EARTH SANCTUARY®

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Earth Sanctuary Ecological Design – 500-Year Plan
Freeland, Washington

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Introduction

The landscape and ecological restoration design currently under way at the Earth Sanctuary, Freeland, Washington on South Whidbey Island, was born from the vision of Chuck and Claudia Pettis to create a sanctuary for both nature and people. The Earth Sanctuary's 72 acres are unique in the South Whidbey Island landscape for their complexity and abundance of aquatic, wetland, and forest habitats. The Earth Sanctuary's three ponds, known locally as the Newman Ponds, have been recognized for their importance as waterfowl habitat and have been designated as a *Habitat of Local Importance* by the Whidbey Audubon Society and the Island County Critical Areas Program. On any given spring morning one may see the local pair of nesting osprey and their new fledglings, adolescent and mature bald eagle, wood ducks, killdeer, tree and Violet-green swallows, cinnamon teal and great blue heron, among others. The Earth Sanctuary is also the home of the Earth Sanctuary Meditation Center a non-denominational, non-sectarian spiritual retreat center.

It is the intention of the Pettis' to combine ecology, art and spirituality in the design of the Earth Sanctuary landscape. The interdisciplinary Earth Sanctuary design team includes: CEO and director Chuck Pettis, architect David Rousseau, landscape architect Dan Borroff, ecologist Kevin Fetherston, artist Mike Sweeney, landscaper Dave Schmidt and spiritual advisor H.H. J.D. Sakya. The human-nature interface of both the designed and natural landscape has been deliberately cultivated from an ecological perspective. The design of the Earth Sanctuary – including stone megalithic art works, landscape design, and the ecological restoration of historically degraded forest and wetland ecosystems – has been guided by the overall goal of preserving, protecting, and restoring the land's biodiversity.

The purpose of this report is to present an overview of the Earth Sanctuary ecological design where we have combined ecological science, landscape design and environmental art. The design process is called the *500 year plan* in acknowledgement that the ecological communities of the Earth Sanctuary will take hundreds of years to recover from past land use practices before they develop into their fullest expression as a diverse and mature ecosystem. Also, the expression *500-year plan* acknowledges the human commitment necessary to preserve, protect, and restore the Earth Sanctuary landscape over the long term. This commitment is being accomplished through the development of land conservation covenants and the design and implementation of the phased landscape and restoration plan.

This report presents the Earth Sanctuary ecological design process in four sections. First, the Earth Sanctuary landscape and land use history is described. Second, the process of delineating and mapping the environmental regulatory landscape, including wetlands, streams, and ponds are discussed. Third, an overview of the vegetation, wildlife, and fish surveys we have conducted – the scientific basis for the ecological design – is presented. Finally, the landscape and restoration design projects are presented.

Site Description and Land Use History

Centrally located in South Whidbey Island the Earth Sanctuary is situated at the headwaters of two watersheds both draining south into Useless Bay in the Puget Sound (Figure 1). The landscape is composed of south to southwest facing forested hillslopes surrounding three depression areas making up the Earth Sanctuary's three ponds (Figures 2 & 3). The shape of the Earth Sanctuary landscape reflects not only the land's glacial history but also, significantly, its land use history.

Figure 1. Earth Sanctuary Watersheds, Local Land Use and Land Cover

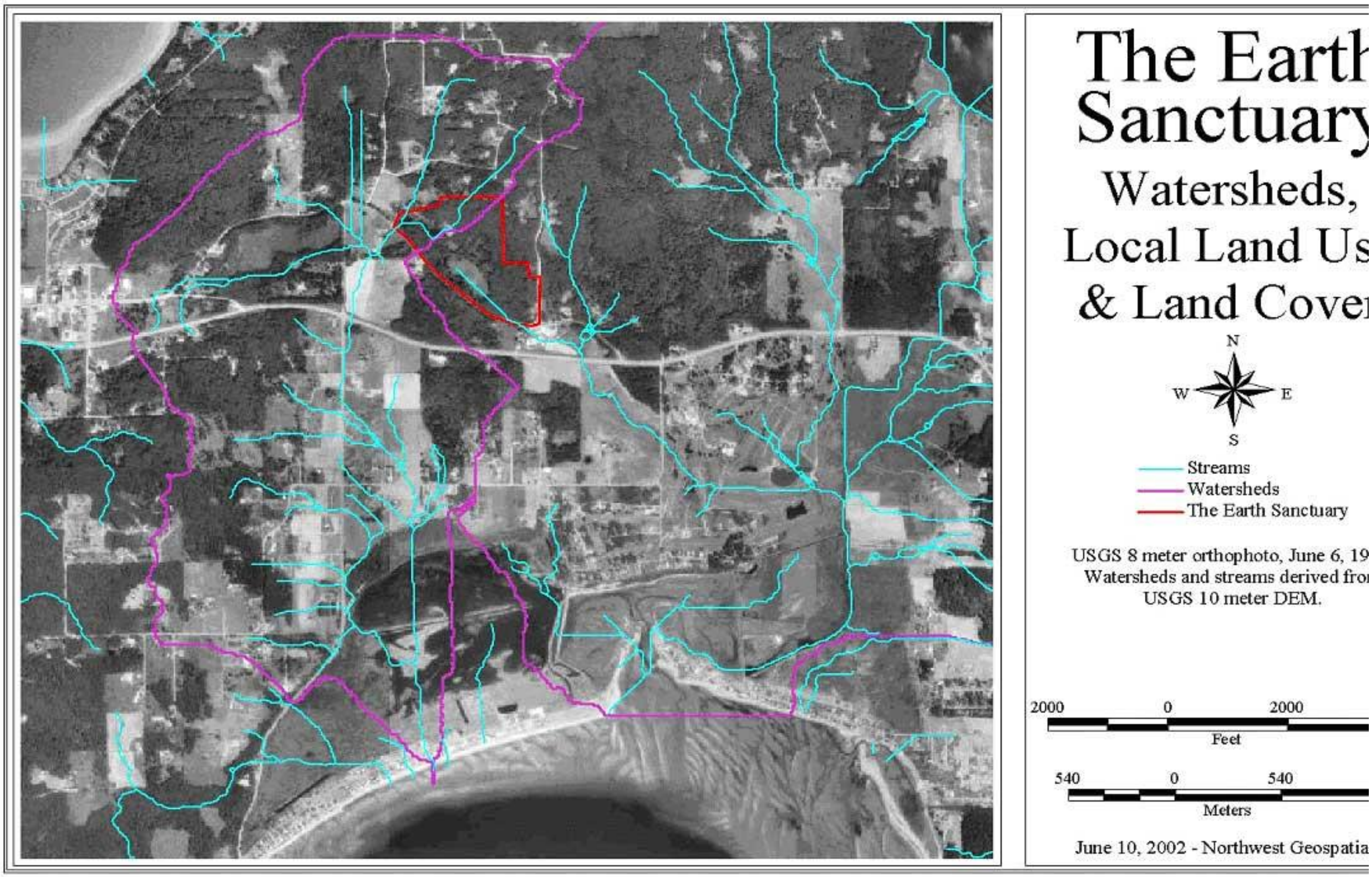


Figure 2. Earth Sanctuary Topography

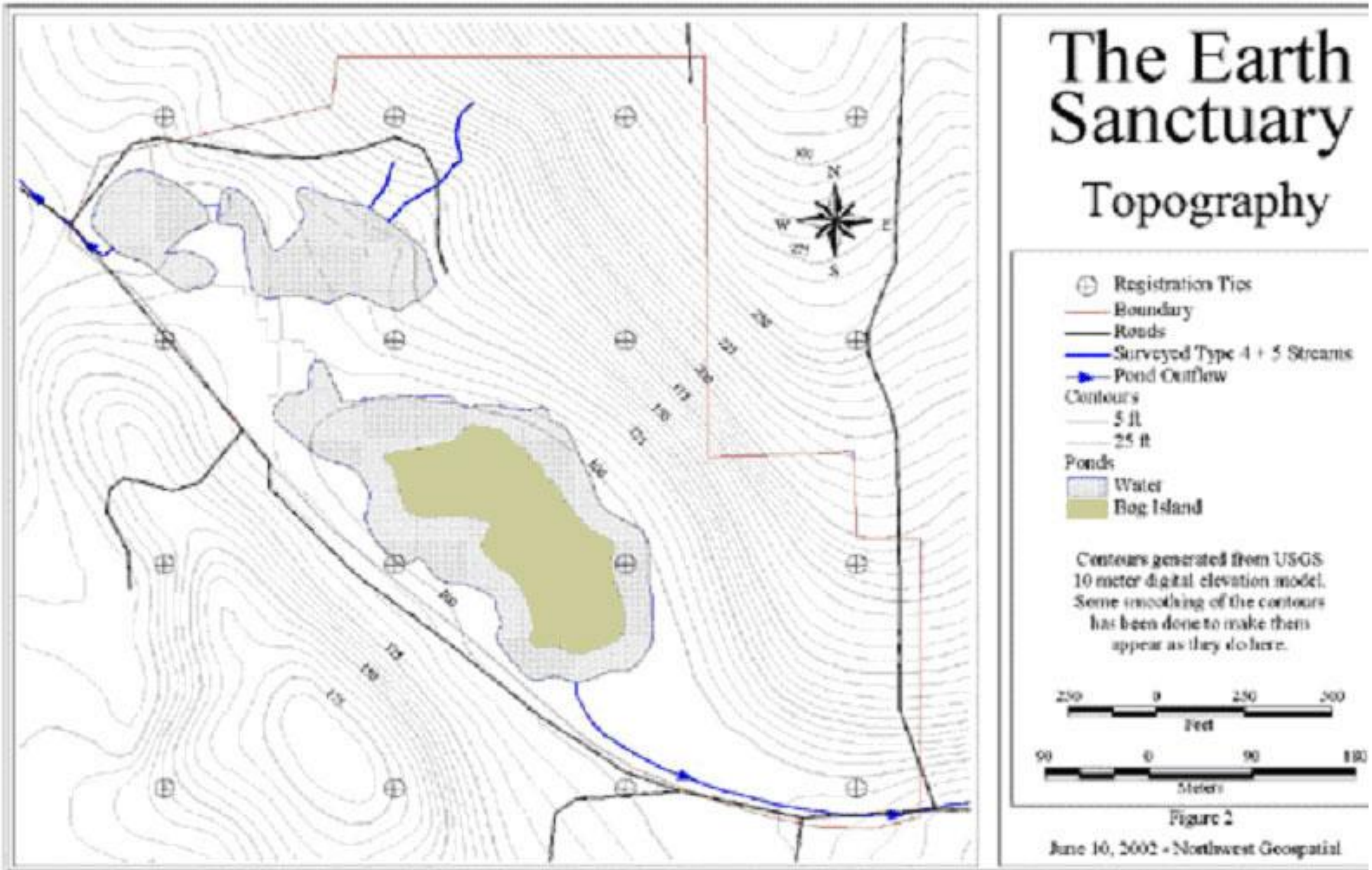


Figure 3. Earth Sanctuary Aerial View Looking Southwest over the Fen, Central and West Ponds and toward Freeland

The South Whidbey Island landscape was formed by repeated glacial advances and retreats during Pleistocene times (1.8 million – 10,000 years ago) resulting in gently rolling hillslopes, perennial and ephemeral streams, ponds, and wetlands. The overall soil-landscape pattern of the Earth Sanctuary is controlled by the properties of two major landforms: hillslopes and nearly level depressions, all capped by deposits of compacted glacial till and well-drained glacial outwash materials (USDA-SCS 1958). It is the different permeability of these glacial deposits together with local topography that controls the distribution and abundance of the Earth Sanctuary's wetlands, streams and ponds. For example, rainfall over the land infiltrates the soil collecting over subsurface-cemented hardpan layers, at depths of 20-48 inches, and either flows down hillslope gradients as groundwater or collects forming the depressional wetlands and ponds found in topographically flat areas. The extensive Earth Sanctuary hillslope wetlands occur where the local groundwater table, due to a shallow underlying hardpan layer, intercepts the hillslope surface and discharges as springs or seeps (Figure 4).

Surface water on the Earth Sanctuary occurs as two artificially created ponds, the West and Central Ponds, the Fen/bog pond system (hereafter called the Fen), two tributary streams to the Central Pond, and two outflow streams draining the Fen to the south and the West Pond to the north (Figure 4). The distribution of the Earth Sanctuary's streams, ponds and adjacent wetlands are the result of both natural topographic drainage patterns and the legacy of historic landscape design.

The West and Central Ponds were designed, circa 1970, by the US Department of Agriculture Soil Conservation Service (SCS) for waterfowl and aquatic wildlife habitat. The natural stream courses that enter the Central Pond historically flowed down gradient through the areas now occupied by both the Central and West Ponds and then off-property along side Newman Road (Figures 5 & 6). The western end of the Central Pond was excavated, and a levy and cement box weir (i.e., water control structure) constructed. The weir dammed the flow of the streams and water backed up throughout the area creating the Central Pond. The extensive number of dead standing and fallen trees throughout the Central Pond is evidence of the now flooded historic forest (Figure 7). The West Pond was excavated to a depth of 10-12 feet and surrounded by an artificial earthen berm. An additional box weir at the southwestern edge of the West Pond controls its water level and outflow. The result of both pond creations is that water flows from the hillslope streams to the Central Pond over its weir into the West Pond and during times of high water flows off-site to the drainage ditch running parallel to Newman Road. The water level of the Fen is also controlled by an artificial cement weir located in the Newman Road drainage ditch immediately south of the Fen. Surface water drains south out the lower end of the Fen into the drainage ditch parallel to Newman Road only during annual peak periods of high water.

Although the original Soil Conservation Service pond design included recommendations for revegetating the excavated areas surrounding both the northern end of the Central Pond and all of the West Pond banks, the revegetation effort was not adequately accomplished. This has resulted in extensive areas dominated by the invasive non-native Himalayan blackberry to the exclusion of native vegetation (Figure 6). Additionally, historic forest clearing operations have resulted in two other large areas dominated by Himalayan blackberry along the north side of the Fen (Figure 6). All of the Earth Sanctuary Himalayan blackberry patches, approximately 3.5 acres, will be restored to native vegetation.

Prior to European settlement, the Earth Sanctuary would have been a mature Douglas fir, Western hemlock forest with minor components of western red cedar, grand fir, and Sitka spruce.

