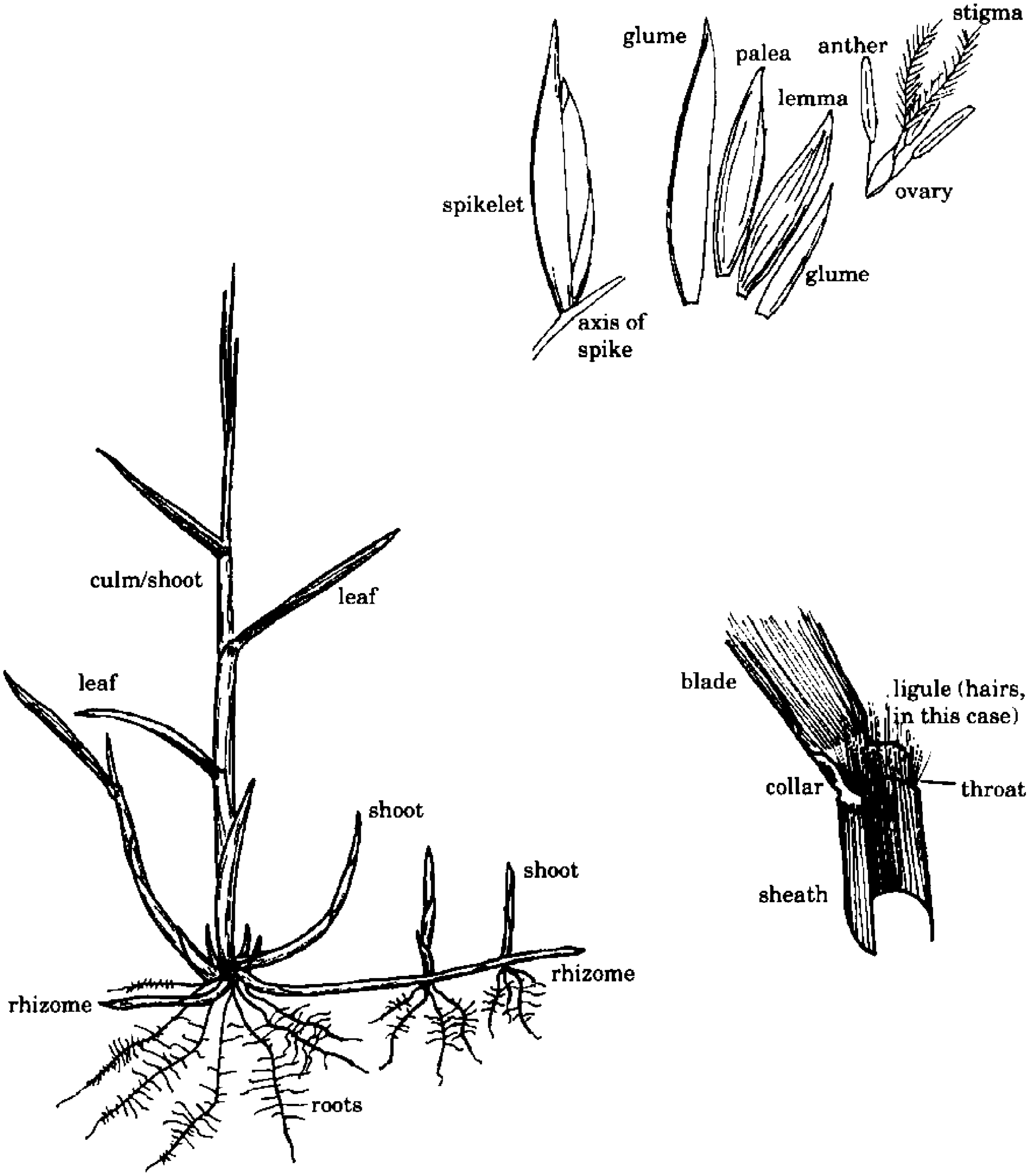
The inflorescence of *Spartina* comprises panicles made up of several spikes with many flowers, or spikelets, on each spike. When ripe, the individual flowers break off below the glumes (the two outer bracts) of the spikelet. The glumes are strongly keeled. One inner bract, the lemma, is also keeled and has one nerve (vein); the other inner bract, the palea, is keeled and has two nerves. Each spikelet has three pollen-producing anthers and a two-branched stigma. The leaves wrap around the stems but do not fuse where they overlap. At the collar, where the leaf flattens out and opens up away from the stem, a short band of tissue grows, called the ligule. In *Spartina* the ligule is composed mostly of fine, straight hairs. Before the leaves open up, when they are still in the bud, they are tightly rolled, or involute. *Spartina* is from the Greek *spartine*, a cord made from *Spartina juncea*.

Spartina alterniflora *Loisel.*
Smooth Cordgrass, Many Spiked Cordgrass, Salt Marsh Cordgrass

Spartina alterniflora is the dominant native species of the lower salt marshes along the Atlantic seaboard and Gulf coast of the United States. It has been introduced to and naturalized in Washington, Oregon, California, England, France, New Zealand, and China (Frenkel and Kunze 1984; Spicher and Josselyn 1985; Ranwell 1967).

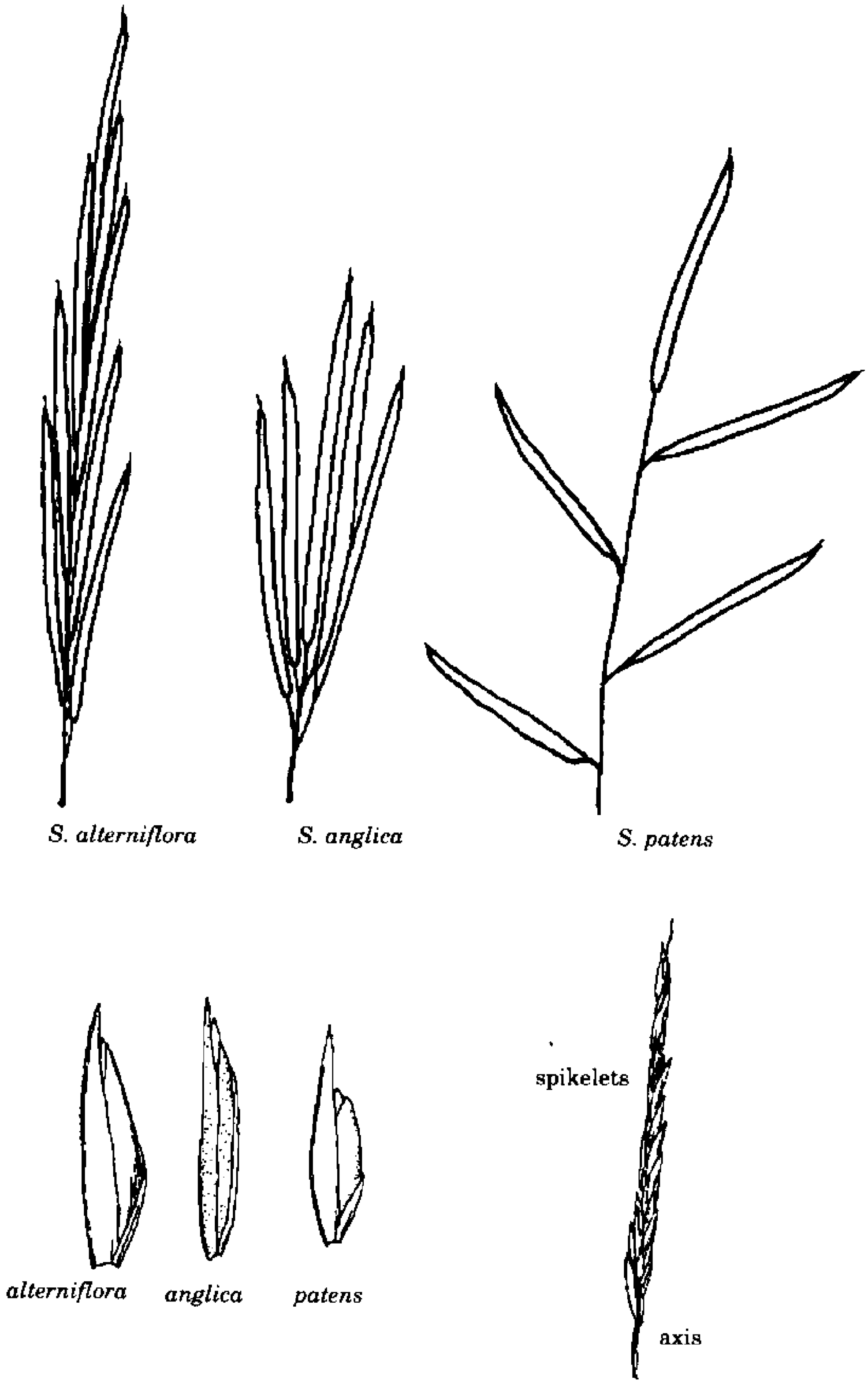
S. alterniflora establishes on substrates ranging from cobbles and gravels to sand and silts in waters where the salinity can range from virtually freshwater to full ocean salinity (1-35 ppt) (Kunze and Cornelius 1982, Sayce 1988 and personal observations in 1989 and 1990). It grows vertically in the intertidal from MHHW (mean higher high water) to 1.8 m below MHHW (Friedman 1988). In Willapa Bay it grows within 1 m of MLLW (mean lower low water) (Sayce 1988). *S. alterniflora* grows laterally by underground stems, called rhizomes, that produce shoots above and roots below; the spread in Willapa Bay averages 0.5 m/yr on a growing edge, a rate consistent with growth reported on the Atlantic coast.

Spartina alterniflora flowers from late July through October in Willapa Bay. Seeds are produced from early September on. On the Atlantic coast it is primarily open-pollinated, that is, pollinated by the wind and other natural agencies that carry the pollen from flower to flower. Seed viability is generally low in its native range, typically about 4%-6%. In 1987, seed viability for a sample of seed from Willapa Bay was 0.04% (Sayce 1988). Seeds require soaking in saltwater for about six weeks to germinate the following spring. Those seeds that do not germinate die; *S. alterniflora* does not build a seed bank in the substrate. Seeds are viable for about eight months (Mooring et al. 1971), from September to May in Willapa Bay.



Typical structure of grass (Gramineae): left, components above and below ground; bottom left, relationship of leaf to culm; top right, spikelet (exploded view). Drawings by K. Sayce.

Before 1980, seedlings of *S. alterniflora* were seen infrequently in Willapa Bay (Frenkel and Kunze 1984). Since then, sexual reproduction and successful seed set have occurred in several years, and new seedlings are now seen throughout the bay (Sayce 1988). *S. alterniflora* in Padilla Bay appears to grow vegetatively; it has not been seen to flower or set seed (Parker and Aberle 1979; Wiggins and Binney 1987; Bulthuis, 1990 personal communication).



