Appendix 3
Vegetation Management in Tidal Marsh Edges, San Francisco Estuary

Summary profiles of selected weeds species high tidal marsh edges, San Francisco Estuary

Background information on species biology, threats, and general control methods summarized from Hickman (1993), Bossard *et al.* (2000) and author's observations, unless otherwise indicated. For photo illustrations, see Appendix 2.

Agrostis avenacea, Australian bentgrass

Life-form and life-history: Perennial bunchgrass, but sometimes behaving as annual, completing life-cycle in one year. Growth habit is either matted or erect clump, with broad to inrolled leaf blades. Silky-branched panicles with thread-like branches develop in large masses. When they mature as seedheads, panicles detach and become wind-dispersed, like filamentous tumbleweeds. Seedheads are readily transported by wind across smooth surfaces (dried mud beds of seasonal ponds, shorelines, ditches, road surfaces) and deposit against vegetation or fences, accumulating in large masses. Seeds germinate on drying beds of seasonal ponds, seasonal wetlands, wet levee road or path edges, or high tide shorelines of brackish marshes. Population increase rates can be dramatic: new colonies can dominate large acreages of open habitat in a single year.

Likely effects on tidal marsh edge vegetation: Unknown; currently this species is primarily a weed of brackish nontidal wetlands in the Bay Area, and has recently established in previously vegetated high tide shorelines and levee paths. It has the potential to dominate newly graded or disturbed wet soils at bay edge habitats.

Management options: Detection and early removal of seed sources near tidal marshes is the best and most appropriate control method for the early stages of regional invasion. Manual pulling of plants in small colonies, during early flowering stages, is probably the most feasible method. Mowing, cutting, of more extensive stands may be used to temporarily delay seed production, but mowed/cut stands will rapidly regenerate new flowering culms. Mowing/cutting may be challenging where this species occurs mixed in native vegetation. High salinity in well-drained soil appears to reduce growth, reproduction, and competitiveness, so late spring/summer salinization (saline irrigation) may be applicable to control in tidal marsh edges near high tide line. Herbicide use may be problematic in high tide zones of tidal marshes because the loose, open structure of the plant, and diffuse, filamentous panicles may make spray contact difficult.

***Brassica nigra*, black mustard** (see *Raphanus sativa,* wild radish; ecologically equivalent in context of tidal marsh edge vegetation management*)*

Annual non-native grasses

(*Avena sativa, Briza maxima, Briza minor, Bromus diandrus, Bromus hordeaceus, Hordeum murinum* ssp. *leporinum, Hordeum marinum ssp. gussoneanum, Lolium multiflorum*, others)

Life-form and life-history: winter-annual grasses, generally erect or ascending. Germination occurs with earliest fall rains that wet the upper soil profile; vegetative growth occurs in winter, flowering in late winter/early spring (depending on temperatures). Seeds mature from spring to early summer (timing, rate dependent on temperature, rainfall; season is extended by late rains), and disperse throughout summer and fall until next fall's rains.

Likely effects on tidal marsh edge vegetation: Rapid and early competition for near-surface soil moisture in winter-spring, pre-emption of space of native seedlings of annual native forbs, perennial grasses, bulbs and shrubs. Annual grasses may exhaust soil moisture in upper soil horizons soon after rains cease, and interfere with re-establishment of native grassland or scrub species. They are especially abundant to dominant in disturbed soils or nutrient-enriched (elevated nitrogen) soils. Leaf litter accumulation of annual grasses (thatch) promotes self-regeneration: annual grasses can germinate and establish in their own leaf litter mats, while, suppresses survivorship of native forbs and bulbs. Severity of invasion and competition effects varies among sites, soils, and grass species. Bromes and oats tend to be aggressive around tidal marsh edges.