Figure 4. Earth Sanctuary – Island County Critical Areas

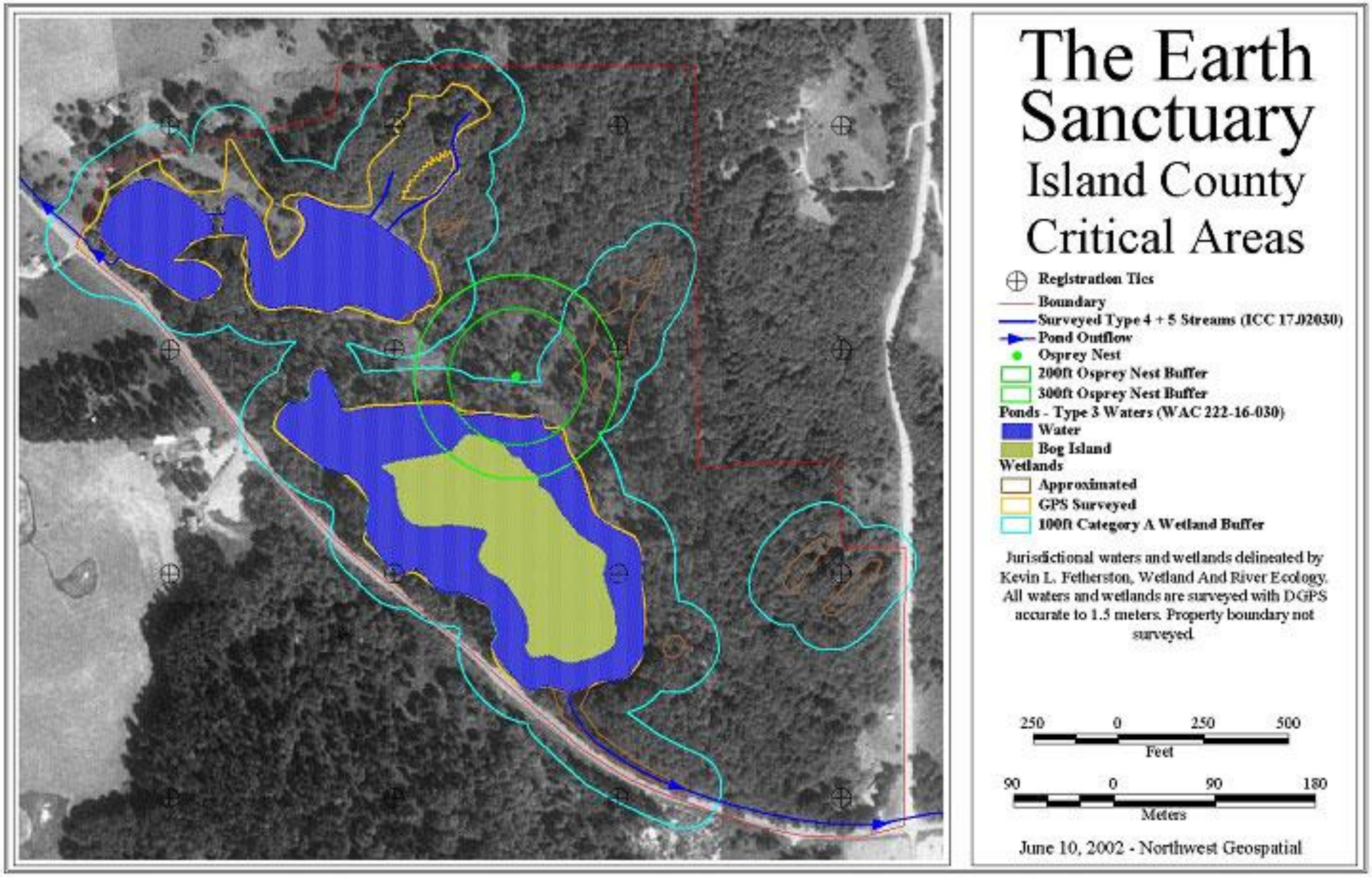


Figure 5. Pre-farm Pond Construction, 1957 Aerial Photograph

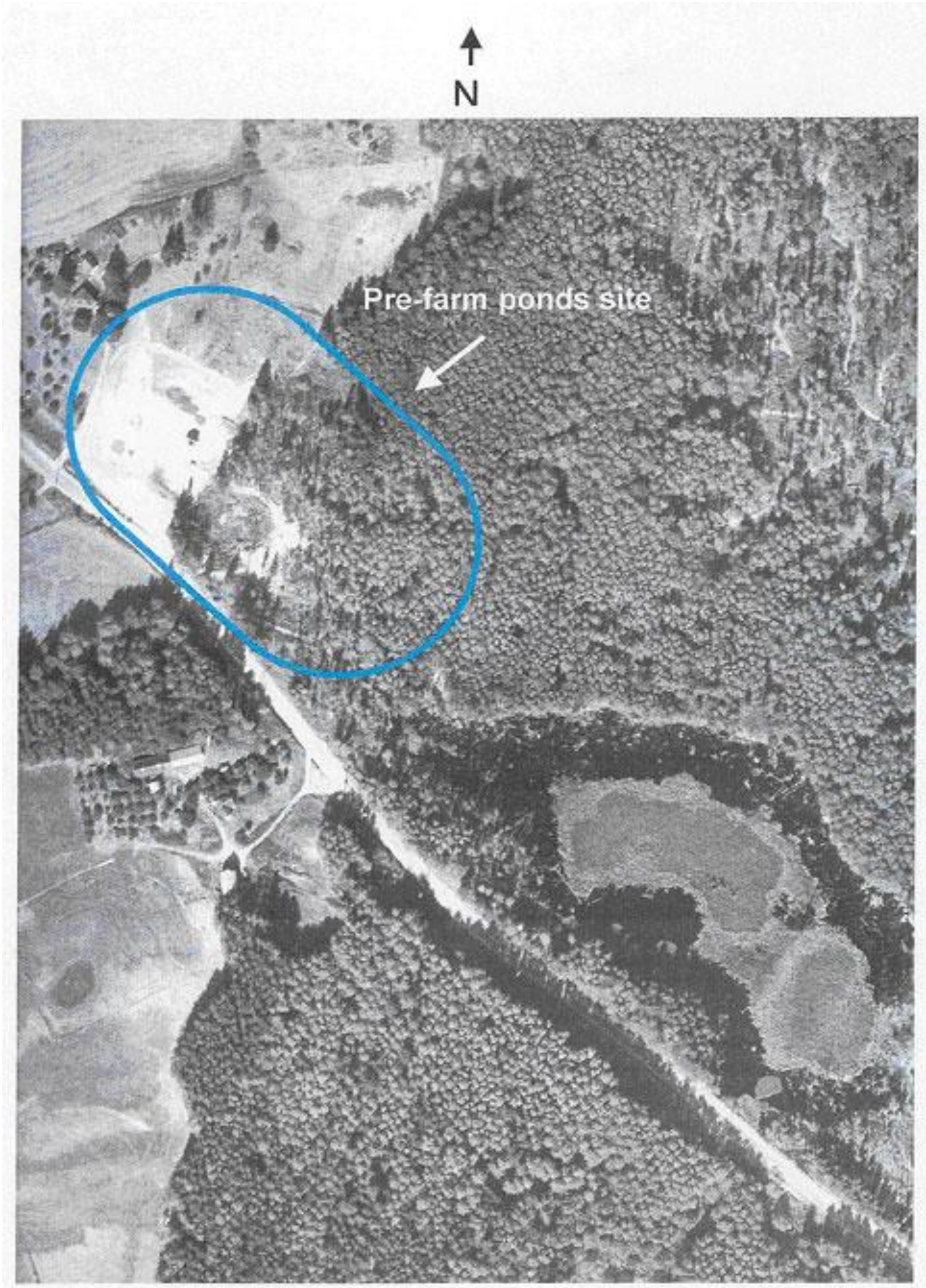


Figure 6. Earth Sanctuary Vegetation Types

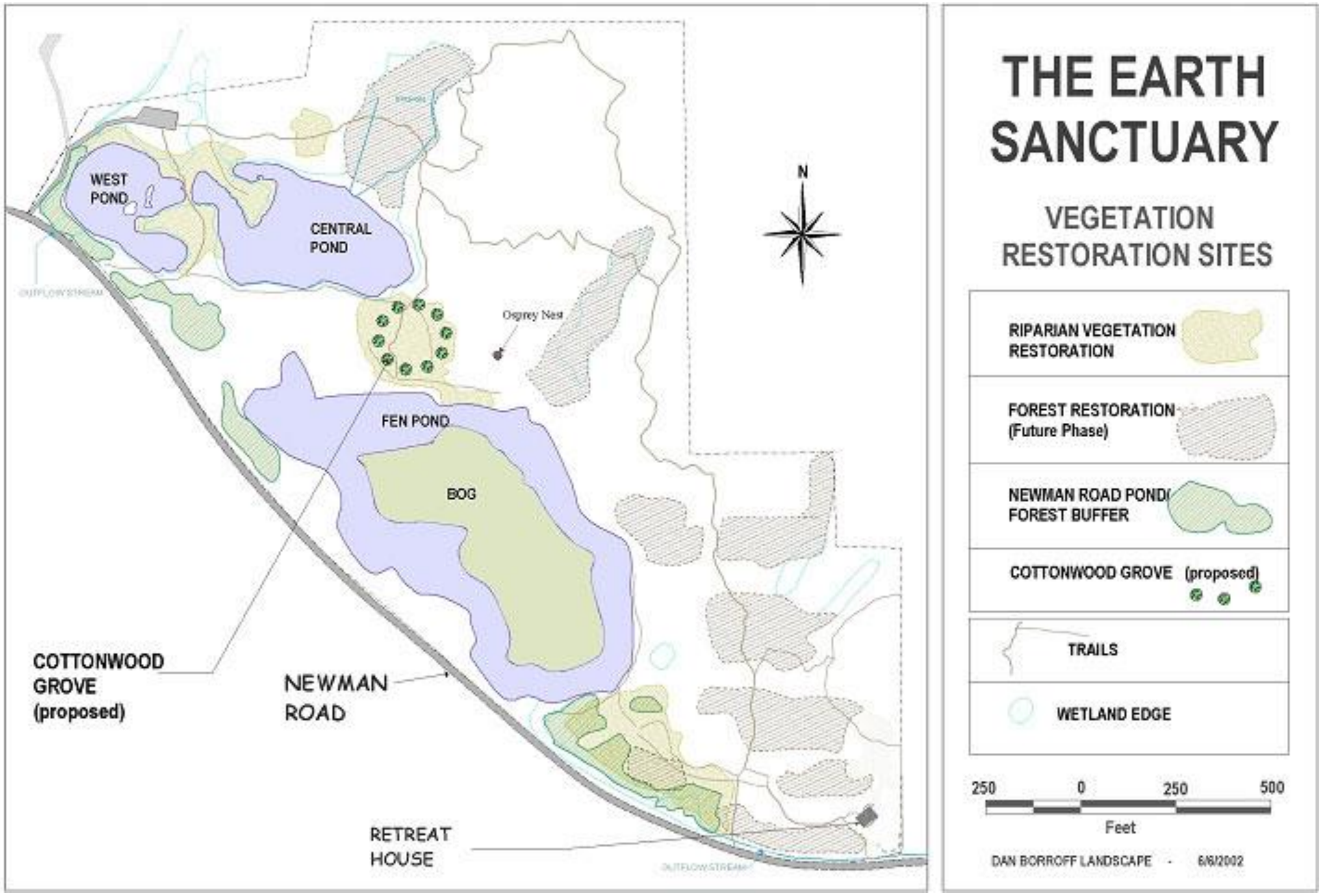


Figure 7. Earth Sanctuary Central Pond

Wetlands, Streams and Ponds – Mapping the Regulatory Landscape

Prior to developing the landscape, restoration, and environmental artwork designs we conducted a two phase delineation and mapping of the Earth Sanctuary wetlands, streams, and ponds and their regulatory buffers - environmentally critical areas regulated under Island County, Washington State, and federal environmental ordinances (Figure 4). The resulting Island County Critical Areas map has served as a guideline for developing the Earth Sanctuary master plan including location of landscape design elements - trail locations, landscape plantings, parking, road access- and environmental artworks (Figure 4). A description of the equipment, techniques and software used for surveying (GPS and Criterion Laser), mapping (GPS) and landscape design visualization (CAD) can be found in Appendix A.

Wetlands were identified and delineated using the technical guidelines and methods described in the *Washington State Wetlands Identification and Delineation Manual* (Washington State Department of Ecology, 1997). Streams and ponds were identified, delineated, and classified according to the Island County Code Section 17.02, *Critical Area Regulations*. The wetland, stream and pond delineation and mapping was conducted in two phases and scales of investigation. Our phased approach was based upon the need to have an initial general overview of the extent and distribution of Critical Areas for master planning followed by project site-specific wetland, stream and pond delineations.

1. First, the initial reconnaissance scale mapping of wetlands, streams and ponds was conducted, including the entire 72 acres during summer 2000. Approximately 80-90% of existing on-site wetlands were delineated and flagged on the ground (Figure 4). Wetland, stream and pond boundaries locations (jurisdictional wetland boundary and pond and stream ordinary high water marks) were then surveyed (± 1.5 meter accuracy) and the data displayed in a geographic information system (GIS) for analysis and map production.
2. Second, project site-specific scale delineations of Critical Areas were conducted in January 2001 for all areas where landscape design, restoration, and environmental artworks were planned. Detailed Critical Areas delineations are required information for the Island County Critical Areas Application submittal to the Community Development Division of Island County Public Works Department for all proposed activities within Critical Areas and their buffers (i.e., roads, trails, and conservation, preservation, or enhancement projects). All proposed project areas were delineated, flagged in the field, and surveyed. Eight jurisdictional wetland sample plots were located characterizing representative vegetation, soils, and hydrology in the proposed project areas. In addition to the eight formal sample plots, hundreds of soil samples were taken with a Dutch soil auger to observe soil characteristics throughout the site. The wetland boundaries were staked with 1X2 inch survey stakes flagged with pink-and-black-striped surveyors tape.

Vegetation, Wildlife and Fish Surveys

We conducted surveys of Earth Sanctuary vegetation, fish, and wildlife to assess the status of the ecological communities, and to provide data to guide the restoration and landscape design. The following is an overview of our approach and findings. Complete vegetation, wildlife, and fish reports can be found in the Appendices B, C, & D.

Vegetation Survey

The objectives of the vegetation survey and inventory were to (1) complete a baseline survey, inventory and map of the upland forest and wetland vegetation, and (2) quantitatively describe the vegetation composition and structure for use in both the wildlife habitat survey and restoration design (Miller and Fetherston 2000; Appendices B & C). Our vegetation sampling approach focused on strategically sampling distinct ecological regions of the Earth Sanctuary for a suite of characteristics. We divided the landscape into distinct forest stand types using (i.e., areas of homogeneous vegetation cover that have developed following forest clearing operations) (Figure 6). Sample transects were laid out across each forest stand type and sampling plots located at varying intervals. At each sample plot we measured and described: plant species composition and abundance, snag (e.g., standing dead trees) distribution and abundance, coarse woody debris (e.g., dead trees on the ground), and soil texture and color. Tree snags and coarse woody debris are critical habitat elements for many forest animals.

Although a variety of habitats could be delineated at the Earth Sanctuary depending on the sample scale chosen, we designated four major forest stand types and a separate class for the Fen vegetation. A brief description of each type is shown in Tables 1 & 2. We sampled a minimum of three plots within each stand type to assess the variability within the immediate area.

Table 1. Description Earth Sanctuary Forest Stand Types

Red alder	Overstory dominated by Red alder. Shrub layer composed primarily of salmonberry and elderberry. Herbaceous layer dominated by sword fern, stinging nettle and trailing blackberry.
Douglas fir/Western hemlock	Stand dominated by Douglas fir and Western hemlock. Small component of western red cedar. Understory vegetation of huckleberry, stinging nettle and sword fern.
Douglas fir/Western hemlock/Red alder	Similar to Red Alder Stand with the addition of some mature Douglas fir and young, understory Western hemlock. Small component of western red cedar. Few huckleberries and sparse stinging nettle. Much sword fern.
Western hemlock/ Douglas fir/Red alder	Stand nearly exclusively dominated by young Western hemlock. Very small component of Douglas fir and western red cedar. Shrub layer composed mostly of sword fern and huckleberry.
Old-growth Reference	Mature Douglas fir/Western Hemlock Stand. Many canopy layers including legacy Douglas firs and mid-story hemlock. Abundant snags and downed logs of large diameter. Understory of sword fern, huckleberry, Oregon grape and twinflower.

Old-Growth Reference Forest Type

An old-growth forest representing the type of forest that occupied Whidbey Island before the onset of modern development was selected as the target reference site for the Earth Sanctuary forest restoration. We chose the area known as the University, or 'U-Grove' at South Whidbey State Park. South Whidbey State Park has the few remaining examples of a mature or old growth forest remaining on Whidbey Island. They have persisted and developed naturally for centuries with minimal human disturbance. A brief description of this forest appears in Table 1 with a detailed description in Appendix B. We sampled three different sites within this forest stand.

Fen and Bog Wetlands

The Earth Sanctuary Fen is a unique wetland ecosystem containing a bog surrounded by marsh and moat and will be discussed here in greater detail here (Figure 8). The Earth Sanctuary Fen is comprised of four major plant communities. The habitat and dominant species of each community are shown in Table 2. The characteristics of each of these communities will be discussed below.

Figure 8. Earth Sanctuary Fen

Table 2. Plant Communities of the Earth Sanctuary Fen

Community	Dominant species	Habitat
Marsh/Moat	Marsh cinquefoil Duckweed Yellow water-lily	Neutral to slightly acidic (pH 6-7) enriched waters. This is an aquatic community surrounding the bog.
Dwarf shrub	Peat mosses Labrador tea Small-leaf cranberry Bog laurel Some lichens Big red stem	Acidic (pH 4.1-5), developed peat in the central areas of the bog. Areas with well developed hummocks and hollows. This community intergrades with the sedge community forming a matrix in some areas.
Sedge	Peat mosses Cotton grass Small-leaf cranberry	Acidic (pH 4.1-5), moist peat. Little hummock development. Wetter areas of the bog mat.
Bog forest	Western hemlock Salal Many lichens	One small area of solid ground or well-consolidated peat in the northwest portion of the bog mat.

- The marsh habitat and moat was mostly neutral in acidity (pH 7) and contained species better known from marshes or swamps than acidic, nutrient-poor bogs. This may be a result of nutrient enrichment from subsurface water that has entered the marsh waters as springs. The entire fen/marsh/bog complex experiences widely fluctuating water levels through the course of a year exposing soils to oxygen and enhancing nutrient cycling (e.g. 1-2 feet draw down during annual summer drought.
- Perhaps the most visually striking plant community of the bog is the dwarf shrub community. This community forms the floating mat of consolidated peat that quakes when walked upon. The community is composed of abundant heaths, sedges, ferns and even a carnivorous plant, the sundew.
- The sedge community is dominated by *Sphagnum* mosses, cotton grass, some dwarf heaths and minor sedges and rushes. This community appears restricted to wetter portions of the mat and reaches its largest extent in a band across the middle of the bog. In the northern reaches of the bog it forms a mosaic with the dwarf shrub community. These two vegetation types mix in a matrix of patches and columns with sedges dominating the wetter areas and Labrador tea occupying the hummocks.
- The central region of the Earth Sanctuary bog is raised in elevation approximately 5+ feet above surrounding marsh surface area. Raised bogs are unique in their rarity in western Washington (Rigg 1958).

Forest and Fen Plant Species Composition

The Earth Sanctuary plant species inventory, as of Spring 2002, included: 71 species of vascular plants, 5-10 species of *Sphagnum* mosses, and 10-20 species of nonsphagnous mosses and liverworts (see species lists Table 1 in both Appendices B and C). A number of these plant species were found exclusively in the acidic bog environment. These included cotton grass (*Eriophorum chamissonis*), sundew (*Drosera rotundifolia*), bog cranberry (*Vaccinium oxycoccos*), bog laurel (*Kalmia microphylla*), Labrador tea (*Ledum groenlandicum*), and *Sphagnum* mosses (Appendix C). In addition to the plant species 10-20 species of lichens were noted (i.e., lichens are fungal/algal or fungal/bacterial symbioses in the Kingdom Fungi). While this is not a complete inventory of plant species occurring at the Earth Sanctuary, it certainly includes the dominant species that define vegetation composition and structure. No rare, threatened or endangered species have been noted to-date.

Wildlife Survey

The objectives of the Earth Sanctuary Wildlife Report were to (1) review habitat resources, (2) evaluate potential habitat restoration measures, (3) discuss impacts of historic and proposed land use practices, and (4) make recommendations for wildlife community monitoring (Kelsey 2001; Appendix D). The Wildlife Report was based primarily on a review of wildlife species lists from the Audubon Society, various field guides, and historical county guides. Detailed species lists of known or potential bird, mammal, amphibian and reptiles on Whidbey Island may be found summarized in Tables 2 to 5 in Appendix D. The tables also list species: general habitat descriptions, likelihood of presence at Earth Sanctuary and their sensitivity to human activity. The following is a brief overview of the report findings (Kelsey 2001; Appendix D).

The juxtaposition of the Earth Sanctuary three ponds, comprising approximately 25% of the land's 72 acres, and the surrounding mixed conifer and alder forest creates a complex mosaic of animal habitats unique in South Whidbey Island. The combination of forest and freshwater ponds attracts wildlife species that would not occur without the presence of both habitat types (Figures 3, 4, & 7).

Figure 9: Adult Osprey Feeding Two Fledglings, Early Summer 2001

Over 200 bird species have been documented on Whidbey Island, many of which could conceivably be found at the Earth Sanctuary (Kelsey 2001). However, those bird species dependent on freshwater and forest habitats are most likely to be seen at the Earth Sanctuary. Marsh, ground, and tree cavity nesting waterfowl are the predominant birds to be found in and around the Earth Sanctuary ponds. Great blue heron, Bald Eagle and Osprey are regular visitors. Currently an Osprey pair are nesting in a wind topped Douglas fir immediately upslope of the northern side of the Fen (Figure 9).

Approximately 45 species of mammals are likely to occur at the Earth Sanctuary. Of these, bats, beaver, muskrat, and river otter are most dependent on the aquatic habitat.

Nine species of amphibians, seven of which require aquatic habitat for breeding, may be found at the Earth Sanctuary. The northwestern salamander, Pacific tree frog and bullfrog were all observed during September 2000. The large non-native bullfrog population dominates the amphibian populations in the three ponds.

Five species of reptiles and a variety of introduced turtle species may inhabit the Earth Sanctuary. Only the introduced turtles are dependent upon aquatic habitat.

Wildlife habitat enhancement recommendations and specific landscape design recommendations are discussed in the landscape and restoration design section below.

Fish Survey

The objectives of the Earth Sanctuary Fish Assessment were to (1) describe the fish community in all three ponds, (2) examine the role of pond fish in the local food web, and (3) provide recommendations for enhancing the local fish community (Garrett 2001; Appendix E). All three ponds were sampled for fish on November 17 and 18, 2000 and June 23, 2001. A variety of methods were used including gill nets, minnow traps, and cast nets. The results were inconclusive as no fish were captured during either sampling effort (Garrett 2001). However, during prior amphibian trapping in September 2000 brown bullhead (*Ictalurus nebulosus*) were captured. Additionally, the remains of two largemouth bass were found on the shoreline of the Fen in November 2000.

Therefore, the Earth Sanctuary ponds appear to contain two nonnative warm water fish species, large-mouth bass and brown bullhead. Fish productivity is most likely limited by available spawning areas, prey density, and predation by birds and small mammals such as the otter (Garrett 2001).

In general, natural freshwater fish production is limited on Whidbey Island in aquatic areas such as the Earth Sanctuary Ponds. Native fish that may have inhabited the Earth Sanctuary ponds include redside shiner, three-spine stickleback, and possibly western brook lamprey (Garrett 2001).

Fish population enhancement approaches, the stocking of fish in the Earth Sanctuary ponds, is discussed in the following restoration section of this report.