Inflorescence of Spartina alterniflora, S. anglica, *and* S. patens: top, *panicles;* bottom left, *spikelets;* bottom right, *spike of* S. alterniflora *showing typical location of spikelets. Drawings by K. Sayce.*

Description. The following physical description of *Spartina alterniflora* is derived from Hitchcock's *Manual of the Grasses of the United States,* but amended in light of the vigor seen in the Willapa Bay plants.

Culms mostly 45-150 (210) cm tall; leaf sheaths pubescent (covered with fine, short, soft hairs) at the throat but not on the collar; ligules about 1.5 mm long; leaf blades 5-15 (20) mm wide at the base, leaf tips strongly involute; flowering panicle made of many spikes; many spikelets on each spike, crowded and overlapping. Spikes 5-8 cm long, the panicle up to 15 cm long. The first glume is very narrow, coming to a fine tip, 6-9 mm long; the second glume is wider, rather blunt at the tip, 9-11 mm long, barely longer than the floret. The lemma is much softer than the glumes; the palea is usually at least as long as or longer than the lemma; anthers 3.5-4 mm long.

Spartina patens *(Aiton) Muhl.*
Salt Meadow Cordgrass

Spartina patens dominates the upper reaches of salt marshes along the Atlantic seaboard and Gulf coast of the United States. Silander (1984) describes it as a rhizomatous perennial grass occurring along the Atlantic coast from Canada to the Caribbean and Central America. *S. patens* dominates the upper salt marsh zone, but in the Carolinas it may colonize and dominate sand dunes, swale grasslands, sand flats, and coastal scrublands. Landin (1990 personal communication) reports that it is not restricted to high marsh areas but can be found along the Gulf coast in lower areas of the salt marsh with long immersion times. A perennial grass, it flowers in late summer.

S. patens has been introduced in British Columbia, Washington, Oregon, California, China, and the Mediterranean (Frenkel and Kunze 1984, Frenkel 1987, Spicher and Josselyn 1985).

Description. The following physical description of *Spartina patens* is derived from Hitchcock's *Manual of the Grasses of the United States:*

Culms are 15-80 cm tall; leaf blades strongly involute, 0.5-2 mm wide, flowering panicle hardly seen above leaves, spikes 1-4, ascending or divergent from stem, spikelets 9-13 mm long, loosely overlapping. The first glume is linear (parallel sided), about 4 mm long; the second glume is lanceolate (lance shaped) and acuminate (sharply pointed), scabrous (rough) on keel and adjacent nerves, glabrous (smooth) on sides; lemma 5-6 mm long, obtuse (blunt), scarcely as long as the palea.

Spartina anglica
Common Cordgrass, Rice Grass

Spartina anglica is the predominant plant in most tidal mudflats along the British coast. Although it can grow on a wide range of substrates, it typically grows on soft, finely particled, mobile muds. Its immersion limit is usually equivalent to six hours of immersion per high tide, but it can be longer.

S. anglica was transplanted extensively around the world. It currently grows in England, France, Germany, Denmark, the Netherlands, New Zealand, Australia, and China, as well as Washington and California in the United States (Ranwell 1967, Frenkel and Kunze 1984, Spicher and Josselyn 1985).

S. anglica tolerates salinities of 5-40 ppt. Woodhouse and co-workers (1974) noted that salinities greater than 45 ppt caused *Spartina* species mortality.

A perennial hybrid species, *S. anglica* flowers from July to November

(Hubbard 1968). Flowering time for *S. anglica* is longer than for most native British salt marsh species and may occur until February (Mullins and Marks 1987).

Seed viability of *S. anglica* is highly variable throughout a marsh but generally low, less than 6% (Marks and Truscott 1985). There does not appear to be a persistent seed bank in the soil. Seed does not appear to be persistent in the substrate or viable the following year (Hill 1982).

Seed heads of Spartina anglica, Juniper Beach, Camano Island. (Photo: T. Mumford, Jr.)

Description. The following physical description is drawn from the 1968 revised edition of C. E. Hubbard's *Grasses*.

Spartina anglica is a deep-rooting perennial, 30-130 cm tall, spreading vegetatively by soft, stout, fleshy rhizomes. Culms are stout and smooth, with many joints, or nodes. Leaves are green or grayish-green, 6-15 mm wide, involute along the culm and flat and spreading above; the overlapping sheaths are glabrous (smooth); ligules are densely, silkily ciliate (hairy), with hairs 2-3 cm long. Panicles are erect and dense, 12-40 cm long, with 2-12 spikes which overtop the leaves. Spikes are erect or slightly spreading, stiff, up to 25 cm long; the axis is 3-angled and smooth, ending in a bristle up to 5 cm long.

Spikelets overlap closely in two rows on one side of and appressed to the axis, narrowly oblong and flattened, 14-21 mm long, mostly 2.5-3 mm wide, mostly 1-flowered, loosely to closely pubescent (covered with fine, short, soft hairs). Glumes are keeled and pointed; the lower glume is two-thirds to four-fifths the length of the upper glume, and the upper is as long as the spikelet, lanceolate to oblong in shape, tough except for the membranous margins, pubescent. The palea is 8-13 mm long.

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Growth Habits and Other Considerations of Smooth Cordgrass, Spartina alterniflora *Loisel.*

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Smooth cordgrass *(Spartina alterniflora* Loisel.) is a perennial saltmarsh grass that in North America occurs naturally on the Atlantic coast from Newfoundland to Florida, and on the Gulf coast from Florida to east Texas. It was introduced to Washington, Oregon, and California (San Francisco Bay) over a period of years. The species appears to be spreading less rapidly in San Francisco Bay and Oregon than it is in Washington, especially in Willapa Bay, where conditions seem to be ideal for propagation of the grass.

Godfrey and Wooten (1979) describe the species as follows:

> Plant with tough rhizomes deep-seated in the substrate, forming colonies. Aerial stems very variable in stature, 2-15 cm tall, slender or coarse, stiffly erect, smooth. Leaf blades 4-15 mm wide or wider toward the flat base, distally usually involute, the margins smooth to somewhat scabrid. Spikes (1-) 5-15, sometimes more, from the central axis, 4-10 cm long, appressed-ascending and overlapping. Spikelets mostly 10-40 per spike, first glume shorter than the lemma, second glume exceeding the lemma, 10-14 mm long, hard, its keel smooth. Colonial in tidal waters of muddy outer shores, salt marshes.

Spartina alterniflora, *Long Island Slough, Willapa Bay, July 1990. (Photo: T. Mumford, Jr.)*

Smooth cordgrass is a highly productive species, contributing an average of 1,300 g m^{-2} exported detritus annually to the estuarine system. The species is an invaluable component of the estuaries where it occurs naturally.

On restoration or creation sites, smooth cordgrass is used primarily as a sediment stabilizer and trap, as a nurse crop for mangroves, and as a nursery area for estuarine fishes and shellfishes. Some waterfowl and wetland mammals eat the roots and shoots.

Propagation

Smooth cordgrass propagates both by seeds and by scaly rhizomes that spread from a tough, vigorous root system. Colonies form when pieces of the root system or whole plants float into a suitable area and take root or when seeds float into a suitable area and germinate. Rhizomes creep extensively and can form dense clumps.

Propagation by Seeds. For saltmarsh restoration and creation, mature seeds are harvested in the fall and stored wet in at least 15 but not more than 35 ppt estuarine water, at 1°-3° C for up to 180 days. Some smooth cordgrass stands on the Atlantic and Gulf coasts have higher percentages of viable seeds than others, and germination tests are necessary to ensure that enough viable seeds are planted in late spring or early summer to establish stands.

The question has been raised concerning viability of seeds of the smooth cordgrass colonizing San Francisco Bay. No laboratory tests have been conducted; however, lack of seed germination in the bay may be due not to seed inviability but to high wave energies and competition from Pacific cordgrass *(Spartina foliosa)*, which in that area grows from +1.0 to +2.5 feet mean water level. Smooth cordgrass seeds also require a dormant period, and they germinate in almost fresh to brackish water rather than salt water. Salt water acts as an inhibitor; seeds stored in fresh water in the refrigerator will germinate in storage. Since estuarine flood waters on the Atlantic and Gulf coasts are generally much fresher in spring than later in the growing season, it is surmised that smooth cordgrass has seeds that are adapted to germinate in nearly fresh water.

Propagation by Seedlings or Vegetative Propagules. Seedlings grown from harvested seeds are often transplanted to restoration or creation sites on the Atlantic coast when donor stands of smooth cordgrass are not available. However, it is still generally acceptable on the Gulf coast and in Florida to selectively harvest small plugs from donor stands, then transplant them immediately to the new site. In nature, this occurs when tides or other actions cause rhizomes and clumps of plants to break away and float to a bare or nearly bare substrate suitable for colonization. This apparently has occurred quite well in Willapa Bay and, to a lesser extent, in other places on the Pacific coast.

One sign of the adaptive ability of smooth cordgrass is that seeds can be sowed on saturated biodegradable matting in long beds and grown in the nursery for a few weeks. The mats are then rolled up and transported to a restoration or creation site, unrolled, and staked into place to create an instant ground cover or turf of cordgrass that is resistant to wave energies.

In general, cordgrass seedlings and larger sprigs are nursery-grown in fresh water, then acclimated to the salinity of the intended planting site over a period of 2-4 weeks prior to actual transplantation.

Habitats Colonized and Occupied

Smooth cordgrass colonizes mud or sand flats in environments of saline or brackish water and low or moderate wave energy. It grows from 0.7 meters below mean sea level to about mean high water in a broad range of substrates (sand, silt, clay, loose cobble, gravel). "Tall form" smooth cordgrass is restricted to newly and rapidly developing stands, margins of creeks, natural channels, and areas subject to daily tidal flooding. "Short form" smooth cordgrass occupies higher levels of marsh near the upper limit of tidal influence. In older salt marshes, both forms often occur. Short-form plants appear to be more stressed, both from lack of adequate tidal flooding and from the very dense root mats that develop in older smooth cordgrass marshes. The short form also produces more seed spikes than young vigorous stands of the tall form, which spreads primarily by rhizomes.

Once established, smooth cordgrass is a strong competitor, and will form monostands at the lowest tidal zones. With the exception of Pacific cordgrass, no other

North American saltmarsh species can compete at the salinities and tidal ranges it tolerates. Smooth cordgrass is highly adaptable and tolerates a pH range between 4.5 and 8.5. Optimal salinity is 10-20 ppt; however, under certain conditions such as summer droughts, it can tolerate 50-60 ppt. The grass can also withstand hurricanes and other storms (including northwesters) and can tolerate inundation up to 12 hours per day.