Management options: Control should be aimed at reduction of seed production and accumulated leaf litter, and reduction of availability of open soil habitat by increasing cover of perennial or woody native species. If native annual *Hordeum brachyantherum* is detected, modify control methods to manual local weeding.
Mowing/raking option: Treat selected patches by mowing or manual cutting of annual grass stands below the height of flowers or immature seed heads during peak flowering in early-mid spring (time varies with temperatures and rainfall, highly variable among years; inspect local condition frequently). In years of late rainfall, regeneration of branch flowering culms may occur, and repeat mowing may be necessary. Rake and remove current-year and old accumulated leaf litter of mowed/cut stands, for two successive years per patch; treat adjacent patches during 3rd year fallow (rest period) of initial treatment patch. After at least one year of mowing/seed reduction treatment, replant with native creeping perennial vegetation that can regenerate after mowing (native clonal perennial grasses, sedges).

Raking-only option: Heavily rake treatment patches in late summer/fall annually to reduce abundance of accumulated thatch (leaf, shoot litter) and seed, exposing soil surface. Mow/cut regenerated annual grasses the following spring. Apply raking option if abundance of low-growing annual grasses (*Aira* spp, *Vulpia* spp.) increases after mowing treatment.

Carpobrotus edulis* x *chilensis **Iceplant**

Life-form and life-history: Clonal perennial succulent subshrub, prostrate, mat-like, massive. Produces abundant small seeds in fleshy fruits, dispersed by vertebrates.

Iceplant can colonize new sites by seedling establishment, and also by vegetative (clonal) fragments dispersed by winter storms in drift-lines at the high tide shoreline.

Likely effects on tidal marsh edge vegetation: Forms monotypic stands in coastal bluffs, coastal grassland, scrub, displacing native coastal grassland and scrub. Persistent leaf and stem litter.

Management options: Manual removal is labor-intensive, but can be effective for small colonies. Disposal of heavy piles of succulent shoot masses is problematic. Leaving piles intact usually results in regeneration, so stockpiles of removed iceplant must be covered with black plastic until it decomposes. Glyphosate herbicide treatment can be effective. If stands of iceplant are mixed with native vegetation, manually removal is indicated.

Centaurea solstitialis, C. melitensis **Yellow and Napa starthistles**

Life-form and life-history: Erect taprooted forb, short-lived perennial or winter annual. Germinates with fall rains from short-lived seed bank; overwinters as vegetative rosette with taproots. The rosette bolts in mid-late spring, branches, and flowers early summer (usually June) to late fall. Severed (mowed, cut) immature seedheads may continue development and yield viable seed. Severed bolted stems can resprout from the base and branch close to ground level.

Likely effects on tidal marsh edge vegetation: Aggressive invader of grasslands, including undisturbed grasslands; prefers disturbed annual grassland. Very similar to yellow starthistle, with which it is easily confused.

Management options:

Mowing strategy: Interrupt life-cycle for several consecutive years: prevent regeneration of short-lived seed banks, and gradually exhaust seed banks, while replacing stands occupied by star-thistle by dense perennial vegetation or shrub cover. Tactics: Cutting or mowing annual plants to ground level during late earliest flowering stages, within 10 days of first flowering. Prevent re-flowering and seed set by monitoring for resprouts, and follow-up mowing, cutting. Manual pulling, digging may be feasible for isolated individuals or clusters. Repeat treatment for several consecutive years in each treated patch to eliminate local seed bank.

Herbicide strategy: Glyphosate, Clopyralid herbicides may be effective, but difficult to apply without adversely affecting non-target native vegetation at appropriate treatment times. Herbicide application may conflict with wildlife management

Post-treatment revegetation strategy: When starthistle density is reduced to low levels, plant cover crop grasses, or directly revegetate with native creeping sod-forming grasses, sedges, rushes or shrubs to prevent long-term recolonization by starthistles.

Conium maculatum**, poison-hemlock**

Life-form and life-history: Coarse, tall, erect biennial or winter annual broadleaf plant, growing from large rosette in winter and spring. Plants may remain vegetative for a year, then bolts and branch into tall (over 2 to 3 m) mature flowering/seed-bearing form. Some populations may behave as annuals. Leaves are compound, fern-like; sap highly toxic ingested or in skin contact. Plants die back in dry summer/fall, and provide minimal winter cover. Large, dense colonies can dominate levees and disturbed tidal marsh edges on clay soil that remains moist in spring, particularly in the North Bay.

Likely effects on tidal marsh edge vegetation: Where dense colonies occur, they exclude seedlings of native vegetation and prevent establishment of native plant communities.