Landscape and Restoration Design

"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."
Aldo Leopold, 1949, *A Sand County Almanac*

The goal of the Earth Sanctuary ecological design – the artworks, landscape design and restoration design – is "to preserve the integrity, stability, and beauty of the biotic community." The design is intended to create an environment that allows people to engage the Earth Sanctuary natural communities while protecting and restoring the land's biodiversity. To accomplish this goal our ecological design is focused in five broad areas:

1. Artworks and landscape design
2. Wildlife habitat enhancement
3. Forest restoration
4. Riparian vegetation restoration
5. Newman Road pond/forest buffer

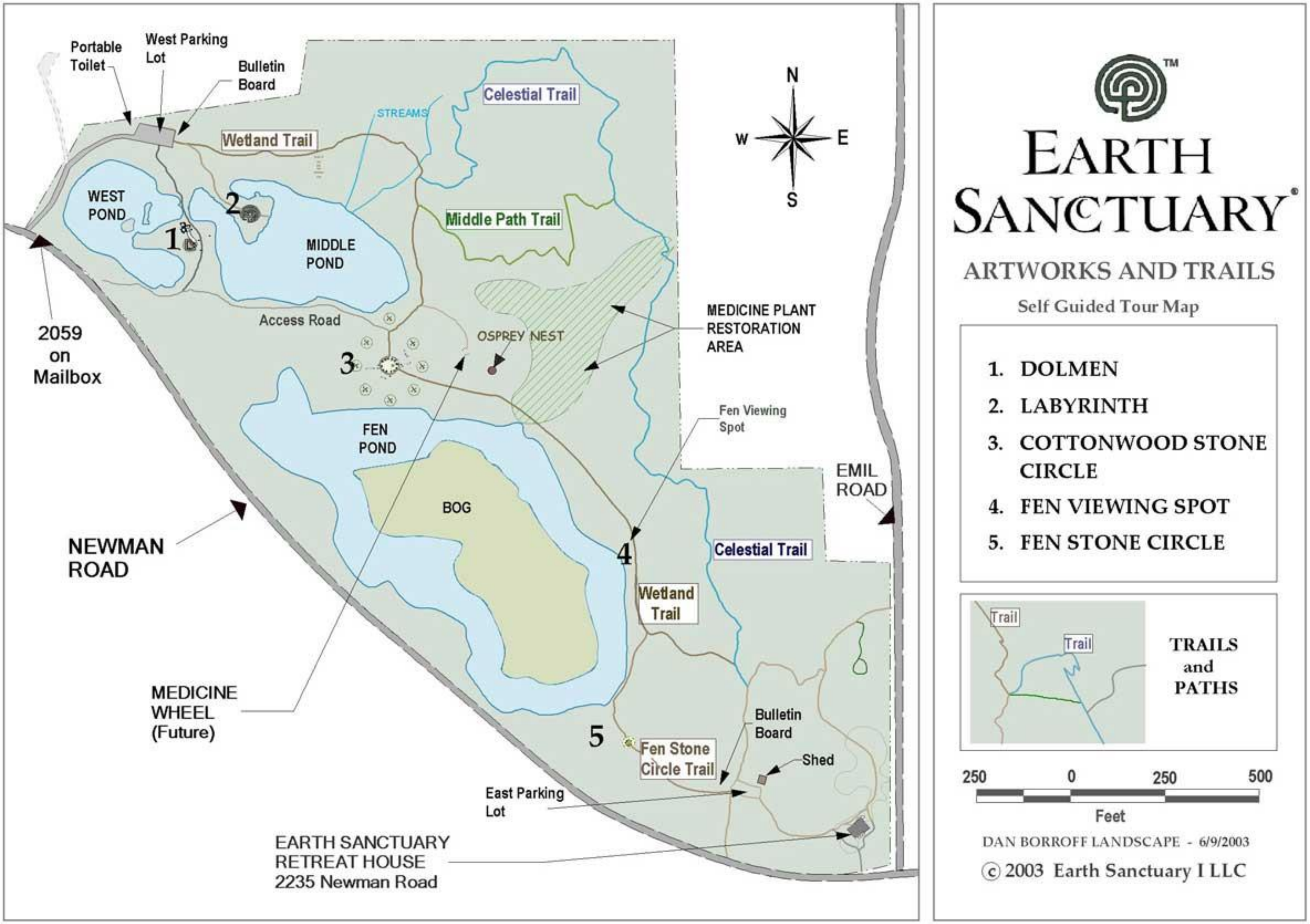
Artworks and Landscape Design

The Earth Sanctuary artworks and landscape design's plantings and trails, are primarily the work of Chuck Pettis and landscape architect Dan Borroff. These include five principle artworks: the Dolmen located on the isthmus between the Central and West Ponds, the Labyrinth located on the Central Pond peninsula, the Stonehenge viewing site overlooking the east side of the Central Pond, the Cottonwood stone circle located on the isthmus between the Central Pond and Fen and the Fen stone circle located on the north facing hillslope above the southern end of the Fen (Figure 10). To-date (June 2002), the Dolmen, Labyrinth, and Fen stone circle have been constructed and landscape plantings installed (Figures 11, 12, 13, & 14). Artwork landscape plantings were chosen from both local South Whidbey Island and regional native Puget Sound lowland plant species. See Appendix F for the complete plant list.

The artworks and artworks' landscapes were designed for meditation, wildlife habitat, and wildlife viewing. The landscape planting designs include 59 native plant species. Each of the artwork sites was designed to increase the diversity and complexity of the local forest and aquatic-riparian herbaceous, shrub and tree buffers. Two of the artwork landscape designs will be discussed in detail here, the Labyrinth and Cottonwood stone circle.

The Central Pond peninsula design includes the centrally located Labyrinth surrounded by a 25-60 foot wide buffer of native wetland herbs, shrubs, and trees (Figures 10 & 14). Over the next 5 years the recently planted aquatic-riparian shrub buffer – composed of black twinberry, red dogwood, beaked hazelnut, clustered wild rose, Pacific ninebark, willow, snowberry, western red cedar, cascara, red currant, stink currant, serviceberry, western crabapple, and mock-orange – will grow to a height of 6-8 feet. The peninsula prior to the Labyrinth landscape design installation was dominated by a monoculture of Himalayan blackberry resulting from its establishment on unvegetated sidecast materials left from the 1970 pond construction. In addition to the shrub and tree buffer, a suite of wetland emergent plant species have been planted along the waters edge including slough sedge, hardstem bulrush, and small-fruited bulrush. The Labyrinth pond buffer is designed to increase the local plant species diversity and vegetation structural complexity, therefore providing greater waterfowl shoreline habitat.

Figure 10. Earth Sanctuary – Landscape Design, Artworks, and Trails


Portable Toilet
West Parking Lot
Bulletin Board
Celestial Trail
STREAMS
Wetland Trail
Middle Path Trail
WEST POND
MIDDLE POND
1
2
3
4
5
Access Road
OSPREY NEST
MEDICINE PLANT RESTORATION AREA
2059 on Mailbox
FEN POND
BOG
Fen Viewing Spot
EMIL ROAD
Celestial Trail
NEWMAN ROAD
Wetland Trail
MEDICINE WHEEL (Future)
Bulletin Board
Fen Stone Circle Trail
Shed
East Parking Lot
EARTH SANCTUARY RETREAT HOUSE 2235 Newman Road
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E
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EARTH SANCTUARY
ARTWORKS AND TRAILS
Self Guided Tour Map
1. DOLMEN
2. LABYRINTH
3. COTTONWOOD STONE CIRCLE
4. FEN VIEWING SPOT
5. FEN STONE CIRCLE
Trail
Trail
TRAILS and PATHS
250
0
250
500
Feet
DAN BORROFF LANDSCAPE - 6/9/2003
© 2003 Earth Sanctuary I LLC

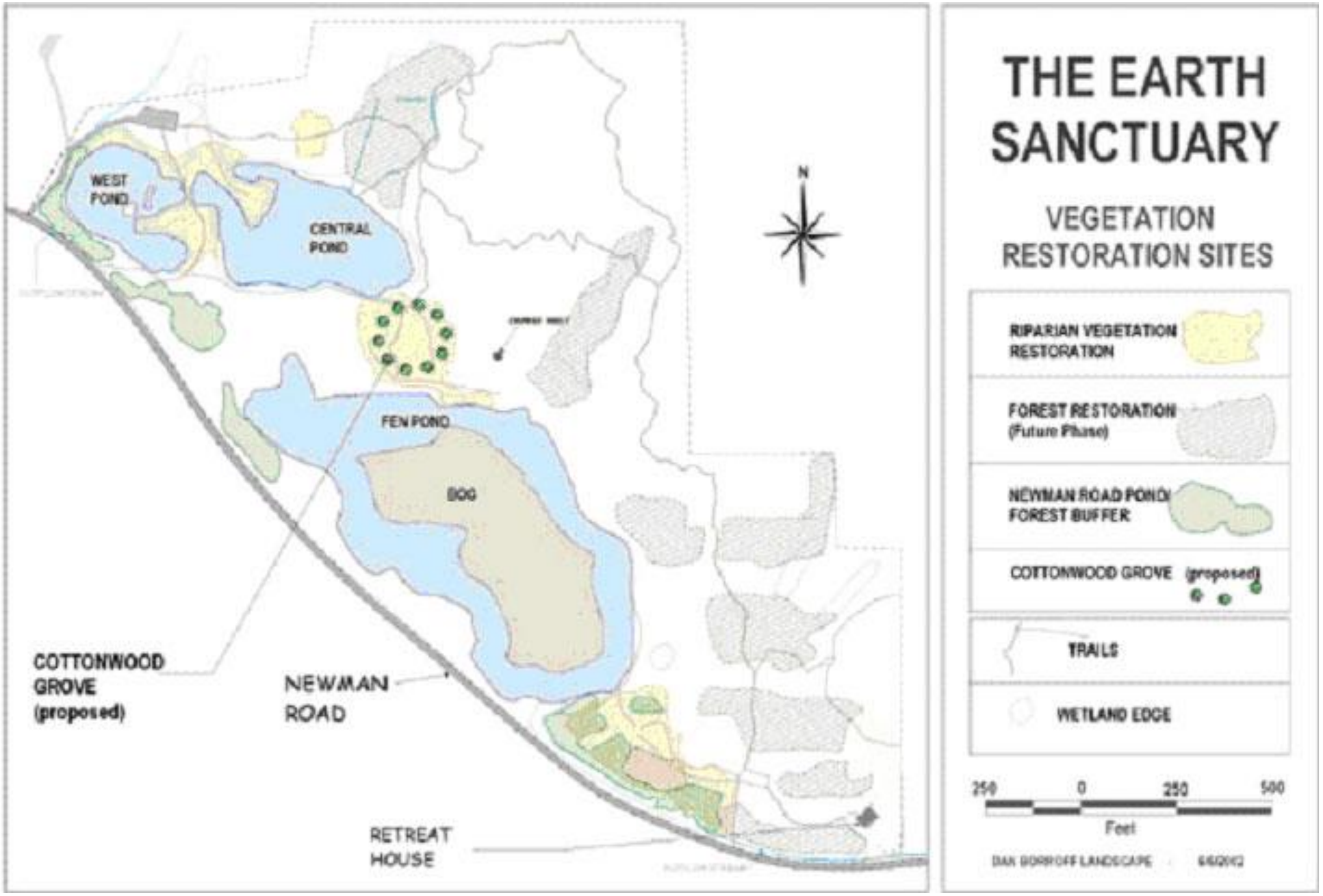
Figure 11. Earth Sanctuary Dolmen

Figure 12. Earth Sanctuary Labyrinth

Photo Copyright Peter Raulerson.

Figure 13. Earth Sanctuary Fen Stone Circle

Figure 14. Earth Sanctuary – Vegetation Restoration Sites



The Cottonwood stone circle, to be located on the isthmus between the Central Pond and Fen, is designed to be a meditation site and hopefully a Great blue heron rookery in 20-30 years (Figures 11, 12, & 16). Great blue heron are known to have had a rookery (i.e., a colony of nests), recently abandoned due to disturbance, within 1 mile of the Earth Sanctuary. Great blue heron frequent the Earth Sanctuary ponds on a regular basis to feed and rest. We have designed the stone circle landscape with an outer circle of seven to ten black cottonwood with the intention of providing the local Great blue heron population with a new nesting site. Planted black cottonwood on good sites in lower Fraser River, British Columbia grow rapidly averaging 20 cm (8 in) in diameter and 16.8 m (55 ft) in height at 10 yrs, and individual trees more than 30 cm (12 in) diameter and 21.3 m (70 ft) in height (DeBell 1990). After 25 years, the Earth Sanctuary cottonwoods can be expected to exceed 30 m (98 ft) in height (DeBell 1990). Great blue heron are known to nest in trees greater than 25 m in height adjacent to good foraging areas such as ponds and streams (Figure 15; Butler 1997).

Additionally, the area adjacent to the Cottonwood stone circle site is dominated by Himalayan blackberry and salmonberry. The landscape design is to revegetate the area in native trees and shrubs, setting the stage for species rich native forest development. The forest composition and density restoration design is based on the findings of the Earth Sanctuary Vegetation Survey and Inventory modeled after the old-growth reference forest stand at South Whidbey State Park (Appendix B).

Wildlife Habitat Enhancement

Strategies for wildlife habitat enhancement at the Earth Sanctuary include (Kelsey 2001):

1. **Silvicultural interventions – red alder thinning and conifer planting.** Red alder thinning and conifer under planting in red alder/salmonberry dominated forest stands will accelerate growth rate of existing understory conifers, replace conifers removed by historic harvests, and increase forest structural complexity. Felled red alder will be left on the forest floor, providing cover and insects for wildlife as well as returning nutrients to the soil.
2. **Preservation and addition of tree snags (i.e., standing dead trees).** Snags are a major component of wildlife habitat within the forest.
3. **Replacement of invasive non-native plant species with native vegetation.** Reintroduction of native plants will increase forest understory diversity and provide berries, nesting materials, and cover for birds and mammals.
4. **Installation of bird nesting boxes.** 20 bird-nesting boxes were installed in the Spring of 2002: (for wood ducks, kestrels, bluebirds, chickadees, owls and woodpeckers). Installation of bat boxes in the forest is also planned. Install nest boxes in the leave tree area for American Kestrel.

Strategies for reducing human impacts on wildlife at the Earth Sanctuary include (Kelsey 2001):

1. Pond trails – Shoreline habitat is critical to many bird and amphibian species. The Earth Sanctuary trails are designed not to encircle the pond perimeters, therefore providing waterfowl and other wildlife undisturbed shoreline habitat. Pond trails provide viewing access at a few select locations (Figure 10).
2. The Earth Sanctuary ponds are reserved for wildlife use only – no swimming, boating, or fishing are allowed.
3. Major vegetation restoration activities are limited to late summer, fall and winter, outside the breeding seasons for the majority of wildlife species.

We are limiting visitor access to critical habitat areas throughout the Earth Sanctuary. For example, the trail leading past the Osprey nest is identified with signage indicating that within 300 feet of the nest is a visitor *Quiet Zone.* Visitors are also requested to observe for any signs of Osprey disturbance during their critical breeding and rearing time period between April and July. If signs of Osprey disturbance occur during this period the trail within 300 feet of the nest will be closed to visitors until mid summer.

Figure 15. Great Blue Heron Rookery in Black Cottonwood Grove, Lower Green River Floodplain.

Fish Community Enhancement

Native fish species enhancement will include the native species red-side shiner and stickleback (Garrett 2001). A potential benefit is that these small fish will provide prey for a wide range of species including small birds and other animals. Introduction of small fish like shiners may also increase the success of both bass and bullhead in these ponds (Garrett 2001).

Riparian Vegetation Restoration

The goal of the riparian vegetation restoration design is to reestablish diverse native plant communities and vegetation developmental processes in degraded aquatic-riparian zones around the West Pond, Central Pond, and Fen (Figure 15). Primary objectives of the riparian vegetation restoration are to (1) remove Himalayan blackberry thickets, and (2) revegetate theses areas with native wetland and riparian plants. The designed plant communities are based on the Earth Sanctuary Vegetation Survey and Inventory (Appendix B). A complete plant list can be found in Appendix F. The riparian vegetation restoration design is summarized in Table 3.

The restoration design includes the following methods:

1. Himalayan blackberry removal is accomplished by first cutting all above ground stems,
2. On-going maintenance program where all new stem growth is cut until blackberry dies out. On-going blackberry removal efforts are expected to take 3+ years.
3. The annual monitoring report will document blackberry removal efforts.

Table 3. Summary of Riparian Vegetation Restoration Design

- Removal of Himalayan blackberry thickets by on-going stem cutting program.
- Design target is to restore natural aquatic-riparian vegetation diversity, structure, and ecological functions.
- Plant community composition based on Earth Sanctuary vegetation survey.
- On-going maintenance program for 3-5 years.
- Annual monitoring of survivorship and nonnative invasive plants.

Forest Restoration

The goal of the forest restoration design is to restore natural forest composition, structure and ecological functions where historic logging practices have diminished forest plant diversity and structure (see Appendix B for further discussion). Our forest restoration efforts are focused in those forest stands with overstory red alder and understory salmonberry dominance (Figure 15). The primary objective of the red alder forest restoration is to increase conifer and shrub diversity and forest structural complexity. Conifer and shrub composition and density design targets are based on Earth Sanctuary Vegetation Survey and Inventory (Appendix B). The restoration design includes the following methods:

1. Thinning of red alder forest canopy around existing understory conifers to accelerate existing conifer growth,
2. Cutting of 30-50+ foot canopy gaps in red alder stands for conifer under planting.
3. Underplanting conifers and shrubs in canopy gaps.
4. Underplanting areas will be grubbed clear of salmonberry rhizomes (i.e., underground horizontal stems).
5. On-going weed removal to assure planting survival.

Table 4. Summary of Forest Restoration Design

- Target is to restore natural forest composition, structure and ecological functions.
- Focus on red alder/salmonberry dominated forest stands.
- Thinning of red alder forest canopy around existing understory conifers to accelerate conifer growth
- Cutting of select red alder to create 30-50+ foot canopy gaps.
- Removal of understory salmonberry above ground stems and below ground rhizomes in 10 ft. diameter planting plots.
- Planting of native conifers in understory shrub gaps.
- On-going maintenance program for 3-5 years
- Annual monitoring of survivorship and nonnative invasive plants.

Newman Road Pond/Forest Buffer

The forest buffer between Newman Road and the ponds provides a critically important sound and visual screening of Newman Road vehicular traffic from the Earth Sanctuary aquatic areas (Figure 4). Additional native conifers have been planted in select areas to increase forest buffer tree densities along Newman Road (Figure 14). The additional conifer plantings will also provide greater forest interior environment throughout the Earth Sanctuary.

Earth Sanctuary Ecological Design Phases

The Earth Sanctuary ecological design – 500-year plan is a long-term commitment to the land and the South Whidbey Island natural and human communities. The overall ecological design is an iterative and emergent process, with each phase building upon the findings and discoveries of the previous work. We have summarized the overall ecological design in Table 5.

Table 5. Earth Sanctuary Ecological Design Phases

Table 5 summarizes the phases of the Earth Sanctuary landscape design, wildlife enhancement, and forest and riparian restoration projects.

Initial design phase, 0-2 years	▪ Land use history investigations ▪ Wetlands, streams & ponds – mapping the regulatory landscape ▪ Vegetation, wildlife and fish surveys ▪ Landscape and restoration design ▪ Project regulatory permitting
Near term phase, 2-5 years	▪ Artworks installations ▪ Installation and planting of artwork's landscaping ▪ Planting Newman Road pond/forest buffer enhancement ▪ Himalayan blackberry removal and forest and riparian restoration plantings ▪ Installation of bird nesting boxes and bat boxes ▪ Planting of cottonwood grove ▪ On-going monitoring and maintenance of restoration and landscape plantings ▪ Fish community enhancement
Mid-term phase, 5-20 years	▪ Continued forest and riparian planting, monitoring, and maintenance ▪ On-going removal of invasive non-native plants (Himalayan blackberry – *Rubus procerus*, Holly – *Ilex aquifolium*, and English ivy-*Hedara helix*) ▪ Maintenance of Central and West Pond weirs ▪ Monitoring and maintenance of bird and bat nesting boxes
Long term phase, 20+ years	▪ On-going removal of invasive non-native plants ▪ Maintenance of Central and West Pond weirs ▪ Maintenance of bird and bat nesting boxes

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Appendices

Appendix A. Survey techniques, geographic information system (GIS), and computer aided design (CAD).

Appendix B. The Earth Sanctuary Vegetation Survey and Inventory

Appendix C. Earth Sanctuary Bog/Fen Wetland Ecosystem Draft Report

Appendix D. Earth Sanctuary Wildlife Report

Appendix E. Earth Sanctuary Fish Assessment

Appendix F. Plant list for artwork landscape, and riparian and forest restoration plantings

Appendix A. Survey techniques, geographic information system (GIS), and computer aided design (CAD).

Earth Sanctuary GPS surveys and GIS analysis and mapping were conducted by Phil Hurvitz and Luke Rogers of *Northwest Geospatial LLP* (www.nwgeospatial.com). A subset of the Earth Sanctuary project GIS generated maps may be viewed on-line at the *Northwest Geospatial* web site.

Surveys of the Earth Sanctuary Critical Area boundaries and other environmental features (trails, environmental artwork locations, habitat elements) were conducted with a *Trimble GPS Pathfinder ProXR* (Trimble, Inc.) and *Criterion 400 Laser* (Laser Technology, Inc.). Given the relatively remote terrain of the Earth Sanctuary the Trimble GPS (global positioning system) combined with Criterion Laser (hand-held rapid total survey station) allowed for a low-cost survey accurate enough for our landscape design needs (± 1.5 meter using differential GPS). Our survey approach combined using both GPS located intermediate benchmarks and traverse surveys tied into located benchmarks.

Earth Sanctuary geographic data – environmental surveys, archival aerial photography, USGS 10m digital elevation map- were input to ArcView (ESRI) GIS for analysis and map production.

Dan Borroff, Earth Sanctuary's landscape architect, used *Vectorworks* (Nemetschek North America) computer aided design (CAD) software to create the landscape design drawings. ArcView GIS maps were imported to the CAD environment and served as base maps for Dan's landscape design work.

Appendix B

The Earth Sanctuary Vegetation Survey and Inventory

DRAFT REPORT
October 2000

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Executive Summary

The goal of the ecological design of the Earth Sanctuary is to optimize forest and wetland habitat and species diversity. To accomplish this goal we are proceeding with a four-step restoration design process building upon baseline surveys of the Earth Sanctuary and an old-growth forest reference ecosystem. First, a baseline vegetation survey, map, and inventory was developed for the Earth Sanctuary wetland and forest vegetation communities. Second, a regionally representative old-growth/mature forest reference ecosystem (South Whidbey Island State Park) was identified and surveyed. The reference forest ecosystem will be the template for the Earth Sanctuary restoration design. Third, Dr. Kathryn Kelsey, wildlife ecologist, and Ms. Ann Garrett, fish biologist, are conducting wildlife and fish surveys at the Earth Sanctuary. Fourth, the findings of the Earth Sanctuary vegetation, wildlife, fish, and reference forest ecosystem surveys will be used to develop the Earth Sanctuary restoration design. This report describes the first two steps, the Earth Sanctuary vegetation survey, mapping, and inventory and the reference forest ecosystem survey.