Smooth cordgrass stands also serve on the Atlantic and Gulf coasts to entrap sediment. Once established, a stand of smooth cordgrass will begin to change the elevation and other characteristics of its substrate. The ultimate fate of smooth cordgrass is to become high marsh, which will gradually displace the smooth cordgrass with higher-elevation brackish species such as saltmeadow cordgrass *(Spartina patens),* gulf cordgrass *(Spartina spartinae),* big cordgrass *(Spartina cynosuroides),* and saltgrass *(Distichlis spicata).* In turn, the high marsh will continue to accumulate sediment and biomass until it becomes a coastal shrub community and, eventually, a maritime forest.

In California, Pacific cordgrass entraps sediment, and stands will mature and eventually give way to pickleweeds *(Salicornia* spp.). Pacific cordgrass will continue to occur along tidal creek fringes and the outer fringes of the developing marsh. There is no ecosystem in the Pacific Northwest equivalent to the cordgrass ecosystems of the Atlantic, Gulf, and southern Pacific coasts.

When the Mud Flat Becomes a Saltmarsh: Changes in Fauna

A number of macroinvertebrate species live in smooth cordgrass marshes; these vary depending upon whether the saltmarsh is on the Atlantic or the Gulf coast. Olive nerites, three species of snails, marsh clams, two species of fiddler crabs, blue crabs, three species of amphipods, four species of isopods, and eleven species of saltmarsh insects were found in samples collected in South Carolina cordgrass marshes in 1988 (LaSalle and Landin 1989). Net and trap collection in the same salt marshes on ebb and flow tides yielded fundulus, weakfish, bay anchovy, Atlantic silverside, and Atlantic menhaden (LaSalle and Landin 1989). Comparisons with a nearby natural saltmarsh found some differences in species composition, but the above-named organisms occurred in both marshes, whether natural or manmade.

The animal communities that occur in smooth cordgrass marshes on the southern Pacific, Atlantic, and Gulf coasts are quite different from those occurring in mud flats at lowest tidal ranges in the Pacific Northwest. Thus, prey items would be different for higher trophic level fish and macroinvertebrates. The impacts on native, commercial, and recreational Pacific Northwest fisheries should be evaluated from an ecological standpoint. Are changes in the Pacific Northwest ecosystems good or bad over time? Are short-term impacts negative, and long-term impacts less so?

In turn, larger fish species that feed on the smaller fish that move into cordgrass salt marshes at high tide depend upon these organisms. The question needs asking: Will the change in macroinvertebrate communities and small marsh-feeding fish also cause a change in estuarine fish species such as salmon?

Millions of shorebirds and waterfowl migrate north and south along the coastal Pacific flyway. The mud flats of Washington and Oregon are famous for the immense flocks they attract. These birds feed upon invertebrates in the mud flats. On the Atlantic and Gulf coasts, smaller expanses of mud flats have caused shorebirds to traditionally come to a few remaining, very critical stopovers where they can find prey.

Will changes from bare mud and eelgrass to smooth cordgrass replace shorebird feeding areas to some critical point of no return?

Geese and ducks on the Atlantic and Gulf coasts tend to use only salt marshes in which open water is interspersed with emergent marsh. At low tides, large numbers of waterfowl rest and socialize on exposed mud flats. They seldom loaf or feed in vegetated salt marshes. Again, the question is: What changes will take place in the Pacific Northwest for waterfowl if extensive mud flats colonize as smooth cordgrass?

Control Considerations

Smooth cordgrass is a sun-loving species; it cannot tolerate moderate or dense shade. Therefore, shading stands (e.g., covering stands with black canvas or black plastic) will kill them. Shading can be coupled with chopping or mowing of stems to provide better coverage. Covers must be well anchored to prevent washing out with tides.

Once well established, the species can tolerate low or moderate grazing by waterfowl, feral goats, muskrats, and nutria. However, grazing pressures in newly established stands have been known to completely eradicate plantings on the East Coast. Purposely attracting waterfowl to Willapa Bay with food plots or other means may serve in some measure to control newly colonized stands. Introducing nutria to Willapa Bay is NOT recommended! Nutria is an exotic species that has exerted tremendous grazing pressure in the lower Columbia River on both low and high marsh plant species, to the detriment of many grazing-intolerant West Coast sedges, grasses, and wetland forbs. While nutria would eat some of the smooth cordgrass, it would probably eat every other desirable plant species first, before it turned to the smooth cordgrass.

As with all grasses, repeated cutting or mowing will eventually weaken the root system of smooth cordgrass. However, this is a highly labor intensive control measure, and mowing equipment would have to be modified to work in soft substrates. Burning is not a solution, since burning must occur at least twice a year to affect the root system, and smooth cordgrass grows at elevations not conducive to creating a dry litter for fuel.

Studies conducted by the University of Georgia during the U.S. Army Corps of Engineers Dredged Material Research Program showed that smooth cordgrass can be smothered by applications of six or more inches of dredged clay or silt . Therefore, it may be possible to selectively "bury" the Willapa Bay smooth cordgrass infestation with fine-textured heavy soils. Such an attempt should be carefully controlled, however, since incorrect depths or inadequate applications could result in an even better substrate for continued smooth cordgrass growth.

Smooth cordgrass is susceptible to herbicides such as Rodeo®, a chemical compound which rapidly breaks down into harmless forms after application. Rodeo® can be applied at low tide by helicopter sprayers. Monitoring and strict controls would be required to be sure that the herbicide is not having an unforeseen impact on other organisms in the estuary.

Smooth cordgrass is intolerant of oils and greases. In an upland vegetation control situation, mixing the selected herbicide with an oil-based substance such as a diesel fuel would aid in immediately smothering and killing the grass. However, there may be a danger in using such substances in the intertidal zone. Only if eradication is deemed the one possible solution to the problem in Willapa Bay should such a substance be considered. Both the herbicide and its mixer (if other than water) would have to be considered a temporary environmental tradeoff for eradication of the smooth cordgrass.

Living with It

The eradication of smooth cordgrass may be a realistic goal where stands are still sparse, in San Francisco Bay, for example, or Puget Sound. In Willapa Bay, however, smooth cordgrass now covers more than two thousand acres and is still spreading. Unless a broad-scale application of an herbicide is approved or extremely labor intensive efforts are undertaken, eradication is probably not possible. It is suggested that while control or eradication measures are sought and tried, an intensive effort be made to determine the long-range impacts of extensive smooth cordgrass stands in the Pacific Northwest. In other words, set a priority to find out if it is possible for Pacific Northwest organisms to adapt to smooth cordgrass and survive with it.

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The information in this text was gained from sixteen years of field and laboratory work with smooth cordgrass, including basic life requirements and growth habits, collection, storage, propagation, transporting, planting, monitoring, evaluation, and heavy metals uptake assessment. The reports and books listed below can provide additional information.

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Insect Herbivores That Feed on Spartina alterniflora

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Spartina alterniflora, salt marsh cordgrass, has been introduced to Willapa Bay, Washington, and Florence, Oregon, without any of the insect herbivores that damage the plant over its native range on the Atlantic and Gulf coasts of North America. Nor do the insects native to the salt marshes newly occupied by *S. alterniflora* in the Pacific Northwest damage the plant significantly; stature and vigor are on average much greater than in the east and south, where the plant suffers much from insect herbivores. Many of the insect herbivores in its native range are probably specific to the genus *Spartina*, but the definitive tests of host breadth have not been done. These tests would be straightforward and relatively simple to perform.

The herbivorous insects most injurious to salt marsh cordgrass fall into the categories of stem borers, sap-sucking leaf feeders, and flower-seed feeders. Of the five species of stem borers on salt marsh cordgrass I have studied, three kill the developing seed head of the plant and the other two attack young shoots. Sap-feeding plant hoppers of the genus *Prokelisia* can attain very high densities on cordgrass and thus kill the plant. Seed-feeding grasshoppers and caterpillars could complement stem borers in reducing seed set.

Relevant Literature

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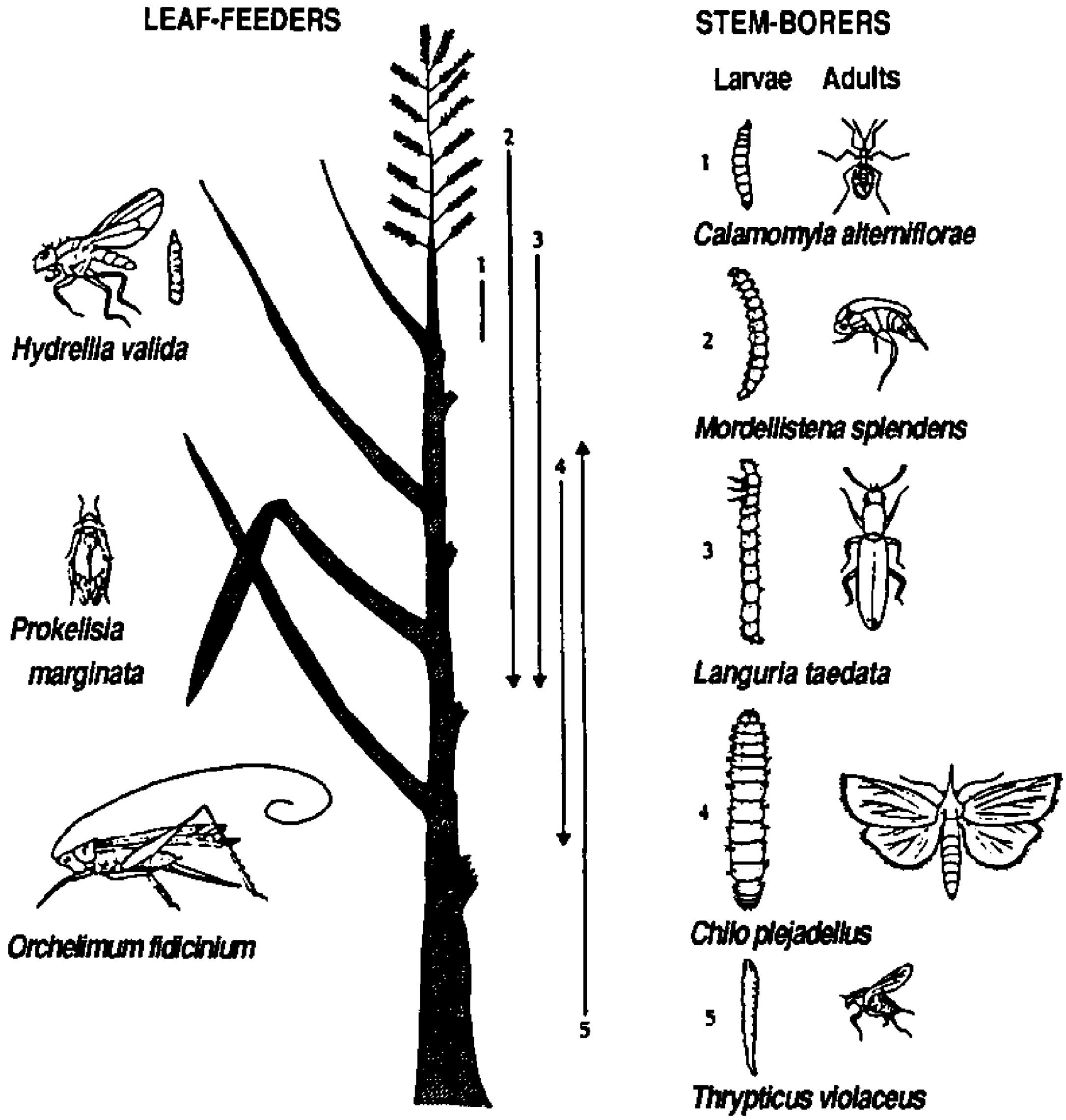