Management options: Manual removal is feasible for small stands, but extensive stands require other methods. For all options, seed production should be prevented to control this annual species. Longevity of the seed bank is relatively short-lived (less than 3 years; most seed germinate the year following production), so control efforts may focus on preventing seed production for three consecutive years, rather than killing all plants. Cutting plants below the soil surface (mattock, tile spade) can kill the growing shoot tip of rosettes (pre-flowering, vegetative), but superficial cutting (weed-whackers, mowing, swing-blades, etc.) can result in resprouting and branching slightly later in spring. Mowing, cutting to near ground level after stems elongate and begin flowering may be lethal, especially if soil and temperatures in late spring or summer are dry enough to limit regrowth. Mowing at this advanced stage of growth, however, is very difficult. Plants are salt-sensitive (especially tender foliage), and saline irrigation or vinegar/soap sprays are likely to cause defoliation. Soil salinization is likely to inhibit and injure growth and survival of seedlings and juvenile plants. Herbicide application (glyphosate) is feasible during pre-bolting, vegetative rosette stages, especially in nearly pure stands.

***Cortaderia jubata*, jubata grass**

Life-form and life-history: Perennial, extremely large evergreen bunchgrass, with coarse, harsh saw-tooth edged foliage up to several meters long, and feathery reed-like flowering culms three to four meters tall or more. (The similar Pampas grass (*C. selloana*) has hairless leafstalks and white, loose, plumed seed-heads,). Jubata grass can dominate patches of bay mud fills above tide-lines, on levees or flats. Jubata grass produces asexual (clonal) seeds, without cross-pollination. It is invasive mostly where maritime climate (fog zone) prevails, mostly near the Central Bay. It is locally abundant in Marin County's estuarine shoreline.

Likely effects on tidal marsh edge vegetation: Local dominance of jubata grass colonies (or pampas grass) can displace native vegetation, particularly following disturbances.

Management options: Manual or mechanical removal with mattocks, brushcutters or chainsaws is practical and effective, but labor-intensive and hazardous because of sharp, saw-like foliage. Seedling removal is efficient. Prevention of seed production by removing flowering panicles before they mature is a useful temporary, short-term prevention strategy if removal of plants cannot be scheduled in time to prevent reproduction. Evergreen jubata grass can also be treated with herbicide spray in late summer/fall (when adjacent native plants are least exposed), and slowly die over winter and the following spring.

***Dittrichia graveolens*, stinkwort**

Life-form and life-history: Mediterranean forb, ecologically similar to native tarweeds and spikeweeds (*Madia, Hemizonia, Centromadia* species) Annual erect broadleaf plant with resinous foliage, green in summer, flowering and seeding in fall. It establishes in disturbed alkaline or subsaline soil, particularly on edges of paths, roads, on levees or adjacent grasslands. Abundant wind-dispersed seeds are transported in fall and winter.

Likely effects on tidal marsh edge vegetation: Uncertain, but potentially able to colonize disturbed soils, particularly after grading. It is unknown whether this species is able to persist in abundance during succession, or whether it is dependent on disturbances.

Management options: Manual pulling of plants in late spring/early summer, when they are readily identifiable as vegetative plants, before flowering, is recommended. Large single-species stands too large for manual pulling maybe injured or inhibited (reduced or delayed seed production, increased mortality) by spray applications of vinegar/soap solution (dessicant), saline irrigation, or herbicide. Mowing or cutting alone is likely to result in resprouting or branching. If the species occurs mixed in large stands of native vegetation, manual pulling or saline irrigation may be the most viable options.

***Ehrharta erecta* erect Veldtgras**s

Life-form and life-history: This is a perennial bunchgrass with erect to strongly spreading (decumbent) stems, nearly evergreen in San Francisco Bay. Winter-spring growth patterns are similar to annual grasses: rapid leaf growth occurs in moist months, but in summer, green leaves persist, particularly in shaded or moist areas. It tolerates sandy, dry soils in summer, but ceases growth. It produces abundant seeds and seedlings, which are capable of establishing in deep shade and emerging through heavy leaf litter. Established plants have tough, tenacious fibrous root systems that are difficult to pull manually, and tend to leave rooted fragments with buds that regenerate after pulling. The longevity of the seed bank is not known with precision, but based on horticultural experience in San Francisco, persistent viable seed banks are likely to last at least 2-3 years.