Standard forest vegetation inventory methods were used to measure plant species diversity, structure, and distribution throughout the Earth Sanctuary and the old-growth forest reference ecosystem.

The trees, on average, were larger at the old-growth forest reference ecosystem than at the Earth Sanctuary. Not only were the trees larger, but also they spanned a greater range of diameters indicating a higher degree of structure in the forest canopy than is found at the Earth. Densities of trees were similar, although the Old-growth Reference Stand was comprised mostly of conifers while the Earth Sanctuary contains a large hardwood alder component.

One of the hallmark attributes of old-growth forest in the Northwest is the presence of large snags in the overstory. The snags in the Old-growth Reference Stand provide over 70 m^3 of volume per hectare while those of the Earth Sanctuary range between 5 and 26 m^3. The Reference Stand provides more habitat structure for organisms than does the Earth Sanctuary.

Introduction

The goal of the Earth Sanctuary restoration is to optimize forest and wetland landscape habitat and species diversity. The long-term objective is a diverse old growth forest landscape. The restoration design for the Earth Sanctuary will be implemented over the next few years setting the stage for a more diverse forest ecosystem to develop over the next five hundred years.

The restoration design for the Earth Sanctuary is a science-based four-step process. First, a baseline inventory and mapping of the Earth Sanctuary wetland and forest vegetation communities was conducted. Second, we identified and sampled a local old-growth/mature forest reference ecosystem (South Whidbey Island State Park) upon which we will base much of the restoration design. Third, Dr. Kathryn Kelsey, wildlife ecologist, and Ms. Ann Garrett, fish biologist, will conduct wildlife and fish surveys of the Earth Sanctuary. Fourth, the findings of the wildlife, fish, vegetation, and reference forest ecosystem surveys will be used to develop the Earth Sanctuary restoration design. This report describes the first two steps, the Earth Sanctuary vegetation inventory and mapping, and the reference forest ecosystem survey.

A reference ecosystem offers a target of desired future conditions for the task of restoration design. It is a qualitative and quantitative description of the development of forest/wetland structure and functions over time (i.e., succession). We sampled the mature forest areas of the Earth Sanctuary property and the South Whidbey Island State Park old-growth forest and quantified a suite of ecological characteristics in each. The ‘U-grove,’ South Whidbey Island State Park, is a low elevation Douglas fir dominated old-growth stand. This data driven reference ecosystem description serves as a template for design and comparative monitoring of the forest and wetland restoration (Fetherston 2000).

Terminology

Statistical

The vernacular of restoration ecology and ecosystem science may be unfamiliar to many individuals. As such, the use of ecological jargon is restrained as much as possible in this report. Definitions of those ecological terms used to describe the procedures undertaken during the baseline ecological assessment can be found in the glossary provided at the end of this document.

Botanical

Botanists use scientific names for clarity since common names vary from region to region. This document uses common names in the text, however many of the analyses and tables contain scientific names for specificity and organization of taxon. Further, the use of binomial nomenclature (genus and species) is unwieldy in statistical analysis of data using databases and spreadsheets. As a consequence, ecologists shorten the binomial nomenclature to a simple 5-letter acronym. Such acronyms may appear in the tables or figures in this document. To create an acronym the first two characters of the genus are added to the first two characters of the species. The fifth character is reserved for distinguishing between any duplicates with a number. As an example, the scientific name of Douglas fir is *Pseudotsuga menziezii*. The acronym for this plant is PSME. If there were already a species with this acronym a number would appear after the acronym to distinguish the two species.

We realize that these three forms of communication for species can become confusing. Therefore we have adopted the following rules for this document:

- Common names are used in the text.
- Common names, scientific names and acronyms appear in tables and figures.
- Where specific species are referred to from the text to tables we will attempt to clarify in the reference to which species we are referring (e.g. 'Table 4.; Density; Western hemlock' to indicate that we are referring to the section of Table 4 concerning density where western hemlock is concerned).

We have also provided in ***Table 1*** the common and scientific names for all the plants discussed in this document as well as their acronyms to assist in deciphering information contained in the tables. Nomenclature follows Hitchcock and Cronquist (1998) for vascular plants and McCune and Geiser (1997) for macrolichens.

Table 1. Taxonomic nomenclature of species found at the Earth Sanctuary, Whidbey Island.

Lifeform	Common name	Scientific name	Acronym
Trees	Grand fir	*Abies grandis*	ABGR
	Big-leaf maple	*Acer macrophyllum*	ACMA
	Red alder	*Alnus rubra*	ALRU
	Sitka spruce	*Picea sitchensis*	PISI
	Douglas fir	*Pseudotsuga menziesii*	PSME
	Willow	*Salix spp.*	SALI
	Western red cedar	*Thuja plicata*	THPL
	Western hemlock	*Tsuga heterophylla*	TSHE
Shrubs	Oregon grape	*Berberis nervosa*	BENE
	Salal	*Gaultheria shallon*	GASH
	Holly	*Ilex verticillatus*	ILVE
	Currant, Gooseberry	*Ribes lacustre*	RILA
	Wild rose	*Rosa gymnocarpa*	ROGY
	Thimbleberry	*Rubus parviflorus*	RUPA
	Himalayan blackberry	*Rubus procerus*	RUPR
	Salmonberry	*Rubus spectabilis*	RUSP
	Evergreen blackberry	*Rubus laciniatus*	RULA
	Trailing blackberry	*Rubus ursinus*	RUUR
	Elderberry	*Sambucus racemosa*	SARA
	Huckleberry	*Vaccinium ovatum*	VAOV
	Red huckleberry	*Vaccinium parvifolium*	VAPA
Herbs	Colonial bentgrass	Agrostis capillaris	AGCA
	Dwarf mistletow	Arceuthobium spp	ARSPP
	Unidentified sedge	*Carex spp.*	CYPER
	Bedstraw, Cleavers	*Galium triflorum*	GATR
	Small-fruited Alumroot	*Heuchera micrantha*	HEMI
	Iris	*Iris spp.*	IRIS
	Twinflower	*Linnaea borealis*	LIBO2
	Skunk cabbage	*Lysichiton americanum*	LYAM
	False lily of the valley, bead ruby	*Maianthemum dentatum*	MADE
	Mitrewort, Bishop's cap	*Mitella pentandra*	MIPE
	Miner's lettuce	*Montia sibirica*	MOSI
	Water-parsley	*Oenanthe sarmentosa*	OESA
	Grass	Unidentified Poaceae	POAC
	Chickweed	Stellaria media	STME
	Coolwort, Foamflower	*Tiarella trifoliata*	TITR2
	Starflower	*Trientalis latifolia*	TRLA2
	Stinging nettle	*Urtica dioica*	URDI
Ferns and fern allies	Horsetail; Scouring rush	*Equisetum arvense*	EQAR
	Horsetail; Scouring rush	*Equisetum telmateia*	EQTE
	Lady-fern	*Athyrium filix-femina*	ATFE
	Deer fern	*Blechnum spicant*	BLSP
	Shield-fern	*Dryopteris expansa*	DREX
	Wood-fern	*Dryopteris gymnocarpa*	DRGY
	Oak-fern	*Gymnocarpium dryopteris*	GYDR
	Sword fern	*Polystichum munitum*	POMU
	Bracken fern	*Pteridium aquilinum*	PTAQ
Bryophytes	Moss #1	Unidentified bryophyte #1	BRYO1
	Moss #2	Unidentified bryophyte #2	BRYO2
	Moss #3	Unidentified bryophyte #3	BRYO3
	Moss #4	Unidentified bryophyte #4	BRYO4
Lichens	Lichen	Lichen	LICH
	Lichen	Unidentified lichen #1	LICH1
	Usnea lichen	*Usnea filipendula*	USFI

Sampling design

Our design involved strategically sampling every distinct ecological region on the property for a suite of characteristics. We divided the landscape into different forest stands and within each stand we sampled the following:

- Plant species composition, distribution and abundance
- Snag distribution and abundance
- Coarse woody debris
- Forest stand age
- Macrotopography
- Soil texture and color

This sampling was accomplished by laying out transects across the property and sampling at varying intervals. The sampling plot consisted of three concentric circular plots of 5.56 m, 11.28 m and 15.96 m radius, respectively (0.01, 0.04 and 0.08 hectares, respectively; Figure 1). Ecological characteristics measured in each sub-plot are summarized in ***Table 2***.

In the inner sub-plot we measured characteristics of tree saplings and seedlings. We sampled overstory trees in the 0.04 ha plot and snags inside the 0.08 ha plot. The different sizes of the sub-plots reflects the amount of area needed to collect an adequate sample for extrapolation to the landscape level of entities ranging from small and/or abundant to large and/or sparse.

Within the circular plots we also measured characteristics of the shrub and herbaceous vegetation using line-intercept and visual estimates of understory plant cover within 1m^2 quadrants. We also recorded total species composition within the plots as well as topographical and soils information. Within each plot one dominant tree was aged by extracting a small core and counting annual rings.

Figure 1. Sampling plot layout.

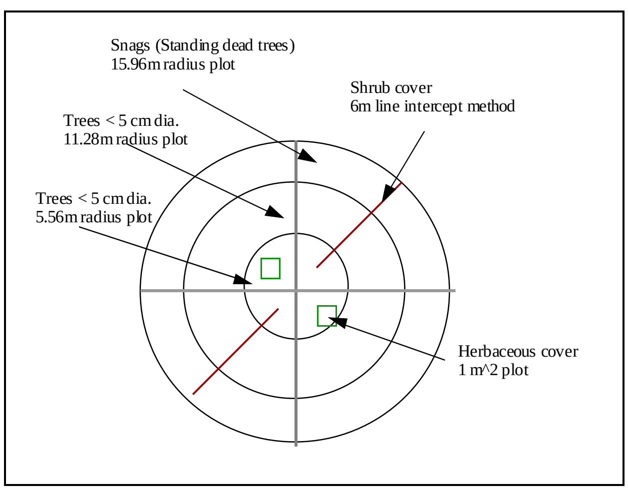


Table 2. Ecological characteristics measured during the Earth Sanctuary baseline assessment.

Measurement	Trees	Snags	Shrubs	Herbs	Coarse woody debris
Plot area	0.04ha/0.01ha	0.08	n/a	1m^2	n/a
Plot radius	11.28m	15.95m	n/a	n/a	n/a
Method	Inventory	Inventory	Line intercept	1m^2 quadrant	Line intercept
Diameter	X	X			X
Species	X	X	X	X	X`
Relative dominance	X				
Height	X	X	X		
Length					X
Decay class		X			X
Percent cover	X		X	X	X

Earth Sanctuary forest stand types

Although a variety of habitats could be delineated at the Earth Sanctuary depending on the scale chosen, we designated four major forest stand types that we felt dominated the landscape. A brief description of each type is shown in Table 1. We accumulated a minimum of three samples within each stand type to fully assess the variability within the immediate area.

Reference forest stand type

An old-growth forest representing the type of forest that occupied Whidbey Island before the onset of modern development was chosen as the objective for the Earth Sanctuary restoration work. We chose South Whidbey State Park as a suitable target reference stand for the Earth Sanctuary restoration effort. Specifically, we sampled in the area known as the University, or 'U-Grove.' This stand has persisted and developed naturally for centuries with minimal human disturbance. A brief description of this forest appears in Table 1. We sampled at three different sites within this stand.

Table 3. Description of the forest stand types designated for the Earth Sanctuary restoration efforts

Red alder	Overstory dominated by Red alder. Shrub layer composed primarily of salmonberry and elderberry. Herbaceous layer dominated by sword fern, stinging nettle and trailing blackberry.
Douglas fir/Western hemlock	Stand dominated by Douglas fir and Western hemlock. Small component of western red cedar. Understory vegetation of huckleberry, stinging nettle and sword fern.
Douglas fir/Western hemlock/Red alder	Similar to Red Alder Stand with the addition of some mature Douglas fir and young, understory Western hemlock. Small component of western red cedar. Few huckleberries and sparse stinging nettle. Much sword fern.
Western hemlock/Douglas fir/Red alder	Stand nearly exclusively dominated by young Western hemlock. Very small component of Douglas fir and western red cedar. Shrub layer composed mostly of sword fern and huckleberry.
Old-growth Reference	Mature Douglas fir/Western Hemlock Stand. Many canopy layers including legacy Douglas firs and mid-story hemlock. Abundant snags and downed logs of large diameter. Understory of sword fern, huckleberry, Oregon grape and twinflower.

Results of the Earth Sanctuary ecological assessment

Species list

Table 1 contains a list of species encountered in our sampling plots during the summer of 2000. Forty-eight vascular plants, mosses and lichens were found. This list is not intended to be exhaustive. Doubtless other species occur which did not appear in our sample plots. This is especially true for the bryophytes (mosses, liverworts and hornworts) and lichens. Bryophytes provide the greatest taxonomic challenge to the botanist, requiring the use of microscopic analysis of anatomical structures to determine their identity to the species level. Such efforts were beyond the scope of the present project. We differentiated between mosses in our plots and collected samples but the priority of more important tasks precluded their identification to species. It is our opinion, however, that there is an abundance of bryophytes at the Earth Sanctuary and it would be worthwhile to inventory them.

Lichens are not plants but a symbiotic partnership between a fungus and an alga or bacterium. Lichens are somewhat easier to identify, generally necessitating only the use of a high-powered hand lens to see morphological features. Some lichens require the use of chemical tests to identify them to species. As with the mosses, we differentiated between species encountered in our plots and made collections, but have not identified them as of the date of this document. Hopefully an appendix of lichen and/or moss species can be appended to this document at a later date.

While we have not undertaken the opportunity to identify the species and functions of lichens at the Earth Sanctuary, we do recognize the important and often under-appreciated contribution they make to a forest ecosystem. Lichens serve numerous functions including:

- Nitrogen fixation. Through a symbiotic relationship with an alga or bacterium, lichens are able to produce nitrogenous compounds similar to what is found in commercial fertilizer, thus ‘fertilizing’ the forest around them. *(N.B.: Red alder has this ability also)*.
- Forage for animals. *Lobaria oregana*, as well as other lichens, is an important winter food source for some wildlife.
- Nesting materials for birds and mammals.
- Interception and metering of excess precipitation to the forest floor.

Lichens achieve their ultimate abundance in old-growth forests in the Pacific Northwest and are considerably less prominent in younger stands.

While the task of inventorying and describing the ecology of all organism groups at the Earth Sanctuary would be rewarding, such an endeavor was outside the scope of the present work. Though not complete, the 48 species-trees, shrubs, herbs, ferns and fern allies, brophytes and lichens-in ***Table 1*** can be considered the most common in the Earth Sanctuary upland forest community. Together with the wetland vegetation inventory (46 species; Appendix 1) total species richness to-date at the Earth Sanctuary is 96 species. This forms the vegetation baseline to which new additions will be added in the future.

Non-native species

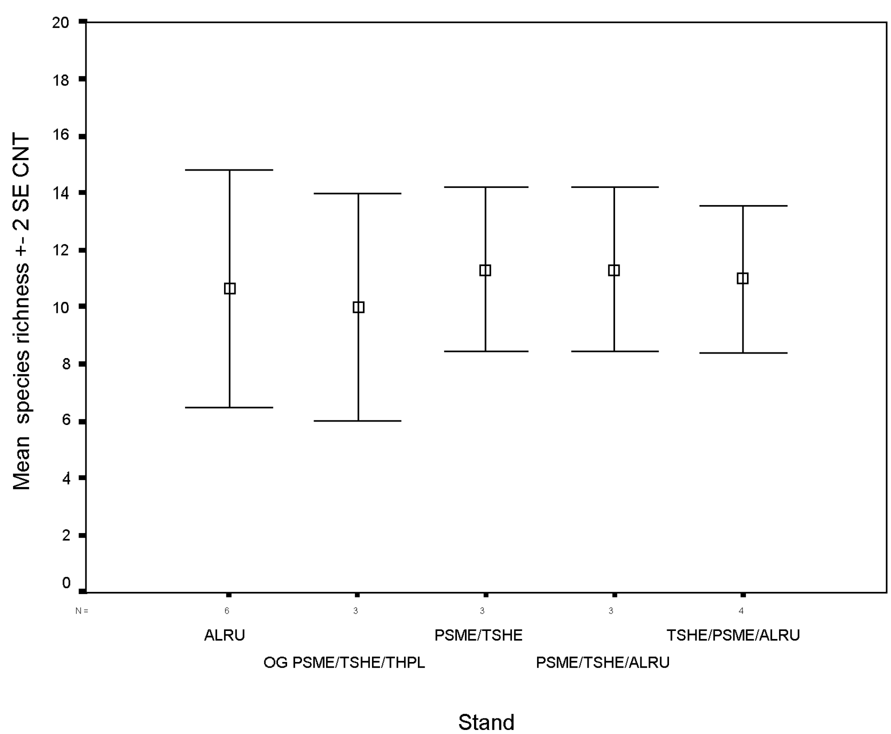
The Earth Sanctuary contains at least two non-native vascular plant species, and a third aggressive native grass, that will be of importance to the restoration efforts. These include Himalayan blackberry (*Rubus procerus)*, holly (*Ilex verticillatus*), and reed canarygrass (*Phalaris arundinacea*).

Species composition

Plant species composition of each stand and sample plot is shown in Table 4. Distinct plant associations could be distinguished in each stand type that we sampled. Typically, the Red Alder Stand contained salmonberry, trailing blackberry, stinging nettle and elderberry in a dense thicket. Where there appeared to be a history of shade, as under western hemlock or mature big-leaf maple, the association shifted towards a lower stature, more open layer of sword fern, trailing blackberry, wild rose and huckleberries (Table 4). Wetter regions produced a component of mitrewort, miner's lettuce, skunk cabbage, coolwort, horsetails and many true-ferns.

Plants of the Northwest tend to be adaptable to an array of environments. Unlike animals, very few vascular plants are old growth obligate, although many find optimum habitat there. Typically, such species include saprophytic plants that require deep, organic soils and heavy shade (Franklin et al. 1981). Species commonly found in low elevation old growth forest can also be found in an array of habitats spanning the range of stand age, elevation, topography and moisture extremes. For instance, trailing blackberry, sword fern, starflower, bedstraw and other plants found at the Earth Sanctuary can also be found in dry, high elevation forests on the east side of the Cascades as well as in the low elevation old-growth and red alder dominated forests of Whidbey Island. Plant species richness (number of species per unit area) was not appreciably different between forest types (Figure 2).

Figure 2. Plant species richness across the forest types sampled at the Earth Sanctuary and South Whidbey State Park.



The understory plant association of the Old-growth Reference Stand consisted mainly of swordfern, salal, Oregon grape, wild rose, huckleberries and trailing blackberry (Table 4). These plants sprawled among the stand in a low, open association on the ground and on logs and snags.

Table 4. Species composition of the stands sampled as part of the Earth Sanctuary ecological assessment.