Leaf feeders and stem borers associated with Spartina alterniflora *on the Gulf coast. The stem borers occupy positions indicated by the numbered lines to the right of the grass stem. (After a drawing by Peter Stiling)*

Distribution and Impacts

Spartina anglica in the United Kingdom

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Almost a century after it was first observed, *Spartina anglica* dominates 6,950 hectares of tidal flats and accounts for 16 percent of the British saltmarsh and 2 percent of the estuarine intertidal zone. Transfer between systems was achieved mainly via planting between 1900 and 1940 by those hoping to stabilize mudflats for sea defense navigation or land claim purposes.

Lateral growth of individual plants and rhizome fragment propagation contribute to *S. anglica* invasion of a system, but it is the comparatively rare years when seedlings establish in large numbers that provide for the dramatic gains of *S. anglica* marsh across tidal flats. Seed production is related to the timing of culm emergence, which is probably controlled by the temperature and photoperiod requirements of this C4 pathway species.

At its lower limits *S. anglica* is without vegetative competition, and for western estuaries vertical distribution has been accurately modelled using tidal range modified by fetch, estuary size, and latitude. This reinforces evidence which suggests that *S. anglica's* seaward descent is controlled by a variety of tide- and light-related factors such as turbidity, current velocity, sediment deposition, and wave action.

Remnants of Spartina anglica, *Juniper Beach, Camano Island. (Photo: T. Mumford, Jr.)*

S. anglica's competitive relationship with the marsh flora at its upper limit has given rise to concern over its impact on marsh succession. *S. anglica* has displaced the annual *Salicornia* pioneer community from southern and eastern Britain, but its interaction with salt marsh perennials is more ambiguous. The main factors which temper the relative competitive ability of *S. anglica* and its rivals are most likely to be sediment type, sediment water content, salinity, temperature, elevation, and grazing or mowing. On fine wet sediments *S. anglica* marshes can remain as monocultures for decades with transition to *Phragmites* and *Scirpus*, whilst on some sandy low tidal range sites *S. anglica* has invaded *Puccinellia* swards. On several northwestern estuaries, midmarsh species invade accreting and expanding *S. anglica* swards.

S. anglica has displaced its North American parent, *S. alterniflora,* to the extent that the latter survives in only one artificially maintained population; but the impact on the native parent, *S. maritima*, is of more concern. *S. maritima* is at the northern limit of its range in Britain and has declined both in range and within sites during the period of *S. anglica* colonization. With no good evidence for displacement by *S. anglica* there is the possibility that *S. maritima's* population is inherently in decline.

Sediment accretion rates within *S. anglica* sward are variable and can be very high, but little attention has been paid to the physiographic and hydrological consequences of *S. anglica* marsh development. Anecdotal evidence suggests that the growth of a fine-sediment *S. anglica* marsh may inhibit freshwater movement through higher shore sediments leading to waterlogging upper marsh and even adjacent land. The behavior of *S. anglica* marshes as large-volume, fine-sediment sinks must have major impacts on the sediment budgets of estuaries. However, only local effects on shore profile, width, and adjacent channel depth have been documented. Similarly, it has been demonstrated that *S. anglica* can be a net exporter of organic carbon for the estuary, but there is little idea of the relative importance of this contribution within a system.

Internationally important wader and wildfowl populations rely on U.K. estuarine intertidal flats for a proportion of their passage or winter feeding. High densities of benthic and epibenthic invertebrate prey may occur in *S. anglica* sward, but they are effectively unavailable to their wader predators. Hence it is feared that *S. anglica* invasion, in common with land disturbance and barrage-induced tidal level alterations, may reduce the area of feeding resource and the duration of its exposure. The consequences are addressed by several lines of research which suggest an increase in winter mortality for some small wader species with a possible impact on total population size.

S. anglica can invade *Zostera* beds and reduce the extent or density of other marsh plants which are food items for herbivorous wildfowl. In particular the loss of intertidal feeding for brant geese *(Branta bernicla)* may increase the scale and duration of this species' use of crops for winter feeding.

The impact of *S. anglica* on commercial interests is less often in focus. *S. anglica* retains a value on some coasts for sea defense, and in eastern Britain there is concern over its die-back and erosion. Land claim resulting from *S. anglica* invasion has additional conservation impacts through loss of high marsh flora and possibly disproportionate effects on shore width and profile. There is a potential for conflict with intertidal fin and shell fisheries and with *Salicornia* harvesting, but in reality the effects must be small or felt only by those with small political voice.

Spartina *Introduction in New Zealand*

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Spartina x *townsendii* was first introduced to New Zealand from England in 1913 in order to assist in the reclamation of tidal flats for useful pasture and later to help protect shorelines and stopbanks from erosion. Successive plantings from the original stands and further imports of *Spartina anglica* from England and *Spartina alterniflora* from North America accelerated during the 1940-50s throughout New Zealand. *S. anglica*, the most abundant species in New Zealand, has been more successful than the original plantings of *S. townsendii*, with *S. alterniflora* successfully established only in the northern regions.

Spartina grew readily and spread aggressively, forming extensive meadows in our estuaries, which were typically open tidal flats, *Zostera* meadows, and macroalgal beds with border fringes of salt marsh vegetation.

The change in the character of our estuaries along with increased awareness of estuarine values resulted in 1963 in legislation prohibiting further planting of *Spartina*. Although primary productivity in a *Spartina* marsh is higher than in native estuaries, there is a major reduction and change in species diversity. Areas that were valuable for recreation and food collection and as sanctuaries for native and migrating birds, as well as for their scenic and native qualities, were thought to be endangered by the spreading growth habits of *Spartina*. The natural flows of rivers and tidal channels concerned water catchment authorities as the ability of *Spartina* to trap sediment resulted in raised flood plains and restricted waterways.

Several interest groups began to attack *Spartina* stands by a variety of methods of which herbicide spraying was the most effective. During the 1980s efforts to control *Spartina* intensified and became more organized.

Scientific field trials followed by monitoring of a *Spartina* eradication program by herbicide spraying have been in progress for six years in the Waimea Inlet, Nelson, New Zealand. From knowledge gained so far, guidelines to minimize environmental damage can be successfully applied. These involve recognition of sensitive areas and of the effects on flora and fauna; control of spray application, volume, and timing; and consideration of climatic conditions.

The long-term impact after removing *Spartina* is not yet fully known. However, because of long delays (over several years) for the full removal of *Spartina* and decay of roots, any impact of extra detritus and sediment movement is minimized.

It is possible to control *Spartina* by herbicide, and minimize short-term impacts, in order to facilitate restoration of native estuarine characteristics, but this requires care and commitment by a well-informed staff.

Organization of a New Ecosystem: Exotic Spartina Salt Marsh in New Zealand

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G. A. Knox, University of Canterbury, Christchurch, New Zealand

Areas of invading cordgrass, *Spartina townsendii* and *Spartina anglica*, were studied at Havelock, New Zealand, and compared with previous work on *Spartina alterniflora* at Crystal River, Florida. The invading *Spartina* ecosystem was approximately fifty years old in 1982, and during that time it had transformed about 80 hectares of mudflat to a canal and distributary pattern with tall, robust plants growing along the canals and shorter, more numerous plants growing in the pans. In the summer, aboveground *Spartina* biomass averaged 998.5 gdw m^{-2}. The average root biomass was 3,092 gdw m^{-2} on the levees and 7,327 gdw m^{-2} on the pans. Net growth for the summer averaged 1.02 gdw m^{-2} d^{-1} on the levees and 4.25 gdw m^{-2} d^{-1} on the flats. *Potamopyrgus*, a minute snail, averaged 45,765 animals per square meter, which were spread like a carpet in the *Spartina*. Several commercially valuable fish species were found using the marsh in a support or nursery capacity.

Preliminary observations indicated that the *Spartina* marsh supported water fowl in abundance comparable to the replaced mudflats, albeit with species changes. There was a general absence of the many crab holes found in marshes of the southeastern United States which are apparently important in water exchange there. In the Havelock marsh, fine *Spartina* rootlets were concentrated near the mud surface, with coarse roots down to 30 cm. Mud pore space salinity was greatest in the fine rootlet zone. Oxidation potentials were greater in the *Spartina* than in the alga-covered or bare mud areas. A diverse marsh flora consisting of *Spartina, Juncus, Leptocarpus, Zostera, Enteromorpha,* and epiphytic *Bostrichia* demonstrated a wide range of energy filtering capacity for maintaining high productivity. A simulation model of *Spartina* generates growth curves and seasonal patterns consistent with the data obtained and with the spread of *Spartina*. Simulation of the marsh model using actual storm data showed the importance of low-frequency, high-energy phenomena in maintaining the marsh ecosystem.

Major changes in the mosaic of coastal ecosystems such as the substitution of cordgrass marsh for mudflat following the genetic hybridization of cordgrass may be an example of the occurrence of macroevolutionary feedback improving productivity and ecological organization after microevolutionary changes have accumulated. Patterns of the hybrid's spread in New Zealand are similar to those seen in Europe, despite the different evolutionary histories of those areas. Marsh productivity and values are high, similar to those in the southeastern United States, and there is little justification for a policy of eradication with poison.

Introduced Spartina *Species in San Francisco Bay*

John Callaway, Louisiana State University, Baton Rouge

Four species of *Spartina* have been introduced in San Francisco Bay where *S. foliosa* is native: *S. alterniflora, S. anglica, S. densiflora,* and *S. patens*. Previous work with *S. densiflora* has shown that it is a prolific seed producer and grows at elevations between *S. foliosa* and *Salicornia virginica*. No studies have been completed on *Spartina anglica* or *S. patens*.