Likely effects on tidal marsh edge vegetation: Potentially severe, but the distribution of this species is currently very limited in San Francisco Bay. Mature populations form mat-like turfs like rhizomatous perennial grasses, even under dense shade of conifers or evergreen shrubs. In coastal vegetation, *E. erecta* replaces native ground layer in coastal habitats, exerting intense competition with native seedlings. It disperses and spreads very rapidly in coastal habitats, including rock crevice habitats.

Management options: Prompt removal of flowering and fruiting culms by cutting is necessary to stop seed production in the short-term. Manual removal by pulling may be feasible in loose, sandy soils, but pulling usually results only in fragmentation. Herbicide spot-treatment (glyphosate) is effective. Soil salinization is also a likely effective control for this salt-intolerant grass, but repeated saline irrigation would be necessary for full control. Detection (recognition, marking/flagging) is key to control. Control will depend on intervention during early stages of spread.

Foeniculum vulgare Fennel

Life-form and life-history: Erect, coarse perennial forb with multiple shoot crowns, taprooted. Summer-flowering, with mature seed in fall. Reproduces by abundant seed with no specialized dispersal syndrome.

Likely effects on tidal marsh edge vegetation: Establishes tall dense stands readily on disturbed, dry, pre-empting space for colonization native species. Fennel is less invasive in intact soils of grassland. Seeds are consumed by many small passerine birds, and presumably small mammals, in fall and winter. Foliage is habitat for larval stages of native butterfly, anise swallowtail. Fennel provides minimal cover in winter.

Management options: For small populations, manual removal can be done by severing the crown from taproot below ground level with a mattock or sharp tile spade. This is likely to kill individuals, but seed banks should be expected to regenerate around crowns for at least 2 years. Spot-treatment with glyphosate herbicide is most effective on young, unelongated shoots or crown-sprouts, but mature plants are relatively insensitive to glyphosate applications because foliar coverage (spray-to-wet) is difficult to achieve with feathery foliage on tall plants. Glyphosate treatment of cut crown stumps has been reported to be relatively ineffective, but treatment of young resprouts following cutting may be more effective. Alternatives to herbicides or manual removal may include spring mowing of dense stands, followed by solarization or black plastic.

Genista monspessulana French broom

Life-form and life-history*:* Erect shrub, evergreen generally 5 to 10 ft tall. Brushy, ascending green branches; flowers in winter-spring. Produces abundant hard-coated seed, slow to germinate; forms very long-lived, persistent seed bank. Broom readily stump-sprouts from above-ground cuts, but stems severed below ground level infrequently regenerate.

Likely effects on tidal marsh edge vegetation: Broom forms dense stands and abundant seedlings that inhibit seedling establishment of native vegetation. Broom converts grassland, low scrub, forest herb layer to broom stands. It also deposits nitrogen-rich leaf litter and root residues, facilitating invasion by weeds with high relative growth rates, such as annual grasses, after broom is removed. Seedlings are recruited in substantial numbers from disturbed soil seed banks for many years after seed reproduction has been eliminated.

Management options: Manually pulling seedlings and juveniles (pre-flowering, small shrubs) is effective for controlling the leading edges of invasions and outlier colonies. Mature stands require concentrated effort, such as brush-cutting or manual cutting, followed by herbicide (glyphosate) spot-treatment of young resprouts or cut stumps, or uprooting with weed wrenches. Uprooting mature plants tends to disturb soil and recruit more seedlings.

Lepidium latifolium Perennial pepperweed

Life-form and life-history: Clonal perennial, root-sprouting from adventitious buds on fleshy rhizome-like roots. Juvenile rosettes (short stems, all leaves near ground level) occur first year; these bolt to become straight, mostly unbranched erect main stems with branching terminal flowering panicles. These produce extremely large numbers of small whitish dry fruits that "pepper" the ground surface when they disperse. Seedling establishment occurs in disturbed soil or debris, but seldom under shaded leaf canopies or accumulated leaf litter. Massive monotypic colonies form in brackish wetlands.