	Stand	Red Alder						Douglas fir/ Western Hemlock			Douglas fir/Western Hemlock/Alder			Western Hemlock/ Douglas fir/Alder				Old Growth Reference		
Scientific name	Common name Plot	EWP 1	T1P1	T2P1	T5P3	T5P4	T6P1	T1P4	T3P1	T4P1	EWP2	T1P2	T1P3	T1P5	T1P6	T5P1	T5P2	WHSP1	WHSP2	WHSP3
Trees																				
Abies grandis	Grand fir													X						
Acer macrophyllum	Big-leaf maple								X		X									
Alnus rubra	Red alder	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
Picea sitchensis	Sitka spruce																	X		X
Pseudotsuga menziesii	Douglas fir		X					X	X	X	X	X	X		X			X	X	X
Salix spp.	Willow									X										
Thuja plicata	Western red cedar	X						X	X		X	X	X			X				
Tsuga heterophylla	Western hemlock						X	X	X	X		X		X	X	X	X	X	X	X
Shrubs																				
Berberis nervosa	Oregon grape																	X	X	
Gaultheria shallon	Salal													X		X				
Ilex verticillatus	Holly	X			X												X			
Oenanthe sarmentosa	Water-parsley				X	X														
Ribes lacustre	Currant, Gooseberry	X				X							X	X					X	
Rosa gymnocarpa	Wild rose													X					X	
Rubus parviflorus	Thimbleberry				X	X														
Rubus procerus	Himalayan blackberry				X															
Rubus spectabilis	Salmonberry	X	X	X	X	X	X		X	X	X	X	X	X		X				
Rubus ursinus	Trailing blackberry		X	X	X			X		X		X	X	X	X	X	X	X	X	
Sambucus racemosa	Elderberry	X	X	X	X	X			X	X	X	X	X		X	X				
Vaccinium ovatum	Huckleberry							X	X	X				X	X	X	X			
Vaccinium parvifolium	Red huckleberry								X					X				X	X	
Herbs																				
Arceuthobium spp.	Dwarf mistletoe	X						X	X		X									
Galium triflorum	Bedstraw, Cleavers	X				X													X	
Iris spp.	Iris					X											X			
Linnaea borealis	Twinflower																		X	
Lysichiton americanum	Skunk cabbage				X															
Mitella pentandra	Mitrewort, Bishop's cap				X							X								
Montia sibirica	Miner's lettuce		X										X							
Tiarella trifoliata	Coolwort, Foamflower	X			X	X						X				X			X	
Trientalis latifolia	Starflower											X							X	
Unidentified Cyperaceae	Unidentified sedge					X														
Unidentified Poaceae	Grass																		X	
Urtica dioica	Stinging nettle	X	X	X	X	X			X	X	X	X	X							

	Stand	Red Alder						Douglas fir/ Western Hemlock			Douglas fir/Western Hemlock/Alder			Western Hemlock/ Douglas fir/Alder				Old Growth Reference		
Scientific name	Common name Plot	EWP 1	T1P1	T2P1	T5P3	T5P4	T6P1	T1P4	T3P1	T4P1	EWP2	T1P2	T1P3	T1P5	T1P6	T5P1	T5P2	WHSP1	WHSP2	WHSP3
Ferns and Fern Allies																				
Equisetum arvense	Horsetail; Scouring rush				X	X														
Equisetum telmateia	Horsetail; Scouring rush				X															
Blechnum spicant	Deer fern													X			X			
Dryopteris expansa	Shield-fern			X					X											
Dryopteris gymnocarpa	Wood-fern				X										X					
Gymnocarpium dryopteris	Oak-fern					X										X				
Polystichum munitum	Sword fern	X	X	X		X		X	X	X	X		X	X	X	X	X	X	X	X
Pteridium aquilinum	Bracken fern					X														
Mosses and Lichens																				
Bryophytes	Moss	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X
Unidentified bryophyte #1	Moss #1		X					X	X			X	X	X	X	X		X	X	X
Unidentified bryophyte #2	Moss #2		X									X		X	X					X
Unidentified bryophyte #3	Moss #3				X	X														
Lichens	Lichen	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X
Unidentified lichen #1	Lichen									X		X								
Unidentified crustose lichen #2	Lichen																			X

Overstory trees

Size structure diagrams

Forest ecosystems are composed of populations of species at varying levels of maturity. Ecologists often create size structure diagrams to help them interpret the age dynamics of a stand. A size structure diagram is merely a graph of the number of trees in a series of size classes. How these levels are structured reveals much about the ecology of an area. A size structure diagram can reveal whether a stand is young and vigorous, or ancient and in a steady state, whether it has grown undisturbed for centuries, or routinely experiences catastrophic disturbance.

A critical assumption must be made to effectively use a size structure diagram: This assumption is that a tree's size is correlated with its age. Intuitively, a small tree is younger than a large tree. There are exceptions, but substituting size for age is a handy way of estimating the number of trees in a particular age class and within a particular stand where growth conditions are uniform.

Figure 3.
Overstory tree size structure diagram of the Red Alder Stand type. Each bar represents the number of trees found in a particular size class.

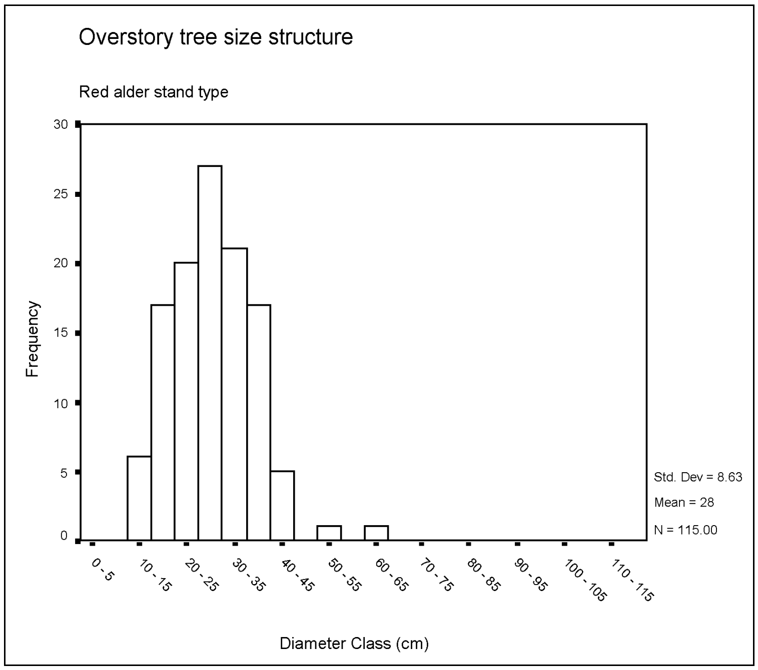


Figure 3 shows the size structure of the Red Alder stand at the Earth Sanctuary. The X-axis shows twenty-four categories of 5 cm increments ranging from zero to 120 cm. The bars and Y-axis show the number of trees encountered in each of the size categories. Figures 4 through 6 show size structure diagrams of the remaining three stand types sampled for the Earth Sanctuary assessment. Figure 7 shows the size structure diagram developed for the South Whidbey State Park Old-growth Reference Stand.

The most striking difference between the Earth Sanctuary property and the Old-growth Reference Stand can be seen in the size structure diagrams for the Red Alder stand Figure 3 and the Old-growth Reference Stand (Figure 7). The trees in the Red Alder Stand are very uniform in size, with the majority ranging from 20-35cm in diameter. This pattern resulted from all the trees initiating in a 'pulse' following logging activity. There is little variety in size, species composition or canopy structure because these trees all grew evenly in size from the same point in time. Contrast this stand with the Old-growth Reference Stand (Figure 7), where there is a huge variety of tree sizes, from large, legacy Douglas firs to mid-story firs, hemlocks and western red-cedars to understory hemlocks regenerating on fallen logs. Each size class is occupied by trees and shrubs in varying stages of life. The plethora of sizes creates canopy layers of different heights and densities.

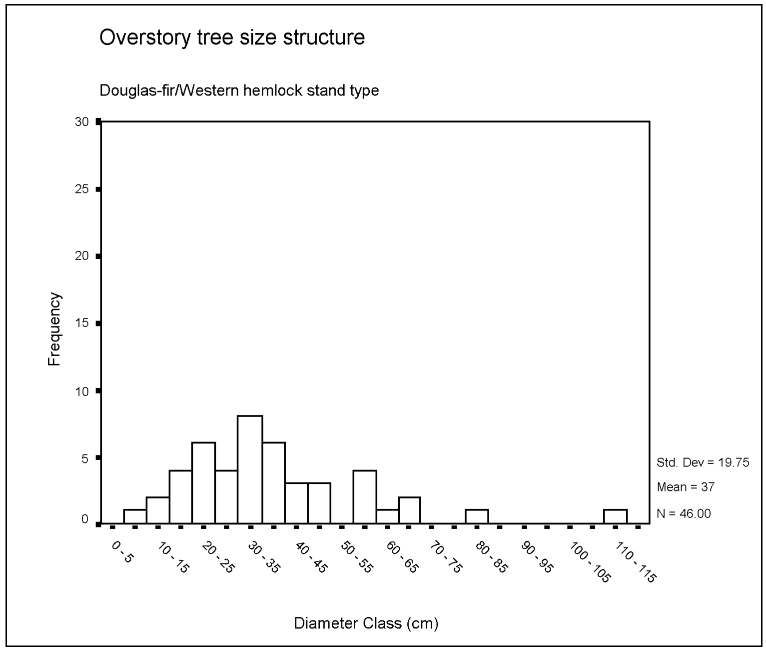


Figure 4.
Overstory tree size structure diagram of the Douglas fir/ Western hemlock stand type. Each bar represents the number of trees found in a particular size class.

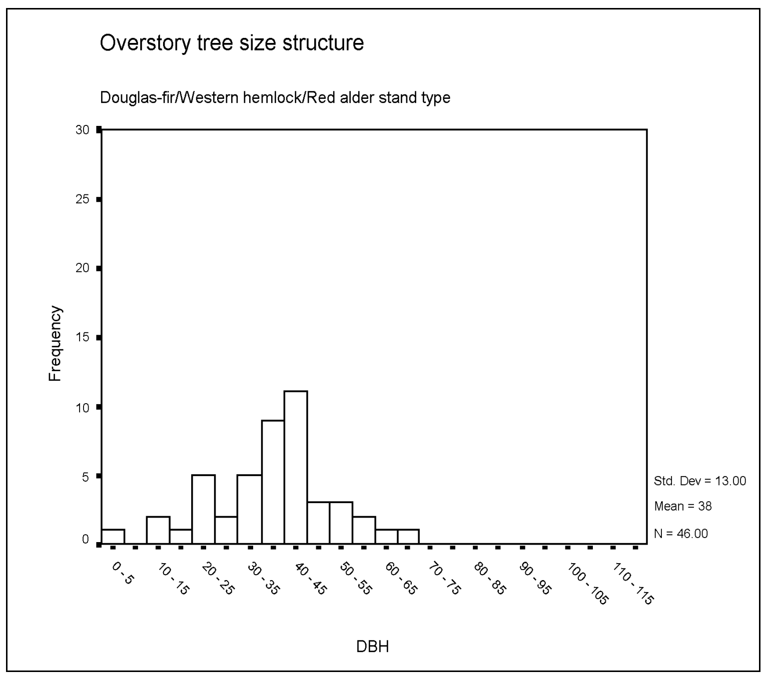


Figure 5.
Overstory tree size structure diagram of the Douglas fir/ Western hemlock/Red alder stand type. Each bar represents the number of trees found in a particular size class.

Figure 6.
Overstory tree size structure diagram of the Western hemlock/ Douglas fir/Red alder stand type. Each bar represents the number of trees found in a particular size class.

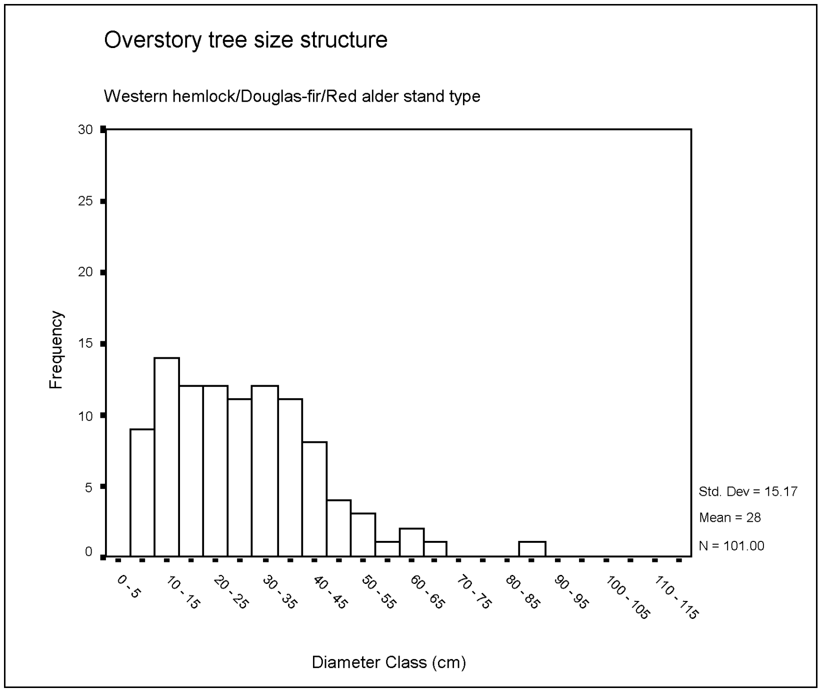
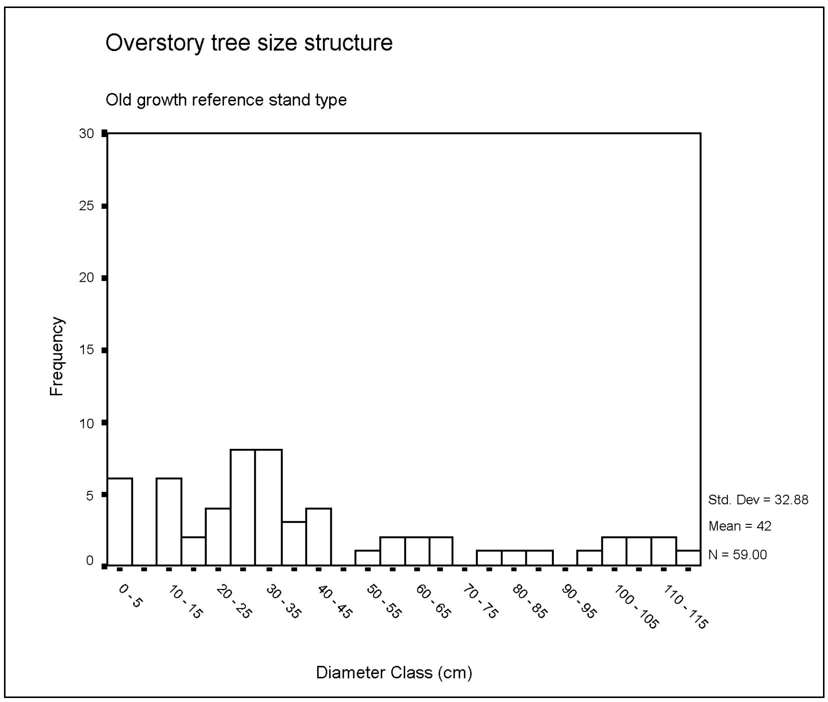


Figure 7.
Overstory tree size structure diagram of the Old-growth Reference Stand type. Each bar represents the number of trees found in a particular size class.



Complexity

The disparity in size structure between the Red Alder Stand and the Old-growth Reference Stand can be expressed mathematically by summarizing not only the mean tree diameter of each stand, but also by measuring how variable the tree diameters were. These data are shown in Table 5, with the statistic of most interest being the coefficient of variation (CV). The coefficient of variation for tree diameter expresses the variability in tree size as a proportion of the mean tree size. When comparing two stands in terms of variability in tree size, the stand with the larger CV value will have more variation in tree diameter and consequently will likely have more structural complexity. Not only are the trees bigger in the Old-growth Reference Stand (mean diameter = 42.2 cm; Table 5) than in the red alder stand (mean diameter = 27.8 cm), but there is a wider range of diameters as well ($CV_{\text{Old-growth Reference Stand}} = 0.78$ vs. $CV_{\text{Red Alder Stand}} = 0.31$;).

The difference in forest structure is most extreme between the Red Alder Stand and the Old-growth Reference Stand, but each of the stands at the Earth Sanctuary had much less variation in tree diameter than the target Old-growth Reference Stand. This variation comes as a natural consequence of a process called succession. The Old-growth Reference Stand at South Whidbey State Park is a good example of how a typical forest develops on the west side of the Cascades in the Northwest. This stand exhibits many dominant Douglas firs of large diameter. These trees likely originated centuries ago after some stand-resetting event (most likely fire) occurred. Douglas fir is a colonizing species, meaning it quickly invades disturbed habitat and rapidly establishes dominance and may maintain it for a century or more. After a time, the forest canopy becomes too dense to support the large number of trees and the forest begins to self-thin. Weaker trees are crowded out of the canopy and die, contributing coarse wood to the forest floor or snags to the mid-story. These snags and logs become useful as habitat for many species of wildlife. Meanwhile, shade-tolerant species such as western hemlock begin growing in the understory, often initiating on Douglas fir logs. Eventually a shrub layer of small trees and shrubs form an understory and the hemlocks mature into a mid-story canopy punctuated with enormous, aging Douglas firs. Periodically a large tree may topple in the wind, a fire may burn through a portion of the stand, or a disease pocket may form, opening a hole in the canopy that is quickly filled with small trees and shrubs reaching for light. A patchwork mosaic of young, mature and old forest forms. These are the processes by which a variety of trees and tree sizes are formed in old-growth forests.

A photograph of an old-growth Douglas fir forest appears in Figure 8. Notice how each of the structural components described above can bee seen, specifically the multiple canopy layers comprised of different size classes of trees and the presence of coarse woody debris on the forest floor. Because Douglas fir is often very tall and often dies standing, it is likely that one or two of the large trees in the photograph are snags, providing habitat for arboreal wildlife. The coefficient of variation summarizes this variation in tree diameters and serves as a proxy indicator of the processes that may be occurring within the forest.

The Conifer Component of the Earth Sanctuary Stands

While the most striking differences in forest complexity were seen between the Red Alder Stand and the Old-growth Reference Stand, the size structure diagrams reveal much about the other three stand types as well. The diagrams for the Douglas fir/Western Hemlock Stand (Figure 4), the Douglas fir/Western hemlock/Red alder stand (Figure 5) and the Western hemlock/Douglas fir/Red alder stand (Figure 6) at the Earth Sanctuary displayed more complexity than the Red Alder Stand (Table 5, Figure 9). These stands exhibit a component of moderately large conifer in their composition. Such trees broaden the curves seen in the size structure diagrams for these species.

The conifers at the Earth Sanctuary likely initiated in two ways:

- They remained after the harvest that initiated the present stand as being too small to bother with, to difficult to remove, or
- They found favorable microsites to establish after harvest.

Table 5. Overstory tree characteristics by stand type and species.