In the past 10-15 years *Spartina alterniflora* has spread quickly in the bay and represents a serious threat to native salt marsh vegetation. Because of this threat, a recent study was undertaken to compare its vegetative and reproductive characteristics with the native cordgrass, *S. foliosa*. The characteristics studied were intertidal distribution, phenology, above- and below-ground biomass, growth rates, seed production, and germination rates. Results indicated that the introduced species is better able to get established than the native species and, once established, spreads more quickly vegetatively than the native plant. *Spartina alterniflora* is likely to continue to spread to new areas in the bay and displace the native plant.

Two possible impacts of this introduction were evaluated: changes in rates of sedimentation and rates of detritral breakdown. Although there do not appear to be any large differences in these rates between the two species, they may become more apparent when the introduced species is well established. Other possible impacts are loss of shorebird and wading bird feeding areas, changes in salt marsh habitat structure, changes in algal production, increased wrack deposition, and changes in benthic invertebrate populations.

Spartina *in Oregon*

Robert E. Frenkel, Oregon State University, Corvallis

Spartina patens and *S. alterniflora* have been introduced into Oregon; both are established in the Siuslaw Estuary, their only verified state location.

Exponential spread of *Spartina patens* on Cox Island is documented by sequential air photos from 1939 to 1980. *S. patens* grows in distinctive circular patches and now occupies more than 3,000 m^2 with no diminished rate of spread. The grass invades the *Deschampsla caespitosa-Scirpus maritimus* community, the most open of the marsh communities with 7.7% bare ground. Patch elevation ranges from 1.83 to 2.05 m above MLLW comparable to its indigenous tidal position on the East Coast. Aerial expansion of individual circular patches is partly by clonal growth, and the plant appears to "smother" competing indigenous vegetation. Flowering culms are common, but fertile seed has not been observed; however, scattered patches suggest spread by seed dispersal. Once established, *S. patens* in Oregon performs comparably to its performance in Delaware and New England, as shown by its general growth form, average above-ground live biomass of 329 gdw m^{-2}, above-ground dead biomass of 411 gdw m^{-2}, and a below-ground to above-ground biomass ratio of 4.80. Introduction probably occurred in the first three decades of this century, possibly in association with discarded packing material on the island, which was grazed at the time. The plant is reported on another island west of Cox Island.

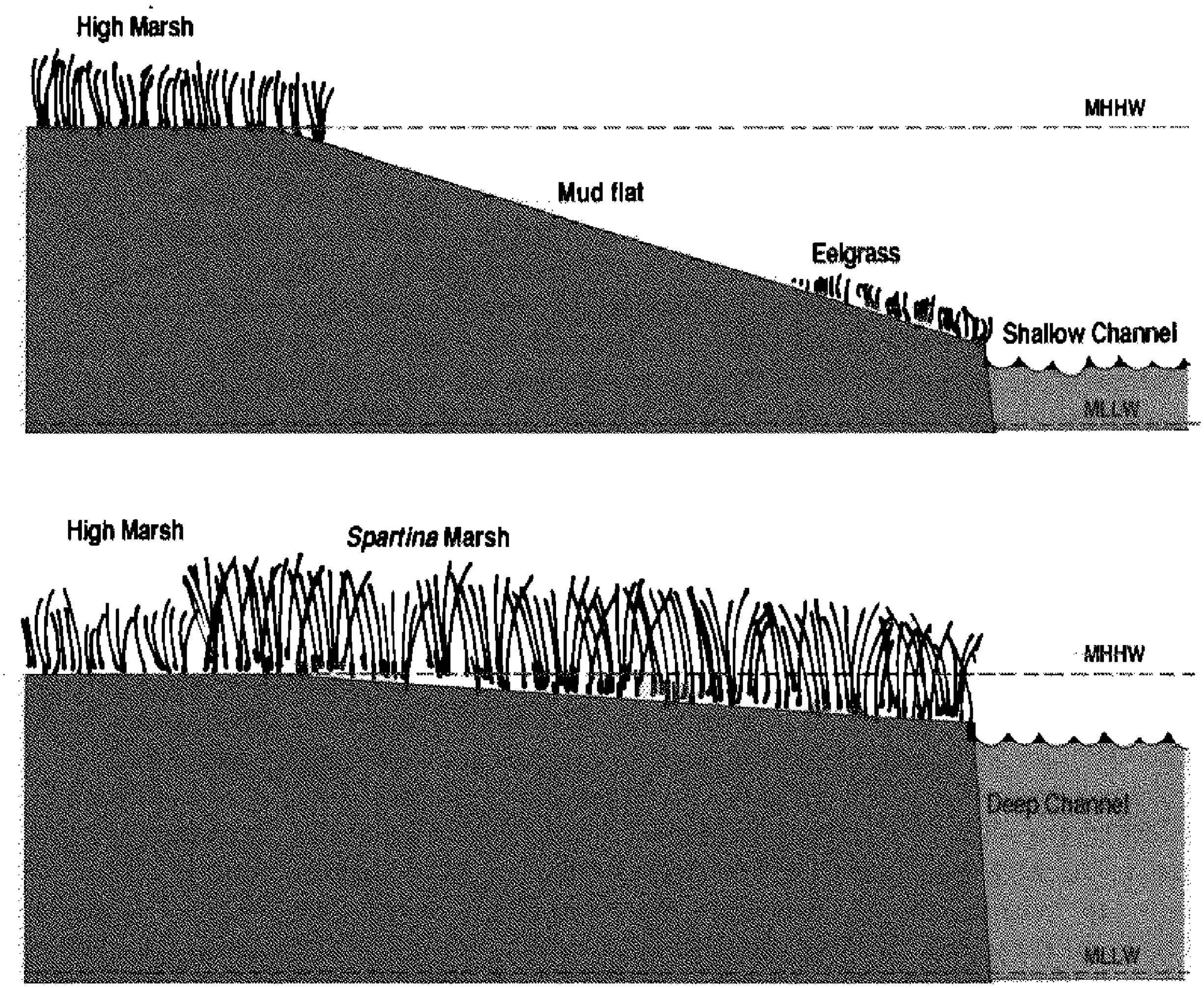
Spartina alterniflora was established as an experimental planting in 1978 or 1979 from stock collected in Georgia. It was planted in a small patch on Port of Florence land, at the eastern edge of a dredge disposal area, and now occupies about 200 m^2. A second, smaller patch is situated about 100 m to the north. Plants are robust but do not flower. The plant appears to spread slowly vegetatively.

Attempts have been made, with no success, to control *S. patens* using black plastic (floated away), rock salt, burning, and herbicide (Roundup®). The individual who planted the *S. alterniflora* claims to have recently succeeded in controlling the grass by mowing and heavy hand-application of a glyphosate herbicide. No verification has been made of this claim.

Species Displaced by Spartina *in the Pacific Northwest*

Kathleen Sayce, Shoalwater Botanical, Nahcotta, Washington

The transition of intertidal acreage in the Pacific Northwest from the present species assemblage to *Spartina*-dominated salt marsh is accompanied by two groups of displacement features. The first is the physical exclusion of species typically found in the intertidal region. These species include eelgrasses, Dungeness crab, clams (but not the Eastern softshell), juvenile fish of many genera, and migratory waterfowl. Utilization of the new habitat created by spreading clones and patches of *Spartina* has been observed for four birds and three small mammals. The second displacement feature is the trapping of sediments by this grass. *Spartina* can capture up to 15 cm (6 inches) of new material annually. The eventual consequence of *Spartina* growing in estuarine environments is



Typical mudflat intertidal area with native vegetation before (top) and after (bottom) infestation with Spartina. *Note higher elevation in* Spartina *marsh due to rapid siltation.*

the removal of the intertidal acreage to salt marsh at and above Mean Higher High Water. This loss of volume in Pacific Northwest estuaries has severe implications for flood control and watershed drainage.

Spartina *in Willapa Bay: A Case History*

James R. Sayce, Pacific County Planning Department, South Bend, Washington

Smooth cordgrass *(Spartina alterniflora)* was introduced to Willapa in the late 1800s from the eastern coast of the United States. The Willapa National Wildlife Refuge (NWR) manager, Grant MacFarland, noted in 1942 that local oystermen expressed concern that it might become a problem. Nearly fifty years later, in 1979, field biologists with the Washington Department of Wildlife recommended that the cordgrass be eradicated from Willapa Bay.

The plant began its rise as a local issue in Pacific County when in 1987 the

Willapa NWR funded investigative research by Kathleen Sayce to inventory and look at the reproductive ecology of *Spartina*. Her 1988 report, coupled with the acquisition of the Niawiakum estuary for the DNR Natural Heritage Program and the consideration of putting *S. alterniflora* on the Washington State Noxious Weed list, prompted Pacific County to sponsor a *Spartina* seminar.

The 1988 *Spartina* seminar group, made up of local fishermen, oystermen, wildlife biologists, upland property owners, and representatives from state and federal resource agencies, addressed the following questions: Do we have a problem? What is the extent of the problem? How to proceed? The group concluded that, yes, *Spartina* is a problem, and that we should have a control program in place within five years, otherwise it would probably be beyond control. The seminar group was also the initiating force for the formation of the *Spartina* Working Group. Early in 1989 the Washington State Weed Board declared *S. alterniflora* a noxious weed in seven western Washington counties.

By summer of 1989 the *Spartina* Working Group, composed of state and federal resource agencies as well as tribal and environmental groups, was meeting twice a month and providing technical assistance. They reviewed and gave critical comment to briefing papers, an action plan, experimental control methods and treatments, and, finally, the outline and content of this workshop.

Important benchmarks were reached in 1990 that brought the problem of *Spartina* more into the mainstream. Local, state, and federal agencies helped review permits for Willapa NWR and DNR experiments in *Spartina* mechanical control and Monsanto experiments in herbicidal control. Of critical importance to this workshop was a joint effort by the DNR and Nature Conservancy on a *Spartina* control literature search to contact researchers worldwide. At about the same time, the Washington state legislature funding for Washington Sea Grant became available. The Washington State Department of Natural Resources, Washington Sea Grant, and Pacific County applied for and received grant funding to hold the workshop. The summer of 1990 also revealed that we are entering a new phase with *Spartina*. By midsummer it was clear to the Willapa NWR that we were dealing with explosive new growth and tens, if not hundreds, of thousands of newly seeded plants.

This new information prompted the Pacific County Board of County Commissioners to declare the presence of *Spartina* an environmental emergency. The declaration was important in that it signified the immediacy of the problem and the commitment of local government to actively participate in finding and implementing solutions. It also completed an important path that was long in coming, that is, the elevation of the issue to the attention of government policy makers.