Likely effects on tidal marsh edge vegetation: Tall, dense, often single-species stands of perennial pepperweed can prevent native vegetation from establishing, and clonal spread of colonies may displace native vegetation, particularly shorter broad-leaf species.

Management options: Seedlings and isolated juvenile plants should be detected early and removed by digging and uprooting, or overexcavating around plants to ensure that no viable roots are left. Do not pull or dig mature clonal colonies; mechanical removal tends to cause fragmentation of roots, stimulating root-sprouting. Repeated mowing during the flowering period (May-October) can only retard seed production, but will not weaken or reduce clonal populations. Mowing followed by solarization or black plastic may be partially effective as a control method, but very long treatment periods and follow-up treatment for lagging resprouts would be necessary because of persistent root sprouting. Foliage is not tolerant of salt spray, even though plants are tolerant of saline soil: overhead saline irrigation on hot, windy days may desiccate and defoliate. Herbicide treatment (glyphosate, imazapyr) by spray or wick application, with repeated applications after resprouting, the only short-term method likely to be effective for control. Long-term vegetative control is recommended by replanting pepperweed removal sites with creeping wildrye.

Phalaris aquatica, Harding grass

Life-form and life-history: Harding grass is a tall, coarse, evergreen perennial bunchgrass with short, thickened persistent rhizomes than widen the clump to become a dense mat over time. It is deep-rooted and can access soil moisture throughout the summer, enabling it to remain green and growing slowly until fall rains reactivate rapid vegetative growth. It reproduces readily by abundant seed produced on tall (over 1 m) culms. It grows in both wet meadows and dry uplands with clay soils, usually where grasslands have been disturbed in the past. It is most abundant on fertile clay soils, and spreads most rapidly on clay soil that is moist throughout the spring. It spreads by dispersal of abundant seed. The longevity of dormant seed is not known.

Likely effects on tidal marsh edge vegetation: Harding grass is primarily a threat to grassland vegetation of levees and natural grassland slopes above the high tide line, where it can dominate vegetation.

Management options: Repeated mowing in spring and summer, close to the ground level, can inhibit but not kill established stands, and mowing can prevent seed production. Following mowing, solarization or herbicide application can be applied as more lethal control methods in terrestrial grasslands near the tidal marsh edge. Solarization and salinization (saline irrigation) may cause significant mortality, but the persistent rhizomes may retain some viable buds that regenerate following treatment; follow-up treatment should be presumed to be necessary.

Raphanus sativa, wild radish

Life-form and life-history: Winter annual or short-lived perennial, growing from a vegetative, taprooted rosette in spring, and bolting into a branched, flowering, and fruiting plant by summer. In moist, cool, locations, plants may behave as perennials, particularly if they are cut, injured, or browsed. In disturbed clay soils of levees, they may form extensive and persistent single-species stands, especially in the North Bay. Seed are produced in dry "pods" (silicles) in summer and fall, dispersed mostly near the parent plant. Longevity of seed is not certain, but most seeds lack innate dormancy and appear to germinate rapidly the season following production. Some seed may remain viable for several years.

Likely effects on tidal marsh edge vegetation: Dominant stands of radish can prevent establishment of native plant communities.

Management options: Reducing or preventing seed production is key to control of this primarily annual weed. Repeated mowing or cutting during early flowering/late

bolting stages can delay flowering and seed production, but mowed/cut plants are likely to resprout. Repeat mowing or other follow-up control is therefore needed. Mowing early in vegetative (rosette or early stem elongation) development is unlikely to be effective. Radish is injured or killed by high salinity, so salinization (saline irrigation) can be used to defoliate flowering stands and inhibit regrowth or cause mortality before seed production. Vinegar/soap solution sprays (dessiccant) may be effective controls during seedling/rosette stages, but larger plants with well-developed taproots are likely to recovery (with delayed development and reduced vigor) following defoliation. Herbicide (glyphosate) application may be effective in treating extensive single-species stands.