Stand		Red Alder			Douglas fir/Western Hemlock			Douglas fir/Western Hemlock/Red Alder			Western Hemlock/ Douglas fir/Red Alder			Old growth Reference		
Diameter (cm at breast height)																
Acronym	Species	Mean (cm)	sd	n	Mean (cm)	sd	n	Mean (cm)	sd	n	Mean (cm)	sd	n	Mean (cm)	sd	n
ACMA	Big-leaf maple	--	--	--	68.00	n/a	1	--	--	--	--	--	--	--	--	--
ALRU	Red alder	28.12	8.52	112	32.75	11.87	21	39.36	8.40	19	30.59	10.35	56	34.74	6.80	5
PISI	Sitka spruce	--	--	--	--	--	--	--	--	--	--	--	--	22.00	8.91	2
PSME	Douglas fir	20.20	n/a	1	62.88	36.30	5	37.76	13.00	12	52.15	14.43	6	73.09	30.27	23
SALI	Willow	--	--	--	37.80	n/a	1	--	--	--	--	--	--	--	--	--
THPL	Western red-cedar	11.00	n/a	1	51.25	16.36	4	39.61	14.60	13	18.33	11.43	3	--	--	--
TSHE	Western hemlock	18.80	n/a	1	29.26	13.41	14	7.75	5.30	2	21.04	16.84	36	20.29	13.81	29
Total		27.80	8.60	115	37.40	19.80	46	37.64	13.00	46	28.07	15.20	4	42.20	32.90	59
CV		0.31			0.53			0.35			0.54			0.78		
Maximum diameter (cm)																
Acronym	Species	Max.			Max.			Max.			Max.			Max.		
ACMA	Big-leaf maple	--			68.00			--			--			--		
ALRU	Red alder	62.80			59.30			51.80			54.40			42.00		
PISI	Sitka spruce	--			--			--			--			28.30		
PSME	Douglas fir	20.20			111.10			65.30			68.70			117.70		
SALI	Willow	--			37.80			--			--			--		
THPL	Western red-cedar	11.00			69.40			61.70			31.50			--		
TSHE	Western hemlock	18.80			57.00			11.50			89.10			44.20		
Basal Area (m^2/ha.)																
Acronym	Species	BA	sd	n	BA	sd	n	BA	sd	n	BA	sd	n	BA	sd	n
ACMA	Big-leaf maple	--			9.08			--			--			--		
ALRU	Red alder	28.98			14.74			19.27			25.72			11.85		
PISI	Sitka spruce	--			--			--			--			0.95		
PSME	Douglas fir	0.80			19.41			11.20			32.04			80.41		
SALI	Willow	--			2.81			--			--			--		
THPL	Western red-cedar	0.24			10.31			13.35			1.98			--		
TSHE	Western hemlock	0.69			7.84			0.24			7.82			7.82		
Total		30.71			64.19			44.05			67.56			101.03		

Stand		Red Alder			Douglas fir/Western Hemlock			Douglas fir/Western Hemlock/Red Alder			Western Hemlock/ Douglas fir/Red Alder			Old growth Reference		
Density (no./ha.)																
Acronym	Species	Density	sd	n	Density	sd	n	Density	sd	n	Density	sd	n	Density	sd	n
ACMA	Big-leaf maple	--	--	--	25	--	1	--	--	--	--	--	--	--	--	--
ALRU	Red alder	467	191.49	6	175	238.48	3	158	38.19	3	350	176.78	4	125	--	1
PISI	Sitka spruce	--	--	--	--	--	--	--	--	--	--	--	--	25	0.00	2
PSME	Douglas fir	25	--	1	63	17.68	2	100	50.00	3	150	--	1	192	94.65	3
SALI	Willow	--	--	--	25	--	1	--	--	--	--	--	--	--	--	--
THPL	Western red-cedar	25	--	1	50	35.36	2	108	76.38	3	75	--	1	--	--	--
TSHE	Western hemlock	25	--	1	117	137.69	3	50	.	1	225	145.77	4	242	87.80	3
Total		541.67			454.17			416.66			800.00			583.34		

Density trees >50cm dbh/ha.											
Acronym	Species	#/ha.	Plots	Avg. count/plot	Plots	Avg. count/plot	Plots	Avg. count/plot	Plots	Avg. count/plot	Plo
ACMA	Big-leaf maple			4.17	3						
ALRU	Red alder	2.08	6	4.17	3	8.33	3	9.38	4		
PISI	Sitka spruce										
PSME	Douglas fir			12.50	3	8.33	3	9.38	4	75.00	3
SALI	Willow										
THPL	Western red-cedar			8.33	3	12.50	3				
TSHE	Western hemlock			4.17	3			6.25	4		
Stand total		**2.08**	**6**	**33.33**	**3**	**29.17**	**3**	**25.00**	**4**	**75.00**	**3**

Because many of the Douglas firs are fairly large, they likely survived the harvest, rather than establishing afterwards. Similarly, western hemlock is not a pioneer species. It prefers to establish in shaded, understory conditions rather than in an exposed, dry clear-cut. It too likely survived the harvest.

While local habitat conditions probably play a role in the development of these stands, the majority of the complexity is likely a result of how the stand initiated.

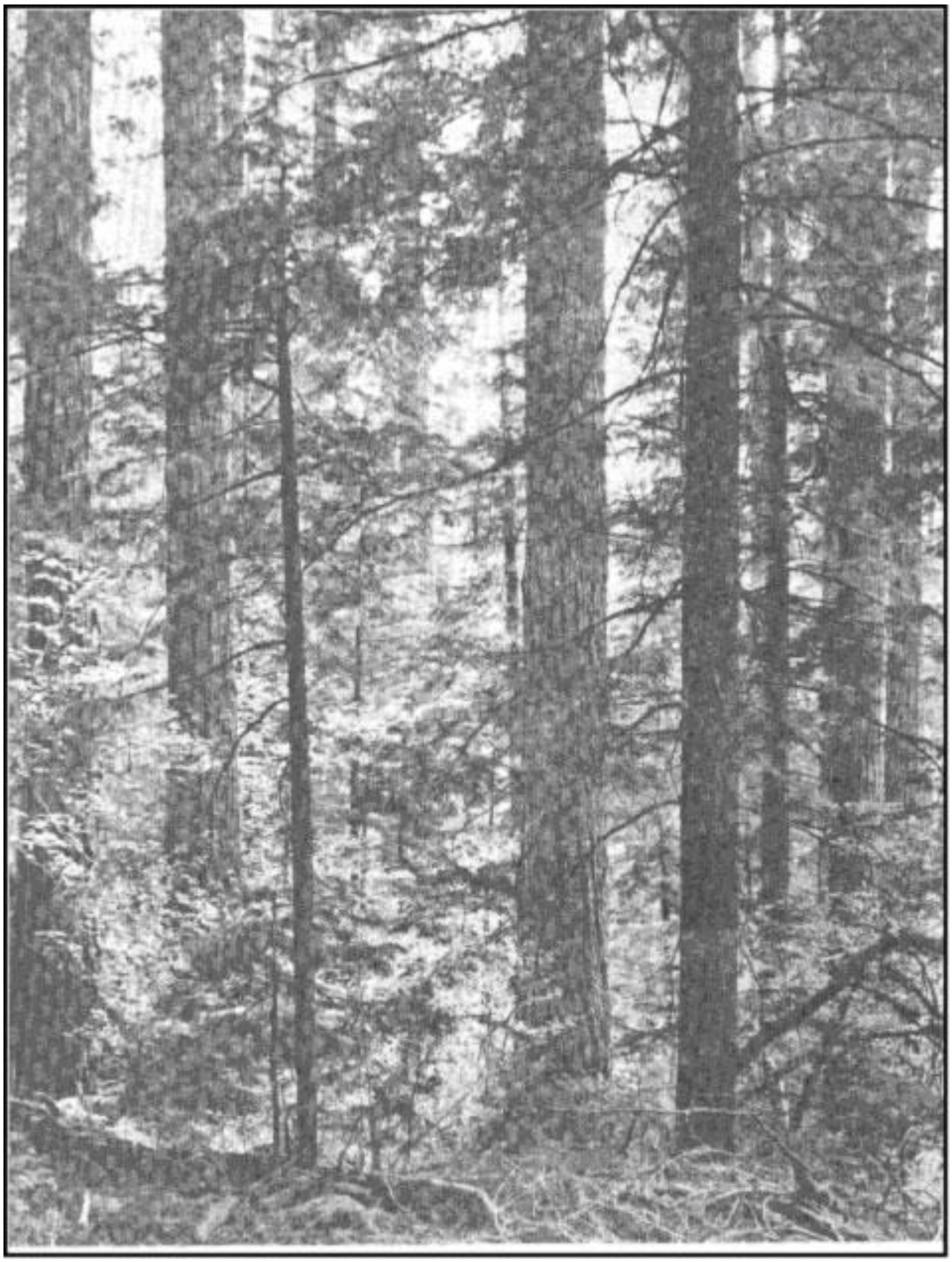


Figure 8. Photograph of old-growth forest showing high degree of complexity in canopy levels, age classes and tree diameters. Photo from Franklin et al. (1981).

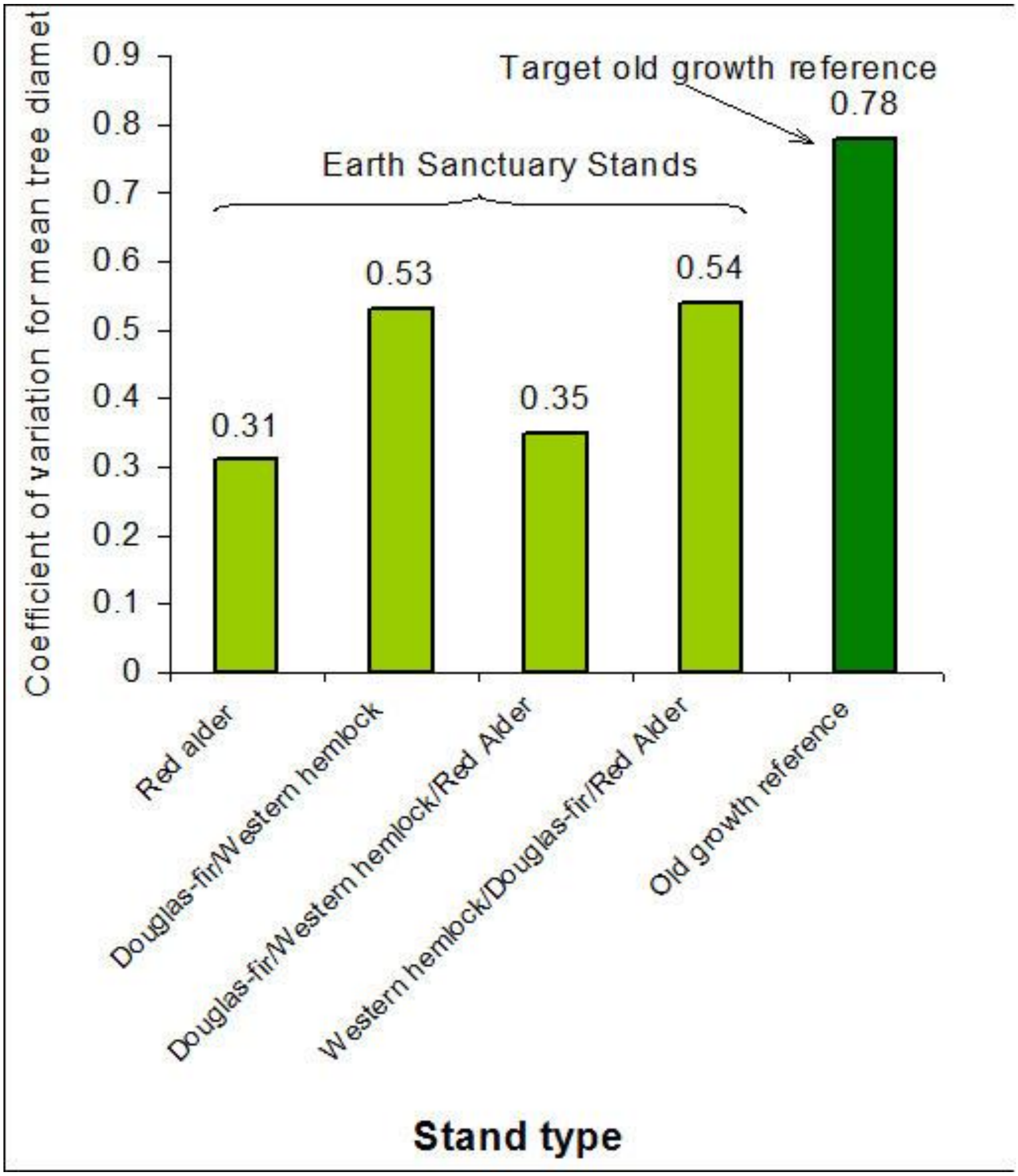


Figure 9. Comparison of complexity of Earth Sanctuary forest types versus target Old-growth Reference Stand. Coefficient of variation is a measure of variability in sizes of trees and is a good proxy indicator of forest complexity.

Overstory forest characteristics

The functionality of a forest is often directly tied to the characteristics of its inhabitants. The abundance and type of species found is dependent on habitat diversity which is in turn related to the amount of canopy structure, snags, logs, size and density of trees (Franklin et al. 1981). We have characterized our findings from the Earth Sanctuary assessment in Table 5.

The mean diameter of the sampled trees was discussed briefly above, along with a discussion of the variability in diameters encountered (coefficient of variation). It should be mentioned that although none of the Earth Sanctuary stands has the same degree of structure as the Old-growth Reference Stands, the stands are not wholly without complexity. What complexity there is comes from the presence of large diameter conifers in the overstory as well as numerous small hemlocks in the understory. There are approximately 63 to 150 Douglas firs per hectare at the Earth Sanctuary (Table 5; Density; Douglas fir) with diameters ranging from 37 to 62 cm diameter (Table 5; Diameter; Douglas fir). While these diameters and densities seem comparable to those found in the Old-growth Reference Stand it may be worthwhile to consider that the basal area (cross-sectional area of a tree trunk) increases exponentially with diameter. Basal area gives a truer estimate of the amount of tree biomass in a stand. Comparing basal area across stand types reveals that the Earth Sanctuary stands are approximately one-third to two-thirds of the basal area of the target stand. We were not equipped to measure tree heights so a calculation of volume could not be done, however one can imagine the disparity when adding a third dimension (going from area to volume) to the calculation of tree size, especially when the Douglas firs at South Whidbey State Park approach 50-60m in height with maximum diameters of 117cm (Table 5; Maximum diameter). The Earth Sanctuary has a lot of growing to do!

Dead coarse wood on the forest floor is an ideal substrate for reproduction of many plant species. Western hemlock and Sitka spruce colonize and become established primarily on coarse woody debris, particularly of large diameter conifer logs (Figure 10). Often in stalled red alder stands that are choked with salmonberry the only tree reproduction occurs on stumps and logs where seedlings are elevated above competing vegetation. At least two stands at the Earth Sanctuary have an abundant regeneration of western hemlock on such pieces of wood. Two stands show densities of western hemlock of over 100 stems per hectare (Table 5; Density; Diameter; Western hemlock). This species will remain in the shady mid-story for centuries, waiting for an opening overhead, or just plod along until it finally pokes through the canopy and starts to shade out its competitors with its very dense foliage. Left to its own devices, in the absence of fire, logging or other catastrophic disturbance, it is likely that this scenario would play out in a century or two, developing into a high-volume hemlock stand with huge Douglas fir snags interspersed here and there. At present however, the western hemlock is adding a component of mid-story structure to the forest while waiting for its chance at dominance.

Figure 10.
Photograph of logs in an old-growth stand. This log is functioning as a 'nurse log', providing substrate, moisture and nutrients to a young generation of western hemlock as well as mosses, lichens and fungi. Animals may use this log as a lookout, travel corridor or refuge from dry conditions.

Snags

Snags (standing dead trees), along with coarse woody debris (downed logs) are perhaps the most under appreciated component of forest structure. It is easy to see why early scientists, perhaps more interested in the volume of harvestable timber than dead, rotten, downed wood, paid little attention to this facet of forest ecology. Snags are coming to be appreciated now as habitat for wildlife and contributors to coarse woody debris on the forest floor. In this section we will describe the results of our snag inventories at the Earth Sanctuary and target Old-growth Reference Stand.

Size structure diagrams

We constructed size structure diagrams from the snag inventory data and they can be interpreted in much the same way as those for the overstory trees. Figures 11 through 14 are snag size structure diagrams for the Earth Sanctuary forest stands. The size structure diagram for the Old-growth Reference Stand appears in Figure 15. One overriding pattern emerges quickly from these data; the snags at the Earth Sanctuary are small and few; the snags at the Old-growth Reference Stand are large and abundant (Table 6; Density; Stand total; and Volume/snag; stand mean).

From the size structure diagram we deduce that there are a few snags of large diameter in the larger size classes at the Earth Sanctuary. These snags occur in the Douglas fir/Western hemlock/Red alder Stand (Figure 13) and the Western hemlock/Douglas fir/Red alder stand (Figure 14). Their presence is good news for the restoration effort because when it comes to value as wildlife habitat, the bigger the snag, the better. Larger snags decompose slowly, provide larger cavities, have thicker bark layers for wildlife, and are taller than smaller snags, providing more protection for inhabitants.

Figure 16 shows the calculated mean volume per snag at each of the study stands. The Douglas fir/Western Hemlock Stand approaches the mean snag volume figure calculated for the Old-growth Reference Stand, but this is likely an artifact of the small sample size. The bigger picture is shown in Figure 17, mean snag volume per hectare. This gives a landscape-level overview of snag biomass. The Old-growth Reference Stand contains over 70 cubic meters of snag volume per hectare while the Earth Sanctuary stands range between 5 and 25 cubic meters (Figure 17;Table 6; Volume/ha). We also calculated snag characteristics at the individual and landscape scales (Table 6).

Figure 11.
Snag size structure diagram of the Red Alder Stand type. Each bar represents the number of snags found in a particular size class.

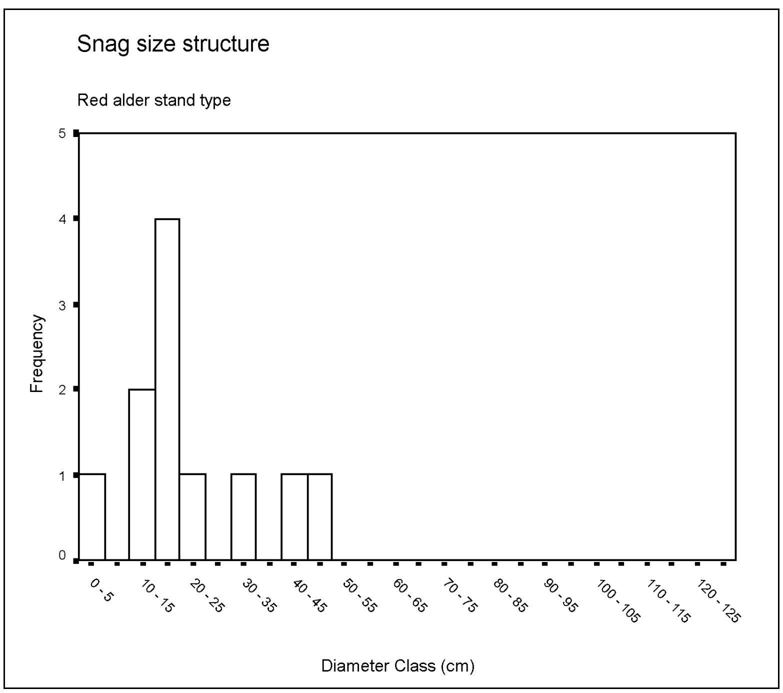


Figure 12.
Snag size structure diagram of the Douglas fir/Western Hemlock Stand type. Each bar represents the number of snags found in a particular size class.

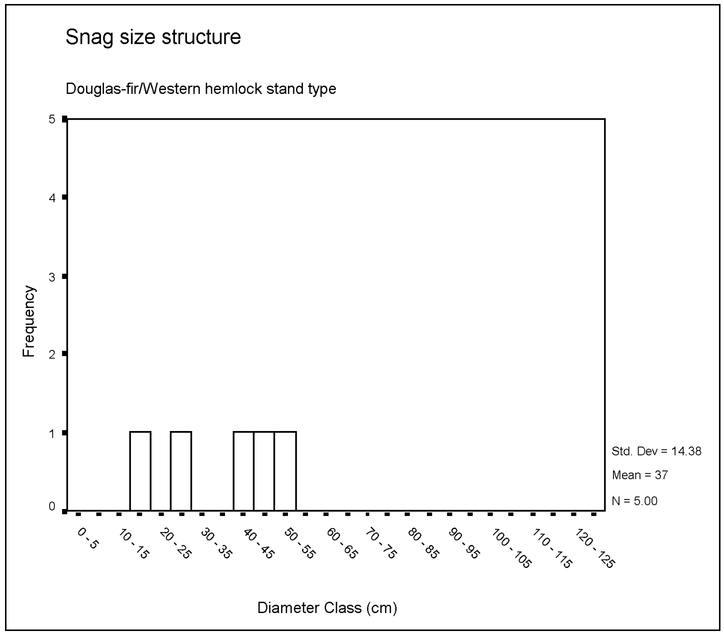
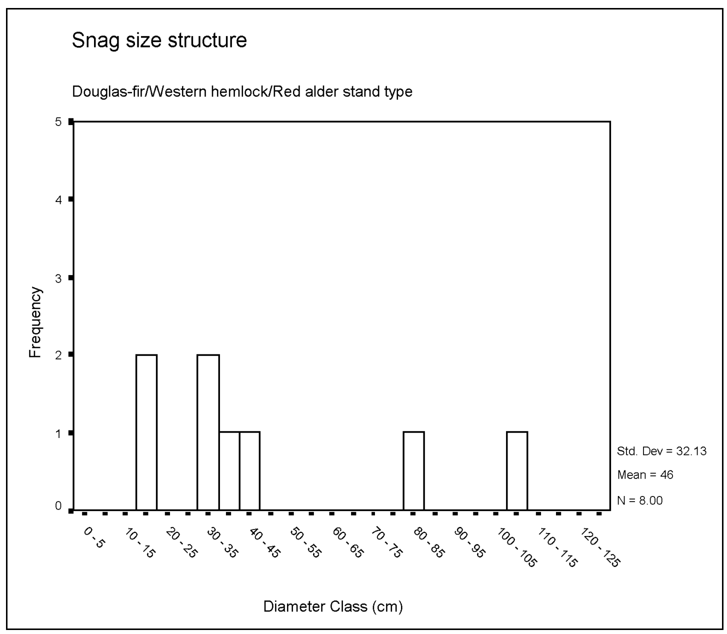


Figure 13. Snag size structure diagram of the Douglas fir/Western hemlock/Red alder stand type. Each bar represents the number of snags found in a particular size class.