Spartina has been covered in the media, with numerous front page articles in local and regional papers, as well as coverage by major network news stations out of Seattle and Portland.

In early 1991 we are planning public informational meetings, an EIS scoping meeting, and a local citizens' advisory task force to guide us in directing a major control effort by summer of 1991. Our interest has mimicked the plant's growth. And we are in a crisis situation that could have been avoided. We are faced with a conservative estimate of 1,100 acres of *Spartina* and revised estimates of 2,000-2,500 acres. How could this plant grow to such a size without being noticed and without something being done about it?

The potential impact of *Spartina* on Willapa Bay was recognized early and at a time when we could have responded more effectively than we can now. This early attentiveness speaks to the excellence and importance of field biologists. These alert observers of the environment are in a position to see and forecast change. They are often our first and best source of environmental information, yet the implications of their observations are often obscured by a cloud of other environmental concerns. If we are to avoid problems like this in the future we must:

- communicate better with those working the resource,
- attempt to understand the ramifications of environmental change,
- assess risk early, and
- strive to alert citizens and decision makers to the danger of letting environmental problems go until they are too big to deal with easily.

Control Methods and Programs

Spartina anglica *Control Programs in the United Kingdom*

Lawrence Way, Nature Conservancy Council, Peterborough, England

Control of *Spartina anglica* has been attempted at 28 sites on 20 estuaries in the U.K. and is proposed for a further three sites. Large-scale control programs were first attempted in the mid-1960s, and several programs have been running for 10-15 consecutive years.

The most frequently expressed objective of control programs is the containment of *S. anglica* to maintain wader feeding habitat. Other objectives motivated by conservation include restoration of *Zostera* beds for wildfowl and the protection of native salt marsh communities. A number of coastal local authorities control *S. anglica* to maintain the visual and recreational appeal of beaches.

Most control programs have chosen a combination of chemical and mechanical techniques to kill *S. anglica*. Weeding of seedlings has stopped *S. anglica* colonization especially on flats remote from established swards. After their first year young *S. anglica* plants develop rhizomes, and digging by hand or vehicle has the potential to leave viable plant material in the sediments. Hand digging is often tried and may be useful in removing low-density infestations of young plants. Large-scale motorized digging has been attempted by a number of control programs but never repeated. The cost and sediment disposal problems are prohibitive.

The choice of herbicide still relies on trials conducted in the 1960s which found that Dalapon® (sodium dichloropropionate) and some pelleted soil sterilants had a lethal effect on *S. anglica*. Modern herbicides, e.g., glyphosate, are obvious candidates for *S. anglica* control, but field use has inconsistent results and serious trials have only just begun. Tighter British herbicide regulations resulting from 1985 legislation permit the use of only Dalapon for *S. anglica* control, but this chemical will soon cease to be commercially available. Dalapon is a very inefficient herbicide, with a lethal dose of 57 kg/ha in 1,000 liters of water, and its application requirements have restricted the rate and scope of many control programs.

Choice of spraying method is dependent on the accessibility and size of the target that *S. anglica* presents. Helicopter, plane, knapsack, tractor, and low ground pressure vehicle have all been employed successfully. The timing of spraying in relation to the tidal cycle, weather, and the growth stage of the plant determines the likelihood of a dose actually killing the plant.

Although control programs have developed successful techniques to kill *S. anglica*, the large-scale effect of control is variable. Eradication has been possible only with small infestations of young plants, and the permanency of eradication depends on the isolation of a site from sources of reinfection. Expanding marshes have been contained successfully by several control programs, but large-scale (e.g., 60 ha) removal of established sward has been achieved at only one site.

Success of control programs must be judged in terms of their original conservation, amenity, or commerce objectives. The ability of waders to feed on areas cleared of

S. anglica depends on the presence and detectability of prey invertebrates which in turn are controlled by sedimentary factors. Waders have been observed feeding on fine wet sediments cleared of *S. anglica*, but no within-site or within-population response has been quantified. There is evidence that *Zostera* and *Salicornia* will recolonize after *S. anglica* removal from flats. *S. anglica* appears to be only one factor contributing to fine sediment accretion at several sites controlled for amenity objectives. The fine sediments are the main cause of concern to recreation interests, and so amenity objectives have only been partially satisfied by control.

Loss of vigor and die-back in *S. anglica* have been recorded in many marshes and could be regarded as a "natural" control. Anecdotal evidence suggests that die-back is related to plant age, and both genetic- and sediment-related factors are hypothesized as causes. In any case such natural control will occur only after many decades of large-scale *S. anglica* infestation.

Acknowledgments. The material discussed in the presentation is based on work for the Nature Conservancy Council contracted by the Cardiff Bay Development Corporation. I would like to thank my colleagues for advice and slide material, especially P. Doody, D. O'Connor, N. Davidson, R. Jones, G. Boobyer, N. Crockford, and R. Gritten.

Control and Eradication Methods for Spartina in Southland, New Zealand

Keith J. Crothers, Southland District Council, Invercargill, New Zealand

To aid with the reclamation of the New River Estuary in Invercargill, New Zealand, cordgrass *(Spartina townsendii)* was planted in 1931. The plantings were highly successful, achieving complete coverage of the area planted within three years, albeit in varied density.

Within twenty years, *Spartina* covered 100 acres of the estuary, and concern was expressed at the rapidity of the spread. By the late 1970s and early 1980s, an area in excess of 300 acres was infested, and other coastal areas were found to have varying degrees of *Spartina* infestations. Not only had the *Spartina* caused an average sedimentation rate increase of 3 cm per annum but also commercial fish nursery areas and wildlife habitats were under threat.

Small-scale herbicide testing commenced in the mid-seventies and led to large-scale aerial spraying trials in February 1979. It was found that *Spartina* was a difficult plant to control or eradicate, but the combination of high rates of herbicide with low rates of water achieved very good results.

A coordinated control program was developed that enabled both aerial and ground applications of herbicide throughout the 1980s. The herbicides used were 250 g/kg amitrole and 370 g/kg Dalapon® (2,2-dichloroproprionic acid, or 2,2-DPA) as the sodium salt in the form of a water-soluble powder.

Upwards of 40 percent of the total infestations have been treated to date and the control measures have been very satisfactory. Regrowth is minimal and easily dealt with by follow-up spot spraying.

Eradication in many areas of the estuary and certainly in some of the outlying areas appears an achievable objective given sufficient financial resources. There appears to be a good case for classification of *Spartina* as a Class B noxious plant. It is now perhaps opportune for New Zealand to make a national assessment of the *Spartina* situation and formulate national policy regarding its status and control.

Loosestrife, Hydrilla, *and Milfoil: Lessons to Be Learned from These Examples*

Terence M. McNabb, Aquatics Unlimited, Kent, Washington

Purple loosestrife, *Hydrilla*, and Eurasian water milfoil are exotic plants that were introduced to the aquatic and wetland environments of North America within the last century. These plants rapidly became major noxious weed problems. *Hydrilla* and milfoil pose a major threat to navigation, recreation uses, flood control, swimmer and boater safety, and the native ecosystems that they invade. Purple loosestrife is a wetland plant that has no wildlife value and rapidly replaces native wetland plants.

All three plants developed into major problems nationwide before the impact on the environment was established. These plants will establish in a wide range of climatic conditions and lake trophic states. All three species are now the focus of regional and national control efforts.

Historically, there have been problems with the implementation of control efforts that target purple loosestrife, *Hydrilla*, and milfoil. Environmental groups have stopped the use of herbicides on pioneer colonies, allowing them to spread. In other cases, the threat was not recognized until the populations had grown beyond levels that could be economically controlled. State and national boundaries have hampered control efforts through differences of opinion within regulatory agencies as to the benefit or impact of a plant species. Another common problem within states that have active management programs is that once an aquatic weed is brought to a maintenance level, newcomers to the area wonder why control efforts are continuing because they do not perceive the problem that would recur if the control efforts stopped.

A conference was held at the Freshwater Foundation in Navarre, Minnesota, February, 1990, to address the problem of Eurasian water milfoil, which had recently been found in the lakes of Minnesota. Aquatic plant experts drawn from industry and from federal and state research, regulatory, and control programs reviewed the issues and identified essential elements of strategy:

- Enact legislation establishing a milfoil control program; designate a lead agency to coordinate a multiagency strategy with citizen and technical input.
- The key to any effective strategy is education and information. Good data are critical to program effectiveness, and there is a continuing need to develop better control methods.
- Assume that resources are limited; focus approach to use them most effectively. Emphasize the most valuable and endangered water bodies; use monitoring programs to ensure containment; treat pioneer stands and established colonies differently.
- Tailor strategy to the case, especially when planning tactics to control an infestation in a particular lake or river system. *Zone* strategies apply to a broad geographic climate or other regional common characteristic; *place* strategies apply to a particular part of that region such as a state; and *case* strategies apply to a particular water body and take into account its specific environmental conditions.

A Preliminary Review of Smooth Cordgrass, S. alterniflora, *Control with Rodeo®*

Ron P. Crockett, Monsanto Agricultural Company, Vancouver, Washington

Rodeo® herbicide has been widely used for aquatic habitat restoration projects. A recent United States E.P.A. label approval now allows Rodeo to be used for weed control in estuary sites. Preliminary results from two field experiments on the Willapa National Wildlife Refuge show promise that Rodeo may be successful in the control of smooth cordgrass (*Spartina alterniflora*).

Treatments simulated three methods of application: backpack spray-to-wet, helicopter, and hand wiper. Rodeo broadcast rates of 4 lbs. a.e. per acre, and 2% v/v spray-to-wet provided 99 percent control 60 days after application. A 33% Rodeo solution applied with a sponge wiper provided 85 percent control.

For Rodeo to be successful in controlling *Spartina* species, the following guidelines should be followed:

- Avoid applications to plants covered with dust or debris.
- Best results will be obtained if there is at least a six hour interval between spraying and initial inundation from tides or rainfall
- Retreatment of established clumps may be required if detached rhizome segments germinate and reinfest the site.

Rodeo® is a Registered Trademark of Monsanto Co., St. Louis, Missouri 63167. Reference to this or other products does not imply endorsement by the publisher or the workshop sponsors.

Chronology of Spartina *Control Methods in Washington, California, and Oregon*

Barbara Aberle, Washington Department of Ecology

Washington

1975 Department of Wildlife personnel applied herbicides to small test plots of *S. alterniflora* in Padilla Bay. The herbicides Atrizene®, Amitrol T®, and Tordon 10K® pellets were tested.

1978 The Department of Wildlife conducted an assessment study of *Spartina* species in northwest Washington. Applications of the herbicide glyphosate (Roundup® formulation) were tested on small plots of *S. anglica* in Port Susan Bay.