Salsola soda **Mediterannean saltwort, saltwort**

Life-form and life-history: Annual succulent salt-tolerant forb, decumbent to ascending, up to 0.5 m. Produces abundant buoyant fruits, dispersed by currents and waves, deposited near high tide lines of estuaries, in beaches and salt marshes. Widespread, non-local seed sources occur around San Pablo and San Francisco Bay.

Likely effects on tidal marsh edge vegetation: Saltwort usually has very concentrated, localized distribution along shorelines, particularly debris in drift-lines. It may compete with *Atriplex triangularis, Grindelia stricta*, other high-tide line species, especially at seedling stages.

Management options: Manual pulling of seedlings and pre-flowering plants (spring to mid-summer). Pulling mature plants bearing ripe seed tends to increase seed dispersal. Seedlings with slender, long, cylindrical leaves may be difficult to recognize because they are often coated with grayish silt deposits, and because they do not clearly resemble mature plants. Cutting large stands is not effective because remaining branches persist, and may proliferate new growth.

Rubus armeniacus (R. discolor) **Himalayan blackberry**

Life-form and life-history: Robust sprawling and suckering shrub, nearly evergreen, to 10 ft tall. First-year canes (primocanes) vegetative, bearing hooked thorns or prickles; lateral branches flower and fruit second year. Canes senesce after fruiting. Vegetative canes act like stolons, swelling and rooting on contact with ground; adventitious shoot buds on lateral roots act like rhizomes; these form clonal colonies. Shoots can emerge from buds that form on roots near the soil surface, spreading by suckering. Cut plants also regenerate from deep-set below-ground buds. Birds disperse fruit and seed; establishes readily by seed, favoring moist microhabitats.

Likely effects on tidal marsh edge vegetation: Large colonies can cover ground layer, shrub layer of native vegetation and persist indefinitely. Colonies prevent disturbed sites from recovering native vegetation.

Management options: Blackberry vigorously regenerates from suckers, resprouts of stumps, for years after cutting even to ground level with brushcutters. Manual removal is difficult and hazardous, requiring protective clothing because of harsh thorns. Soil salinization in spring and summer, especially saline irrigation of foliage on hot, windy days (leaf surface evaporation) is likely to cause significant dieback, but vegetative regeneration is likely to occur in the following year. Treat with glyphosate spray during spring vegetative growth or early flowering. Responsiveness to glyphosate is reduced uptake after fruiting.

Oxalis pes-caprae **Bermuda-buttercup, Bermuda-sorrel**

Life-form and life-history: Perennial clonal fleshy herb, spreading from bulbils (viviparous production of bulbs in maturing inflorescence) and bulbs formed on fleshy rootstalks. Dry-season dormant, vegetative emergence in fall; flowering December-April in coastal California. Oxalis forms dense mat-like foliage in winter-spring, flowering also winter-spring. It rapidly withers in late spring, enters dormancy, and is difficult to detect in summer. It disperses mostly by gravity, slope movement, and disposal of earthen fill containing bulbs.

Likely effects on local native plant populations: Oxalis strongly interference with seedling establishment of almost all fall-germinating/winter-germinating plants, especially annual native herbs. Proliferates fastest in disturbed soils, but also invades intact soils.

Management options: Mechanical removal (digging, pulling, hoeing) is infeasible because innumerable bulbs fragment during digging. Systemic herbicide (glyphosate) is the most effective short-term control method. Long-term control may be achieved by planting over it with tall native clonal perennial vegetation, such as creeping wildrye. Black plastic/solarization methods are generally ineffective with only one year of treatment because of persistent dormant bulb population, fragmentation of resistant or dormant bulbs. Soil salinization or solarization may be effective treatments if repeated for multiple consecutive years.

Tetragonia tetragonioides **New Zealand spinach**

Life-form and life-history: Short-lived perennial forb; procumbent, often mat-like, nonclonal; evergreen, fleshy. Produces abundant buoyant seed, often deposited in dense maternal seed-shadows in absence of shoreline erosion.

Likely effects on local native plant populations: This species is limited to shoreline habitats. Mat-like stands are likely to compete with native shoreline annuals, perennials.

Management options: Manual removal, with bagging of seed-bearing plants. Harvested plants with seed may be disposed in warm, arid, upland locations, away from wetlands, or disposed off-site.