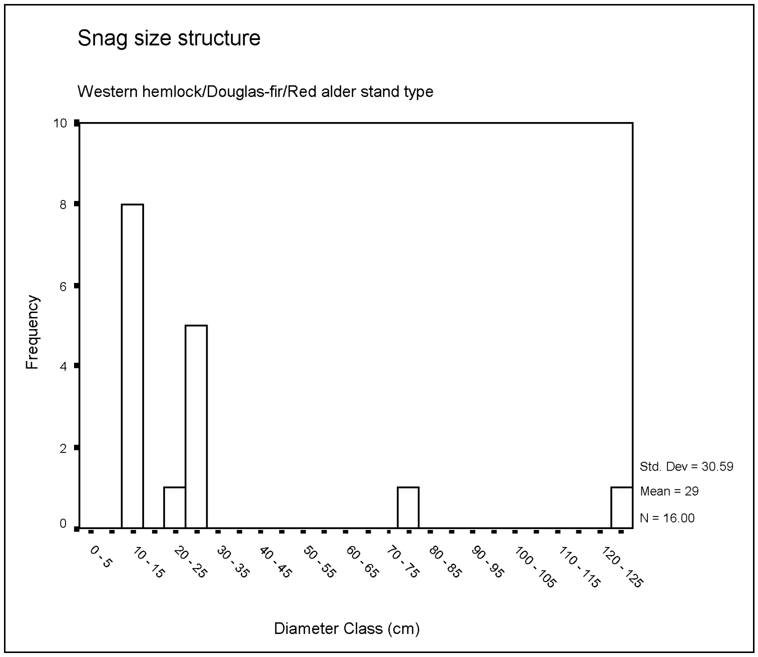


Figure 14.
Snag size structure diagram of the Western hemlock/Douglas fir/Red alder stand type. Each bar represents the number of snags found in a particular size class.

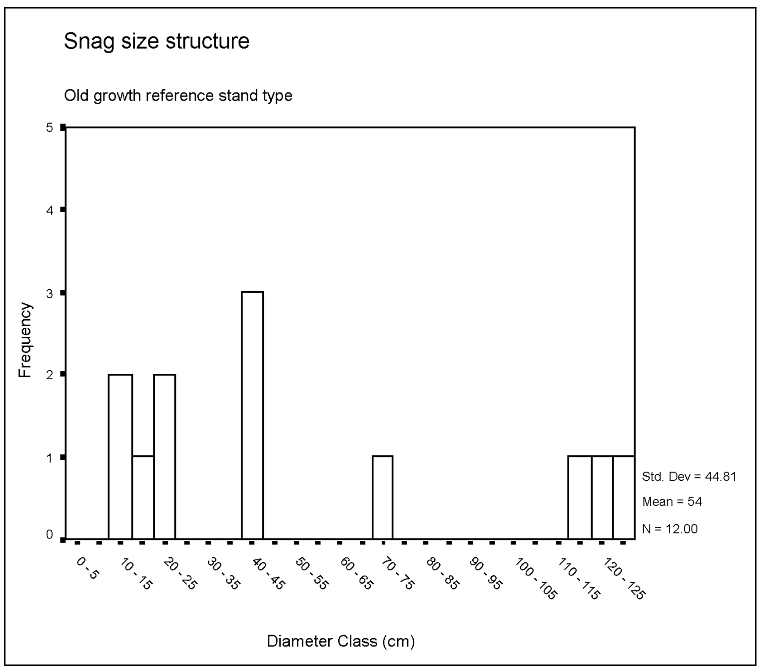


Figure 15.
Snag size structure diagram of the Old-growth Reference Stand type. Each bar represents the number of snags found in a particular size class.

Table 6. Snag characteristics

		Red Alder			Douglas fir/ Western hemlock			Douglas fir/ Western hemlock/ Alder			Western hemlock/ Douglas fir/ Red alder			Old growth reference		
Density (snags/ha.)	Decay class	Density			Density			Density			Density			Density		
	1	--			8.33			4.17			34.38			20.83		
	2	16.67			8.33			16.67			6.25			12.50		
	3	4.17			4.17			4.17			6.25			16.67		
	4	2.08			--			8.33			3.13			--		
	Stand total	22.92			20.83			33.33			50.00			50.00		
Diameter (cm)	Decay class	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
	1	--	--		44.75	--	1	34.60	--	1	20.07	8.68	4	38.76	37.28	2
	2	20.51	9.51	4	33.75	23.69	2	27.70	14.14	2	28.30	0.28	2	22.90	15.01	3
	3	15.80	--	1	27.40	--	1	35.50	--	1	71.05	79.97	2	92.00	45.25	2
	4	0.00	--	--	--	--	--	95.25	--	1	76.00	--	1	--	--	--
	Stand mean	18.20	5.57	5	39.15	14.96	3	37.53	21.44	3	30.13	14.09	4	47.18	40.45	3
Height (m)	Stand	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
	Stand mean	8.51	5.75	5	10.17	6.33	3	4.27	1.27	3	4.92	2.05	4	8.01	3.71	3
Volume (m^3)/snag		Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
	Stand mean	0.22		3	1.22		3	0.47		3	0.35		4	1.40		3
Volume (m^3)/ha.		Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
	Stand mean	5.07			25.51			15.75			17.54			70.01		

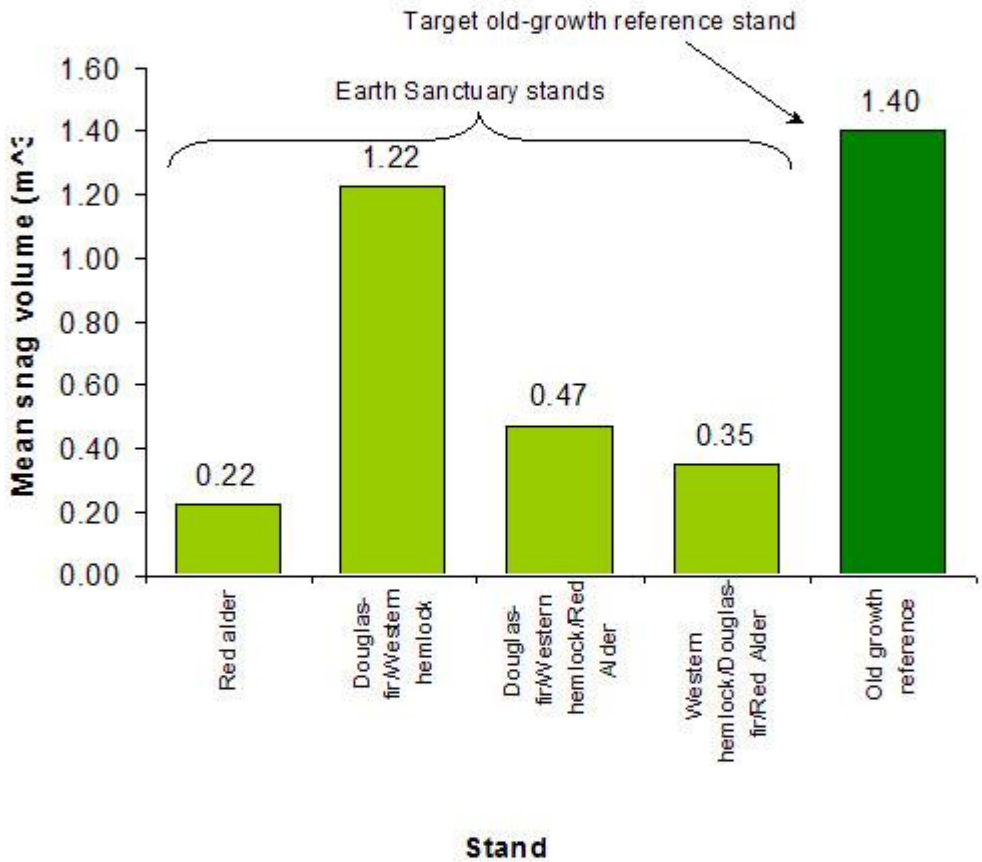


Figure 16. Mean volume per snag.

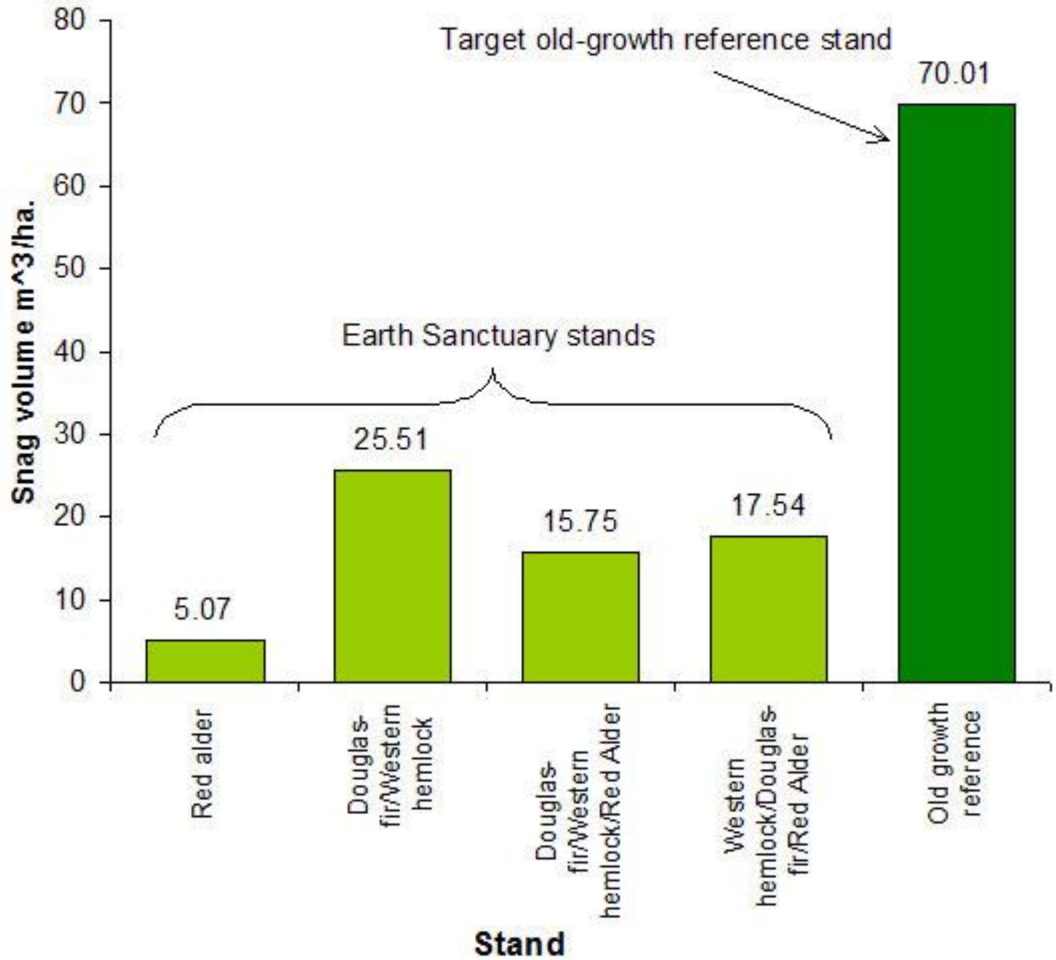


Figure 17. Snag volume per hectare.

Coarse woody debris

The term 'coarse woody debris' in its most basic usage refers to logs on the ground. For restoration and habitat optimization purposes, large wood is desirable for a number of reasons. Wood functions as (Maser and Trappe 1984, Franklin et al.1981):

- Habitat for wildlife (sites for feeding, reproduction, 'lookouts', protection and food)
- Nutrient and moisture 'storage tanks.'
- Substrate for many conifer seedlings (Western hemlock, Sitka spruce)
- Soil stability

Decay class

The functionality of a log with respect to the above characteristics is dependent on what is known as its decay class. To summarize, ecologists use five decay classes to describe a log's attributes. Decay class one indicates a fresh log that has hardly decayed. Decay class five represents a log that is only partially distinguishable from soil humus, that is oval in shape, without bark, with a heavy layer of epiphytes (plants that grow on other plants or logs), and that is invaded by plant roots and fungus. The remaining classes intergrade between these extremes (Maser and Trappe 1984, Fogel et al. 1972).

The kinds and abundance of organisms that can be found using a log at any one time are dependent on the decay class of the log. Hard logs serve as protection or lookouts for small mammals. Bark and inner cambium of fresh logs provide food for insects. Heavily decayed logs serve as moist refuges for amphibians and as rooting substrate for plants.

Coarse woody debris at the Earth Sanctuary.

Coarse woody debris characteristics for each of the stands sampled as part of the Earth Sanctuary restoration work is shown in Table 7.

The Old-growth Reference Stand contained large conifer logs in an advanced state of decay and few hardwood logs. The mean percent cover (percent of ground covered) of coarse woody debris was 8.1% and the mean volume per log was 2.04 cubic meters (***Table 1***). The mean decay class was 4.2, indicating that the logs sampled were in an advanced state of decay. Conifer logs were disproportionately larger than hardwood logs.

The Earth Sanctuary stands, with the exception of the Douglas fir/Western Hemlock Stand, contained roughly the same percent cover of wood (1.6 to 9.8% cover; Table 7) but it was an order of magnitude smaller in size (0.12 to 0.2 m^3).

The structure and pattern of coarse woody debris found in the Douglas fir/Western Hemlock Stand was contrary to the other stands (Cover = 27.5%; Mean volume =1.04 m^3). This stand contained some large chunks of wood on the ground that was likely left behind during harvest operations as unmerchantable timber. This stand most resembled the Old-growth Reference Stand with respect to coarse woody debris.

Logs in the Old-growth Reference Stand were more decayed than those of the Earth Sanctuary. This difference may be due to the species composition of the logs. It is likely that the Earth Sanctuary stands had a larger component of hardwood coarse woody debris in them than did the reference stand. Alders tend decompose at a much faster rate than conifers and larger logs will take longer to decay than smaller ones.

Table 7. Coarse Woody Debris Characteristics

Stand	Class	Percent cover		Volume (m^3)/Log		Decay class		
		Mean	sd	Mean	sd	Mean	sd	n
Red alder	Conifer	8.2	7.4	0.02	0.03	3.67	1.15	3
	Hardwood	6.8	4.3	0.23	0.27	4.33	1.15	3
	Undetermined	13.2	9.4	0.19	0.25	4.00	1.55	6
	Stand	9.8	7.4	0.16	0.22	4.00	1.28	12
Old growth reference	Conifer	7.1	0.6	2.32	3.18	4.33	0.58	3
	Hardwood	4.5		0.07	0.00	3.00	0.00	1
	Undetermined	10.9	4.7	3.20	0.00	5.00	0.00	1
	Stand	8.1	3.6	2.04	2.54	4.20	0.84	5
Douglas fir/Western hemlock	Conifer	27.5	9.1	1.04	1.19	3.67	1.51	6
	Stand	27.5	9.1	1.04	1.19	3.67	1.51	6
Douglas fir/Western hemlock/Red alder	Conifer	11.2	6.9	0.21	0.30	3.00	1.41	2
	Undetermined	2.8	0.0	0.03	0.04	4.00	0.00	2
	Stand	7.0	6.2	0.12	0.20	3.50	1.00	4
Western hemlock/Douglas fir/ Red alder	Hardwood	4.2		0.17	0.00	2.00	0.00	1
	Undetermined	4.6	0.9	0.21	0.16	3.50	1.00	4
	Stand	1.60		0.20	0.14	3.20	1.10	5

Discussion

In order to fully appreciate the task of restoring a young alder stand to an old-growth Douglas fir forest one must define the characteristics of the target ecosystem.

A definition of 'old-growth forest.'

Franklin et al. (1981) describe the characteristics of old-growth forest:

1. Approximately 175 to 250 years are required to develop old-growth forests under natural conditions in both Coast and Cascade Ranges. Development of old growth is faster on good sites than on poor sites.
2. Few plant or animal species are solely confined to old-growth forests, although many species—including several vertebrates, saprophytic plants, and epiphytic lichens—find optimum habitats in such forests. Some organisms, however, may require old growth to maintain viable populations. Moreover, there are substantial differences in composition and relative abundance of species between young- and old-growth forests.
3. Gross productivity is maintained at high levels in most old-growth stands, but mortality generally balances growth. Thus, the merchantable board-foot volume tends to remain constant for several centuries or gradually decreases because the amount of defect increases. Total organic matter keeps increasing because of accumulated masses of dead tree boles, mostly as down logs.
4. Old-growth forests are highly retentive of nutrients; large amounts are incorporated into living and dead organic matter. Losses of limiting nutrients, such as nitrogen, are low.
5. Nitrogen-fixing epiphytes are abundant in old-growth trees, and bacterial nitrogen fixation appears to be common in the large woody debris characteristic of old-growth forests.
6. The structure of old-growth forest is more heterogenous than that of young forests; coefficients of variation in tree sizes are greater, and understory patchiness is much higher than in young-growth stands.
7. Most of the distinctive features of old-growth forests can be related to four structural features; large, live old-growth trees, large snags, large logs on land and in streams.
8. A large, old growth Douglas fir is individualistic and commonly has an irregularly arranged, large, coarse branch system, and often, a long crown. It is ideal habitat for specialized vertebrates, such as the red tree vole, northern spotted owl, and northern flying squirrel, as well as nitrogen-fixing lichens.
9. Large snags are valuable as habitat for a variety of vertebrates and invertebrates and as a future source of logs.
10. Logs on the forest floor are important habitats for small mammals, including species that disperse spores of mycorrhiza-forming fungi. They also are sites for substantial bacterial nitrogen fixation and are essential as seedbeds for some trees and shrubs.

These qualities are the targets of the Earth Sanctuary restoration.

Composite Description of the Earth Sanctuary Stands and Old-Growth Reference Stand

Many of the characteristics described above are summarized for the Earth Sanctuary assessment in simplified form in Table 8**Error! Reference source not found.** below. Although the story is much more complex than what is shown, Table 8**Error! Reference source not found.** summarizes the most important information needed for the restoration design.

The trees, on average, were larger at the Old-growth Reference Stand than at the Earth Sanctuary (Table 8). Not only were the trees larger, but also they spanned a greater range of diameters indicating a higher degree of structure in the forest canopy than is found at the Earth Sanctuary (Forest structure below, Coefficient of Variation of diameter; Table 8; *see also Figure 8*, page 47). Densities of trees were similar, although the Old-growth Reference Stand was comprised mostly of conifers while the Earth Sanctuary contains a large hardwood alder component. The basal area (cross sectional area of all the trees in a stand) of the Old-growth Reference Stand can be thought of as an index of tree size and density in one measure. While 101 m^3 is not extraordinarily high for a Douglas fir old-growth forest, is does represent a significant amount of living biomass in one area. Some areas of the Earth Sanctuary begin to approach this figure, but clearly this forest has a long time to go before it reaches its full biomass potential.

One of the hallmark attributes of old-growth forest in the Northwest is the presence of large snags in the overstory. The reason snags are so conspicuous in such stands is because it takes a tremendously long time for a stand to develop to the point at which the first generation of trees have not only begun to reach their full growth potential, but to die and produce the first generation of snags. This process will take centuries. There are substantive differences between conifer snags and hardwood snags as well. Large standing Douglas fir snags will persist for a long time, providing much habitat for wildlife. Alder snags decay and fall very quickly and rarely reach a size large enough to provide use as habitat for other organisms (Maser and Trappe 1984).

The snag density and volume data are shown in Table 8. The snags in the Old-growth Reference Stand provide over 70 m^3 of volume per hectare while those of the Earth Sanctuary range between 5 and 26 m^3.

Coarse woody debris is similar to snags in terms of function. Many of the functions of logs are described and can be seen in Figure 10. If anything, accumulation of coarse woody debris in a forest occurs more slowly than snag accumulation.

Percent cover of coarse woody debris was similar between all stands (Table 8; CWD % cover). Log volume was very different, however (Table 8; CWD Volume/log). Again, the Old-growth Reference Stand provides more habitat structure for organisms than does the Earth Sanctuary.

The Old-growth Reference Stand provides an example of a stand with a steady recruitment of wood into the snag pool and, over time, the coarse woody debris pool. Many of the older, larger overstory trees will, in time, be recruited into the snag pool, just as many of the snags will topple and become part of the coarse woody debris pool. These will in turn provide wildlife habitat and seedling substrate for the next generation of trees (Maser and Trappe 1984). In an old-growth stand this process has reached a cyclical steady state. In young stands such as exist at the Earth Sanctuary, this process will be discontinuous for many years, until there is a sufficient supply of overstory trees to start and maintain the cycle.