1987 The U.S. Fish and Wildlife Service sponsored a study of *S. alterniflora* in Willapa Bay. This study included an evaluation of mowing, crushing, and herbicide treatment as possible methods of *Spartina* control.

1988 A 1 m^2 patch of *S. alterniflora* was successfully removed by digging at the Niawiakum Natural Area Preserve.

1989 A study by the U.S. Fish and Wildlife Service at the Willapa National Wildlife Refuge tested covering with mats of black plastic as a method for control of *S. alterniflora* in Willapa Bay.

1990 A U.S. Fish and Wildlife Service and Department of Natural Resources project tested two methods of *Spartina* control: mowing and covering with black plastic.

1990 Applications of glyphosate were made on small test plots of *S. alterniflora* in Willapa Bay.

California

1989 The California Department of Fish and Game built a dike around a 450 m^2 patch of *S. alterniflora* in Humboldt Bay to prevent spread of the plant and to eliminate exchange. The patch was mowed and covered with black plastic. Digging was attempted to remove a small clump of *S. alterniflora* in San Francisco Bay.

Oregon

1981 Burning, salting, and covering with black plastic have been tested as control methods for *S. patens* at the Cox Island Natural Area Preserve.

1982 Glyphosate was applied to *S. patens* at Cox Island preserve.

Regional Strategies

Willapa Bay

Mary Lou Mills, Washington Department of Fisheries, Discussion Leader
Richard Strickland, Washington Sea Grant, Reporter

In response to the questions assigned to the working group, those assembled (31 in addition to the leaders) quickly and strenuously agreed that the growth of *Spartina* in Willapa Bay warrants action now, before the end of the next growing season. Because the U.S. Fish and Wildlife Service field season begins in February, the group advocated that in January a list of vital research questions be compiled and a plan of action outlined to address those questions in the coming year. The group then moved on to a discussion of what actions might be appropriate.

At first, a number of possible actions of various types and magnitudes were noted in a "brainstorming" process. As the list grew, however, the discussion was restructured to determine which actions demanded immediate attention and which would require long-term efforts. Given the sense of urgency in the group, emphasis was placed on what could be done on the short term for the next growing season. Some participants suggested an immediate campaign to hand-pull *Spartina* seedlings.

Clumps of Spartina alterniflora *at Willapa National Wildlife Refuge, east of Long Island. (Photo: T. Mumford, Jr.)*

The group soon recognized that the individual actions they were listing might not be carried out, or might have little significant effect, unless they were part of an overall plan that was backed by a commitment of resources from agencies. Therefore, the group determined that the primary short-term requirement is an organizational structure to lead the anti-*Spartina* effort. (This recommendation also addressed the fourth question posed to the group, that of what the workshop organizers should do next besides publish the workshop proceedings.) The recommendation was threefold:

- The lead agency or agencies should be selected. As the largest landowners on Willapa Bay and the agencies with the most direct experience and greatest stake in the problem, Pacific County and the Washington Department of Natural Resources are logical choices as co-leads.

• The existing interagency task force should be continued as a vehicle for focusing the concerns and giving a voice to all the affected parties. Under the guidance of the lead agency or agencies, the task force should be enlarged by some undetermined number to include representatives of affected communities.

• A single person, dubbed the "*Spartina* Czar," should be designated to supervise the anti-*Spartina* effort. Pacific County employs a *Spartina* coordinator, but for greater effectiveness a position reflecting commitment at the state or federal level was deemed crucial.

The working group designated an extensive list of short-term actions, recognizing that resources are probably not adequate to undertake all of them immediately. They noted the importance of setting priorities among these options but did not have time to set the priorities themselves, nor to establish criteria for selecting the priority actions. The group deferred that task to the proposed lead agencies and task force. The recommendations are listed below in no particular order of priority.

Short-term Actions for Managing the Anti-Spartina Effort

• Assess the the present and potential environmental problem and what is known about the effectiveness and impacts of control measures. This assessment would aid in presenting the problem to the public and to government officials.

• Induce private citizens and groups to contact the legislature about funding to support the other actions. The legislature should be contacted by the end of November about a direct supplemental budget appropriation for the current fiscal year, which ends in June, as well as about funding for FY92. There was some uncertainty about whether a $350,000 special appropriation to address *Spartina* had actually been deleted from the Department of Natural Resources budget for FY92, as alluded to by Commissioner Boyle.

• Involve the community in the broadest sense during the coming spring. One prong of this effort would build support for funding and action by educating the public through various means about the seriousness of the *Spartina* threat. The other prong would open channels through which potential opponents of *Spartina* control measures could voice their concerns and thus be brought into the search for solutions.

• Designate *Spartina* as a Class B noxious weed in Pacific County. This would allocate some responsibility for control of the weed to private individuals and land owners.

• Explore the possibilities for integrated pest management as a control measure. One component of such management, the selection of biological control agents such as insects, requires at least three years of testing, so no time should be lost in beginning the search. A first step should be taken by contacting plant pathology and insect experts. Preferred biocontrol options would use indigenous species rather than introduce exotic species. The ergot fungus was cited as one (albeit hazardous to human health) *Spartina* pest that might be adapted as a control measure.

• Explore the potential for improved watershed management to contribute to *Spartina* control. Reduction of sediment input caused by logging practices might make Willapa Bay less hospitable to *Spartina* and might reduce the negative impacts of the *Spartina* that does grow.

• Set priorities among all these options, and determine which can be afforded and which should be done first.

Short-term Actions for Direct Control

- Hand-pull seedlings to prevent establishment of new *Spartina* clones. This could be accomplished by volunteer labor. Some oyster growers have offered to pay laborers to pull seedlings on their beds and some other grounds.
- Supply simple packages of equipment and basic skills instruction to small landowners to allow them to rehabilitate and maintain their own grounds. Mowing, covering, and hand-pulling could be considered for inclusion.
- Identify immediate research needs and set a research agenda for the field season starting in February. Examples of possible research include continued exploration of the ways to make limited herbicide application by spraying and wicking more effective.
- Nature Conservancy and Natural Heritage Program representatives expressed a desire that chemical means not be employed yet on the Niawiakum Preserve; they prefer further mechanical efforts.

Longer-term Actions

- Conduct "fall-back" research to help residents cope in case control measures are ineffective. Such research might investigate possible commercial uses for *Spartina*, utilization by native flora and fauna, ways to predict and detect long-term negative (and positive) impacts, and ways to adapt to any presence of *Spartina*.
- Identify and secure long-term funding from federal, state, local, and private sources.
- Establish a mechanism for citizen monitoring of both impacts and management of the anti-*Spartina* effort. This program was referred to as "watching the watchdogs" and maintaining "squeaky wheels."

Camano Island and Whidbey Island

Don Kraege, Washington Department of Wildlife, Discussion Leader and Reporter

The Camano-Whidbey Island working group concentrated on impacts of *Spartina* and possible actions in the Port Susan and Skagit Bay areas of northern Puget Sound near Stanwood. Potential impacts of *Spartina* in this area were somewhat different from those identified for other infestation areas.

Possibly the greatest immediate cause for public concern is the effect of *Spartina* on property values on Camano and Whidbey islands. The infestation in Triangle Cove on Camano Island already has waterfront property owners concerned due to loss of open water, which has changed accessibility and aesthetics of the bay. In addition to impacts on property values, the group also identified major potential effects on wildlife and fisheries of the estuaries and associated recreation. For example, the Department of Wildlife's Skagit Wildlife Area recorded approximately 140,000 user days of recreation last year. Although not a significant brant use area, the bays are home to approximately 35,000 lesser snow geese which breed on Wrangel Island, USSR, and interchange between the bays and the Fraser Delta, British Columbia—truly an international resource. *Spartina* threatens to out-compete the native three-square bulrush *(Scirpus americanus)* on which the geese rely for food throughout much of the winter. The bays are also used heavily by other waterfowl, shorebirds, and raptors. Oysters do not occur in commercial quantities in this area, but soft-shelled clams have been sought after by commercial harvesters.

Based on the potential impacts identified above, the group agreed that immediate action was warranted in the Camano-Whidbey Island area. An action plan was outlined which focused on coordination, inventory, information and education, research, and control. An immediate need surfaced as the top priority: the development of a regional coordinator position to oversee implementation of an action plan, i.e., a "*Spartina* czar." This person would be responsible for making sure that all aspects of the plan keep momentum and are coordinated among the various agencies, organizations, and individuals involved in the issue. Funding for the position should come from grants or legislative sources.

High salt marsh consisting of Scirpus maritimus *L. and* Spartina anglica, *Davis Slough, Camano Island. (Photo: T. Mumford, Jr.)*

Next in priority should be an effort to inventory the current extent of infestation in the two estuaries. The Department of Wildlife completed a rough inventory in 1979, but this work needs to be updated and expanded to document the current extent of the problem. This effort could be completed by the mapping sections of the resource agencies, combined with ground-truthing to delineate infestation areas not effectively mapped by remote sensing. Along with this work would be the assemblage of historical data on wildlife use of native salt marsh plants to demonstrate potential habitat losses with further infestation.

Concurrent with the inventory effort should be development of an information and education program to accomplish several purposes: enlist public support for control efforts, secure funding, and recruit volunteers to assist in control. The program would also identify current practices that spread *Spartina*, e.g., dredging, clam harvest, direct planting. The group identified a multitude of state and local agencies, organizations, and citizen alliances which should be informed of the situation, including Audubon Society, Ducks Unlimited, Washington Native Plant Society, and various homeowner associations. Education could be accomplished via brochure, videotape, slide show, and news releases. The same information would be useful in raising awareness of the issue among legislators, county commissioners, and agency administrators, thereby encouraging funding of control efforts.

Success of the information and education program would dictate further direction of the action plan, since adequate funding is needed to implement research and long-term control. The situation in these estuaries is somewhat more complex than at

Willapa, since *Spartina* occurs to a large extent intermixed and in close association with desirable salt marsh plants. Control will most likely involve a combination of methods discussed at this workshop. In lieu of further research on acceptable control methods, it appears that the best short-term strategy is to organize extensive agency and volunteer efforts to eliminate seed production, pull newly established seedlings, and eliminate pioneering populations. We may have to accept continued vegetative spread of large *Spartina* infestations in this area until acceptable long-term control techniques can be developed through research efforts. Research should concentrate on control method effectiveness and impacts on non-target species.

Continuation of the *Spartina* Working Group which organized this workshop is critical to addressing the *Spartina* a problem in the Camano-Whidbey Island area and the rest of the state. Due to current agency funding limitations, this cooperative interagency effort will allow continued pooling of resources and expertise to address the problem until a more intensive program can be initiated.

Puget Sound and British Columbia

John Pitts, Washington Department of Agriculture, Discussion Leader
Alma Johnson, Washington Sea Grant, Reporter

The participants in this group quickly agreed that the growth and spread of *Spartina* did indeed warrant action, "the sooner the better," and that the state should consider it a first priority. The rampant spread of *Spartina* in the Willapa Bay region was viewed as embodying a moral in management: Pioneer colonies must be eliminated while they are still manageable.

To accomplish this, the group recommended that a lead agency (with a lead person) be designated immediately to:

- coordinate *Spartina* activities among the state and regional agencies,
- determine the jurisdictions and primary interests of tribal, federal, state, and local agencies, and
- locate funding and manpower for *Spartina* control.

Additionally, it recommended that pioneer colonies be quantified for a first inventory in each county. The local government can help identify ownership of the land on which such colonies are found and coordinate control efforts. Environmental groups, conservation districts, cooperative extensions, and weed boards are local resources that can be tapped for assistance.

The group stressed the importance of involving not only agencies but also private citizens in efforts to control *Spartina*. A concerted educational program is needed, to explain to land owners, land users, community groups, and other areas of the public what *Spartina* means to the Northwest Pacific coastal region, why it is important to control it as quickly as possible, and how it can be done (e.g., covering, digging out, hand-pulling, and spraying). Educational "hit teams" (headed by *Spartina* experts) can help gain the cooperation and concern of the public.

The group agreed that it is vital to engage the attention of the news media to report *Spartina*-related activities. Keeping *Spartina* in the news would sensitize people to the seriousness of the situation and, in so doing, create a favorable environment for funding control.

Controls, once they have been established, should be monitored, using a protocol that will have to be developed. Positive and negative effects should be documented and published, and alternative control plans implemented if the original choice does not succeed.

Participants in working session on regional strategies. (Photo: V. Loe)

In conclusion, the group outlined the action to follow the *Spartina* workshop:

- Identify points of contact in agencies and community groups.
- Record consensus of plenary group as advising a "100% attack."
- Target threatened groups or users with specific information on the *Spartina* problem (e.g., oyster industry, bird watchers and protectors, flood control managers).
- Get the attention of local and statewide news media for *Spartina* issues.
- Develop monitoring protocols.
- Explore *Spartina* as a management tool in some areas.
- Set priorities. Recommended as first priority: the eradication of pioneer colonies, especially of *S. patens*.

Oregon and California

Steve Harbell, Washington Sea Grant, Discussion Leader
John Callaway, Louisiana State University, Reporter

In Oregon the main species of concern is *Spartina patens* at Cox Island, in the Siuslaw Estuary. It appears that the plant is limited to one area and is not spreading extensively by seed. However, because of the impacts to native marsh vegetation, *S. patens* should be eradicated before it begins to spread. Because it is found in the mid-marsh, the substrate is very firm, and it should be relatively easy to mow. Mowing should be on a regular basis, with some monitoring of success under different mowing regimes. Although there has not been public agency support to remove *Spartina* in Oregon, the Cox Island land is owned by the Nature Conservancy, and it is hoped that they will take a lead role in this eradication project. The only other *Spartina* species in Oregon is *S. alterniflora*, and its distribution is very limited, with one small patch in the Siuslaw estuary. Because of its extremely limited distribution, it should be very easy to remove, with repeated mowing or covering.

In California, the main area of concern is San Francisco Bay. The best approach to the problem in this area is to remove any small, newly established populations before they become well established, and control *Spartina* at a few locations where eradication could be attempted. Both *S. anglica* and *S. patens* currently are found in very small patches and could be eradicated completely. *Spartina densiflora* has a larger distribution, but it should be limited to its current distribution in Corte Madera Marsh.

The worst problem in San Francisco Bay concerns *S. alterniflora*. Because of the very high potential for spread, this is the most immediate concern in the bay. Attempts are currently under way to eradicate it from Hayward Marsh (a recently restored salt marsh) where it is beginning to spread very quickly. This eradication will provide very important information on techniques and will give an indication of potential success rates at other sites in San Francisco Bay.

We also discussed some other important issues concerning the eradication or control of *Spartina* in San Francisco Bay. The use of biological control methods is not advised in San Francisco Bay because of the presence of native cordgrass, *S. foliosa*, and likely detrimental effects that such control methods would have on the native species. Additionally, the presence of the California clapper rail, an endangered species, in San Francisco Bay will complicate the issue of eradication. Although it has not been determined to what extent the clapper rail uses *S. alterniflora* versus *S. foliosa*, rails have been seen using the introduced cordgrass areas. Also, it was suggested that a detailed model be developed of the spread of *S. alterniflora* over the next 5-10 years, to highlight the potential for impacts in San Francisco Bay. This model should include best-case (no seedlings) and worst-case (high rates of seedling establishment) scenarios, to show the possible range of impacts.

Memento

Some Considerations about Exotic Spartina Invasions

Daniel E. Campbell, University of Rhode Island, Narragansett

Scientists should be discriminating in their choice of the words to describe a problem. Words that imply the worth of a thing prior to its scientific evaluation introduce unnecessary bias into the process of scientific investigation and into the public perception of natural processes. For instance, animal and plant invasions are often described in pejorative terms such as "infestation," even though some introduced species have been beneficial on the whole, e.g., world-wide introduction of *Gambusia*, the mosquito fish; the introduction of nereid worms to the Caspian Sea; and the introduction of striped bass to the West Coast of the United States. In the People's Republic of China, introduced *Spartina anglica* is considered a positive addition to the ecosystem because of its ability to stabilize shorelines and reclaim land from the sea. On the other hand, *Spartina* introduced into New Zealand is perceived as a public nuisance because in some estuaries it colonizes the mudflat feeding grounds of wading birds. There is no way to know *a priori* what the net effect of the introduction of exotic *Spartina* in Washington will be, so for the present I believe we should adopt an objective tone in our deliberations. The problem of animal and plant invasions is examined in an excellent book by C. S. Elton (1958), who observes:

> We are faced with the life-and-death need not just to find out new technological means of suppressing this plant or that animal, but of rethinking and remodelling and rearranging much of the landscape of the world that has already been so much knocked about and modified by man; while at the same time preserving what we can of real wilderness containing rich natural communities.

Elton also provides the following assessment:

> The enormous problem which we face is to manage, control, and where necessary alter the pattern of food chains in the world without upsetting the balance of their populations.

Elton's assessment leads us naturally to the field of ecological engineering where solutions to some problems posed by exotic invasions may lie. Odum (1989) defines ecological engineering as the techniques for designing and operating the economy of man with nature. Traditional engineering replaces nature with man-made solutions, whereas ecological engineering produces designs that use natural structures and processes to solve problems. Ecological engineering may also be thought of as the management of the process of ecological self-organization.

It is this process of ecosystem self-organization that we are observing as *Spartina* spreads in Willapa Bay and other areas of coastal Washington. Because *Spartina* is the primary producer supporting an entire ecosystem, we may expect that native species that can adapt to the new conditions produced by *Spartina* will participate in the self-organization process. If we are to manage this process, we must have a set of principles to guide the creation of an ecosystem that not only will be useful to man but also will fit comfortably within the regional mosaic of ecosystems. Once again, Elton expresses this idea most eloquently:

> Unless one merely thinks man was intended to be an all-conquering and sterilizing power in the world, there must be some general basis for understanding what it is best to do. This means looking for some wise principle of co-existence between man and nature, even if it has be be a modified kind of man and a modified kind of nature.

One such design principle has been developed by H. T. Odum following Lotka and others, and it is expressed by the maximum power principle and its corollaries. Maximum useful power production appears to be the primary factor that determines survival in nature over the long run. In any self-organizing system, designs that conform to this principle and its corollaries ultimately will be produced. Ten characteristics of systems that maximize power are given by Odum (1989):

- Reinforcement of autocatalysis. (Positive feedbacks exist that increase useful energy consumption.)
- The energy availability controls the exponent of autocatalysis. (The intensity of energy use depends on the energy available.)
- Alternating pulses of production and consumption.
- Surges of consumption beyond production.
- Storage of recycling materials.
- Nonautocatalytic support for consumers. (Supplies a seed population that can reproduce rapidly when needed.)
- Competitive and cooperative components in sequence.
- Power maximizing frequency of long period pulses.
- Self-regulating time constants to maximize useful filtration of energies.
- Impedance characteristics for control of timing.

The overall goal of managing ecological self-organization is to reduce man's direct power over nature by allowing nature to do some of the work that engineers, chemists, and biologist now do. Ecological engineering solutions work with natural processes instead of against them. Research should be done to facilitate useful self-organization of the developing *Spartina* ecosystem in Willapa Bay. Controlled experiments could be set up in which various native species are added to test *Spartina* plots and the results recorded. In this way, we can facilitate the development of a *Spartina* ecosystem that will be beneficial.

Elton tells a story which illustrates the human side of the problems presented by ecological change. He compares humanity to passengers together on a long train ride where there are three great questions waiting to be asked about the relationship between man and nature. These three questions give rise to three separate viewpoints from which conservation can be justified.

The first question he raises is a religious one and not usually considered first. Many people in the world believe that animals have a right to life. They ask, should we not preserve and protect all sentient beings as is their birthright? Millions more people would agree that animals at least have a right not to be persecuted or abused, and still more would agree that a species of animals should not be driven to extinction.

The second question is an intellectual one asked by artists, poets, and scientists. They ask, should we not value and preserve nature because it is beautiful, exciting, and interesting? Nature is the greatest subject for human study, research, and artistic inspiration.

The final question is a practical one asked by many who have observed the worst excesses of man's use and abuse of the natural world. These people want to know if mankind is the worm in the heart of the rose, who by reproduction, consumption of scarce resources, and other actions has brought about much of the degradation and disruption of nature that we observe all around us. They ask, what can we do to reclaim our shattered world or at least mitigate our present excesses?

For Elton the answer to all three questions is found in the promotion of ecological diversity. Ecological diversity insures the survival of a maximum number of species; it produces interesting and beautiful surroundings through variety; and it enhances the stability of ecosystems. Elton recommends that as change occurs in an ecosystem, we should immediately ask three questions which reflect humanity's three great concerns:

- What animals and plants live in the new system and which ones are displaced by it?
- What beauty or interest is lost or gained in the change?
- What extra risk will be added to the accumulating instability of communities and ecosystems by the change?

Do we know the answer to these questions with regard to exotic *Spartina* invading the estuaries of coastal Washington and the Northwest? If not, scientific research must quickly provide some of the answers if we are to evaluate the overall impact of invading *Spartina* and decide whether proposed eradication, control, or management strategies are most suitable for the establishment of a productive and sustainable mosaic of ecosystems in the future.

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