Table 8. Composite summary of stand types sampled at the Earth Sanctuary and South Whidbey State Park.

Stand	Old-growth	Earth Sanctuary
	Mean	Range of means
Tree diameter (cm)	42	28-38
Tree density (stems/ha.)	583	417-800
Tree basal area/ha. (m^2)	101	31-68
Forest structure (CV of dbh)	78%	31-54%
Snag volume/ha (m^3)	70	5-26
Snag density (stems/ha.)	50	23-50
CWD Volume/log (m^3)	2.04	0.12-1.04
CWD % Cover	8%	1.6-27.5 %

Implications for restoration

Franklin et al. (1981) provide some guidance for restoring old-growth qualities in managed stands.

> Foresters wishing to maintain or create ecosystems with old-growth characteristics can tie management schemes to maintenance or development of the four key structural components:
>
> 1. Large live, old-growth trees
> 2. Large snags
> 3. Large logs on land and
> 4. Large logs in streams

Coarse woody debris in streams is valuable habitat for wildlife, but is not applicable at the Earth Sanctuary as large drainages are absent. The remaining components are important areas to target to promote a forest functioning optimally for species diversity, habitat variability and aesthetic appeal as a retreat center.

Three hundred acres has been suggested as a minimal size for a stand of old-growth forest to maintain populations of some birds and small mammals (Franklin et al. 1981). This size also minimizes 'edge effects' and reduces the potential for wind damage. While the property is limited to approximately 70 acres, the habitat diversity is high, containing ponds, wetlands, seeps, hillslopes and stands dominated by conifers and alders with moderate age and size variability. Franklin et al. (1981) offer further insights into restoring old-growth forest characteristics.

> Some ecological aspects of old-growth forests can be maintained by managing for individual attributes; for example, leaving scattered old- growth trees, rotten logs, or snags on cutover lands. The linked nature of these key structural components, as well as the requirements of some organisms for the total environment of an old-growth stand, makes management of entire stands a simpler approach to retention of such ecological features (Franklin et al. 1981).

Fortunately, some areas of the Earth Sanctuary contain large logs and legacy trees and these will be useful in developing complexity of habitat in the forest as it matures. These areas should be retained and enhanced as much as possible. The restoration design will take the key structural components listed above, identify where these presently exist, and propose a strategy that will enhance and streamline the maturation process of the forest.

Glossary of terms

Arboreal	Associated with trees or forests.
Basal area	The cross-sectional area of a tree trunk.
Bryophyte(s)	Category of plants including mosses, liverworts and hornworts.
Coefficient of variation	A statistical term used to describe the amount of variation in a measure. Since the units are expressed as a proportion or a percentage, CV allows relative comparison of measures that may be in different units or different scales. CV=Standard deviation/Mean.
dbh	Diameter at breast height. Traditional measure of tree girth used by foresters.
Percent cover	Portion of a unit of area covered by the item in question. A plant or log that occupies one quarter of a sample plot represents a cover of 25%. The total sum of percent cover for a plot may exceed 100% if plants layer over one another.
Quadrant	A square or rectangular plot of known area that is laid on the vegetation to estimate coverage of vegetation by plants. Incremental markings on the edges aid in ocular estimates of vegetation cover.
Snag	A standing, dead tree >25cm diameter at breast height.
Vascular plants	Plants containing tissues for actively conducting water and nutrients. (e.g., not mosses, liverworts, hornworts, algae, cyanobacteria or lichens).

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Appendix C. Earth Sanctuary Bog/Fen Wetland Ecosystem Draft Report

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October 2000

Bog/Fen Wetland Ecosystem

Introduction

The proposed Earth Sanctuary property contains a fen/bog wetland system. One objective of the baseline ecological analysis was to examine the flora and plant community structure of this system. We visited the bog on July 15, 2000 to fulfill that objective. Our observations are described in the following sections.

Peatland ecology is a complex subject to describe without a general knowledge of hydrology, water chemistry and plant community ecology. Consequently, this section of the report begins with an overview of peatland ecology in order to supply a context for understanding the technical descriptions of the fen/bog system that follow.

Peatland Ecology

Definition of Peatlands
Worldwide, a number of different terms exist for peatlands. 'Mire,' 'moor,' 'swamp', 'bog', 'fen', and 'muskeg' are all terms used to refer to peatlands The term 'peatland' is a broad appellation encompassing wetlands where plant production exceeds decomposition and organic materials accumulate as peat. Ecologists typically restrict the use of 'bog' to depressional basins receiving water primarily through precipitation. Bogs are acidic and nutrient-poor peatlands. Typically, such areas are dominated by *Sphagnum*, or peat, mosses. 'Fen' is a term for peatlands that are relatively richer in nutrients than bogs, that exhibit some evidence of surface water flow, and that are more alkaline than true bogs. While marshes are not technically categorized as peatlands, many of their species can be found in peat-building wetlands, and some complex peatlands contain marginal marsh-like areas. The word 'peatland' can be used to describe both bogs and fens and is a useful, encompassing word to describe nutrient-poor wetland habitats with organic substrates.

Peatland Ecology
Peatlands occur where hydrologic conditions favor water accumulation and retention over all or much of the growing season. Peatlands occur throughout much of the world, but are most common in the northern parts of North America and Eurasia.

Peatland plants receive nutrients via ground or surface water movement, atmospheric precipitation, nitrogen fixation, or decomposition of organic material. Decay occurs very slowly below the uppermost layers of peat as a result of moderate to extreme acidity, low oxygen levels and cold temperatures. As a consequence, nutrients tend to be sequestered within undecayed plant material that accumulates as peat.

Bogs are more acidic than fens due to their hydrologic isolation and to the physiological capacity of *Sphagnum* mosses to acidify their immediate surroundings. *Sphagnum* mosses actively generate the acidic conditions in which they thrive. Their growth habit impedes surface water movement which reduces nutrient influx. Accumulated peat also tends to insulate lower soil layers, and, as a result, only the upper layer, where the living tissue is, remains warm enough to allow life processes to operate efficiently. Diminished growth of vascular plants inhibits transpiration, raising water levels, and also reduces shading from overhead foliage. These conditions favor growth of *Sphagnum. Sphagnum* mosses conduct water upwards via capillary movement along their pendant branches and retain it in absorbent hyaline cells, creating and maintaining the very wet conditions which favor its growth. Thus, a number of feedback mechanisms exist to facilitate the continued dominance of *Sphagnum* in such areas.

Peatland Plant Community Structure

Over time, peat accumulation and plant community development in bog basins result in the concentric zones of vegetation which are emblematic to bogs. One zone commonly found in bogs is a moat, or aquatic moat around the perimeter. The moat is a region surrounding a peatland where aquatic vegetation grows, but peat development is retarded compared to the more central regions of the bog. The moat habitat has widely fluctuating water levels, especially in areas affected by summer drought, as in the Pacific Northwest. The moat also intercepts surface water runoff that delivers nutrients from the upland habitat. Wind and surface water movement churn oxygen into the water that accelerating decomposition and nutrient cycling.

Internal to the moat one finds more classic 'bog' species. Among them can be found *Sphagnum* mosses, sedges and rushes, and a variety of acid-loving heaths including cranberries, huckleberries and laurels. These plants often are found growing on a floating 'mat' that quakes when walked upon. The outer edges of the mat are generally least consolidated and contain the most aquatic, fen-like species. Further towards the center the mat is generally more solid where peat has accumulated and contacted the basin bottom. In the very most central areas of bogs one can find the beginnings of 'hummock and hollow' peat development that topographically resemble ski moguls. The hummock tops are occupied by terrestrial species while the hollows harbor more aquatic ones. *Sphagnum* mosses are often arrayed vertically according to their moisture preferences on the hummocks.

Generally, acidity increases from the moat to the more central portions of the bog where *Sphagnum* mosses dominate and peat is maximally developed. Where peat has accumulated most deeply, or where basin morphology is shallow, the peat contacts the bottom and begins to accumulate higher than the local water table. *Sphagnum* mosses are able to actually 'pull' the water table up by capillary action. These raised areas do not quake, or move, as do the more marginal areas of the peat mat. Such habitats can, in some instances, rise many feet above the water table and allow the establishment of stunted forests with non-*Sphagnous* mosses and a more terrestrial flora.

While the above discussion is somewhat simplified, in reality the spatial distribution of peatland vegetation is complex, and changes along many gradients such as pH, moisture, surface water chemistry and flow pattern, basin morphology, and shade. Species diversity often correlates positively with peatland complexity. More microhabitats generally beget more species. The following discussion will describe the earth Sanctuary bog in relation the above factors.

Bog/Fen Ecosystem Structure

Flora

Twenty-seven vascular plants were found in the Earth Sanctuary bog (Table 5). While this is not a complete list of species occurring there, it certainly includes the dominant ones that define its composition and structure. Some plants, bog orchids notably, flower only intermittently or during short intervals during the year. Therefore it is likely that this inventory is not complete; doubtless other species will be found in the coming seasons. No rare, threatened or endangered species were encountered during this visit.

The list of mosses and lichens comes with a caveat: Mosses and lichens are notoriously difficult to identify to the species level without the aid of high-powered microscopes or chemical tests. Since the scope of such work is beyond that required as part of a baseline analysis, we have only identified these organisms to family, genus or species where possible using characteristics observable to the eye with a hand lens, but not a microscope. Consequently, many species remain undetermined at this point. The list of mosses is very superficial and lichens considerably less so (Table 5). We estimate the moss flora at approximately 5-10 peat (*Sphagnum*) mosses with an additional 10-20 non-Sphagnous mosses and liverworts. The lichen flora is approximately 15-20 species. Total plant and lichen diversity is estimated at approximately 56-76 species. The distribution and abundance of each species is the topic of the next section.

Table 5. *Flora Earth Sanctuary Fen/Bog Ecosystem (Nomenclature follows Hitchcock and Cronquist 1998 for vascular plants, McCune and Geiser 1997 for lichens, and Lawton, 1971 for mosses)*

Group	Common Name	Taxonomy	Growth Form
Vascular Plants	Duckweed	*Lemna minor* L.	Aquatic herb
	Eurasian water-milfoil	*Myriophyllum spicatum* L.	Aquatic herb
	St. John's wort	*Hypericum anagalloides* C. & S.	Aquatic herb
	Bracken fern	*Pteridium aqulinum* (L.) Kuhn	Herb
	Bur-reed	*Sparganium* spp.	Herb
	Cat-tail	*Typha latifolia* L.	Herb
	Common rush	*Juncus effusus* L.	Herb
	Cotton-grass	*Eriophorum chamissonis* C.A. Mey	Herb
	Hard-stemmed bulrush	*Scirpus acutis* Muhl.	Herb
	Marsh cinquefoil	*Potentilla palustris* (L.) Scop.	Herb
	Purple-leaved willowherb	*Epilobium ciliatum*	Herb
	Skunk cabbage	*Lysichitum americanum* Hultén & St.John	Herb
	Smooth sedge	*Carex laeviculmis* Meinsch.	Herb
	Sundew	*Drosera rotundifolia* L.	Herb
	Undetermined Grass	Poaceae	Herb
	Yellow water lily	*Nuphar polysepalum* Engelm.	Herb
	Bog cranberry	*Vaccinnium oxycoccos* L.	Shrub
	Bog laurel	*Kalmia microphylla* (Hook.) Keller	Shrub
	Hardhack	*Spiraea douglasii* Hook.	Shrub
	Labrador tea	*Ledum groenlandicum* Oeder	Shrub
	Red huckleberry	*Vaccinnium parvifolium* Smith	Shrub
	Salal	*Gaultheria shallon* Pursh	Shrub
	Salmonberry	*Rubus spectabilis* Pursh	Shrub
	Willow	*Salix* spp.	Shrub
	Red alder	*Alnus rubra* Bong.	Tree
	Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.	Tree
	Western redcedar	*Thuja plicata* Donn.	Tree
Mosses	Big red stem	*Pleurozium schreberi*	Moss
	Broom moss	*Dicranum* spp.[1]	Moss
	~4-8 undetermined Peat mosses	*Sphagnum* spp.[1]	Peat moss
	Spread-leaved peat moss	*Sphagnum squarrosum*	Peat moss
Lichens	Antlered perfume	*Evernia prunastri*	Foliose
	Cetraria	*Cetraria orbata*	Foliose
	Hooded bone	*Hypogymnia physodes*	Foliose
	Lipstick cladonia	*Cladonia macilenta*	Foliose
	Parmotrema	*Parmotrema chinense*	Foliose
	Ragbag	*Platismatia glauca*	Foliose
	Tattered rag	*Platismatia herrei*	Foliose
	2 undetermined *Cladina*	*Cladina* spp.[2]	Fruticose
	2 undetermined *Usnea*	*Usnea* spp.[2]	Fruticose
	3 undetermined *Cladonia*	*Cladonia* spp.[2]	Fruticose

[1]Requires microscopic analysis for positive ID to species.
[2]Requires chemical tests for positive ID to species.

Plant Communities

The Earth Sanctuary bog contains four major plant communities. The habitat and dominant species comprising each community are shown in Table 2. The characteristics of each of these communities are discussed below.

Table 6. Plant Communities of Earth Sanctuary Bog

Community	Dominant species	Habitat
Marsh/Moat	Marsh cinquefoil Duckweed Yellow water-lily	Neutral to slightly acidic, enriched waters. This is an aquatic community surrounding the bog.
Dwarf shrub	Peat mosses Labrador tea Small-leaf cranberry Bog laurel Some lichens Big red stem	Acidic, developed peat in the central areas of the bog. Areas with well developed hummocks and hollows. This community intergrades with the sedge community forming a matrix in some areas.
Sedge	Peat mosses Cotton grass Small-leaf cranberry	Acidic, moist peat. Little hummock development. Wetter areas of the bog mat.
Bog forest	Western hemlock Salal Many lichens	One small area of solid ground or well-consolidated peat in the northwest portion of the bog mat.

Marsh/Moat Community

The bog is surrounded by marsh and moat. This area exhibits a variety of aquatic species such as Eurasian milfoil, duckweed, yellow water lily and St. John's Wort. Moisture loving species included cattails, marsh cinquefoil and hard-stemmed rush. The inner perimeter of the marsh community is punctuated in places by dense colonies of hard-stem rush. These areas form a unique plant community occupying the very edges of the floating mat.

The marsh habitat was mostly neutral in acidity (pH 7) and contained species better known from marshes or swamps than acidic, nutrient-poor bogs. This may be a result of nutrient enrichment from subsurface water that has filtered through the adjacent upland forest soils into the marsh aquatic waters. The entire fen/marsh/bog complex experiences widely fluctuating water levels through the course of a year exposing soils to oxygen and enhancing nutrient cycling (e.g. +/- 1-2 feet draw down during annual summer drought). Climatic patterns for the Washington coast range from heavy winter precipitation to annual summer drought.

Dwarf Shrub

Perhaps the most visually striking plant community of the bog is the dwarf shrub community. This community forms the floating mat of consolidated peat that quakes when walked upon. The community is composed of abundant heaths, sedges, ferns and even a carnivorous plant, the sundew

Hummock and hollow peat development is most pronounced in the dwarf shrub community. These phenomena results in humps of peat with moisture loving species occupying the low-lying regions and more mesic ones thrive on the hummock tops. Interesting lichen communities have taken up residence on the shaded stems of Labrador tea and one species of *Cladina* forms extensive colonies the size of basketballs right in the peat itself.

There is strong evidence in the dwarf shrub community that water levels were lower in the past in the bog/marsh/fen. Some standing and fallen cedar snags of considerable dimensions can be found on the mat of the bog. This tree species cannot establish and thrive in the continually saturated soil conditions now existing throughout the bog. Furthermore, dead standing snags in the aquatic marsh areas are a legacy from when water levels in the bog were much lower. Water level changes likely resulted from the Newman Road embankment along the southern end of the basin. The root plates and trunks of these snags are now habitat for many mosses and lichens.

Sedge Community

The sedge community is dominated by *Sphagnum* mosses, cotton grass, some dwarf heaths and minor sedges and rushes. This community appears restricted to wetter portions of the mat and reaches its largest extent in a band across the middle of the bog. In the northern reaches of the bog it forms a mosaic with the dwarf shrub community. These two vegetation types mix in a matrix of patches and columns with sedges dominating the wetter areas and Labrador tea occupying the hummocks. The sedge community also circumscribes the dwarf shrub community elsewhere, forming an intermediate zone between the marsh/moat zone and the drier, more raised peat of the bog forest and dwarf shrub community.

Bog Forest Community

The bog forest is a small, but interesting community found in the center of the bog. The dominant plants are Salal and Western hemlock. An abundance of lichens covers the dead tree boles. The substrate appears to be either an area of very compact, raised peat, or an actual hump in the landform that protrudes through the bog. The area does not quake and is not particularly spongy.

Geographical Uniqueness

The Earth Sanctuary is a “raised or concentric domed bog.” Raised bogs are characterized by accumulations of peat deposits that fill the entire basin raising the bog surface above ground water levels. The central region of the Earth Sanctuary bog is raised in elevation approximately 5+ feet above surrounding marsh surface area. Raised bogs are unique in their rarity in western Washington (Rigg 1958).

“Many sphagnum bogs are slightly or even conspicuously higher in the center than at the margins. Bogs having this dome or ridge form raised bogs to distinguish them from flat bogs. Raised bogs are common in the eastern United States, but they are not characteristic in Washington. A few sphagnum bogs in western Washington are, however, sufficiently raised so that their convexity can be recognized by merely looking at them. Some are 5-6 feet higher in the center than at the margins, but the slopes are gentle.”

Geomorphology and Hydrology

Hydrology

A discussion of the hydrogeology is necessarily limited by a lack of hard hydrological and topographic data. However, many characteristics of the landscape indicate that this peatland has been a flow-through hillslope wetland in the past. There are associated wetlands to the south of the bog, indicating a history of water drainage. Whether the present peatland system drains under the road on the south side is not known. Our cursory investigation failed to discover a culvert through the road. It is possible that evaporation and transpiration alone accounts for much of the water loss of the bog.

There does not appear to be a distinct stream feeding into the system either. Rather, it appears that an abundance of springs and seeps on the northern, upland forest area flow into the basin. It is almost certain that the present peatland habitat was better drained in the past, before the road impeded the water flow. At present, however, it appears that flow, if any, is slow and constrained to the marsh/moat due to the overwhelming presence of *Sphagnous* peat in the center of the bog. The moat contains marsh and fen species such as cattails, yellow water lilies, duckweed and Eurasian milfoil. These species typically require waters that are more nutritionally rich and oxygenated, and more neutral in acidity than those found in the center of the peatland. From this information it can be inferred that there is at least a minimal amount of subsurface water in-flow to the marsh aquatic area from the upland mineral soils.

Classification

The bog exhibits the following characteristics:

- Classic concentric vegetation distribution
- A moat (open, aquatic margin)
- A floating mat with abundant dwarf heaths and grounded central portion
- Minimal, if any, water flow through the system

These characteristics are consistent with those of a topogenous dwarf shrub moat bog (Damman and French, 1987).

Peatland Succession

Classic lake-fill succession theory postulates that eventually the *Sphagnum* will fill the basin, consolidate into compact soil and allow terrestrial plants and trees to invade the habitat. Other scientists theorize that just the opposite will occur. It may be surmised that the peatland will accumulate higher and the mat extend further over time. Many events could interrupt or even re-set this successional process, however, and include fire, drought, flooding, development, and animal activity (beavers). Bog succession has been a matter of contention among peatland ecologists for many decades and is unlikely to be resolved any time soon. It is thus difficult to predict the future development vector of the bog with certainty.

Summary

The bog/fen system can be considered a raised moat bog with classic concentric vegetation zonation and little water movement. Four major plant communities were found including dwarf shrub, sedge, bog forest and marsh/moat communities.

It appears that the hydrology of the wetland was changed at one point in the recent past, most likely when Newman Road to the south was installed. Many standing and dead snags in the bog attest to lower water levels in the past.

The flora is moderately large. Future visits may discover other species missed during our initial visit. The bog shows some complexity, with components of marsh, fen and true bog evident in its flora and structure. Our visit did not reveal rare species although many of the species found are obligate or highly dependent on peatland acidic habitats. They cannot exist elsewhere. Diminished numbers and acreage of peatlands lost to development have increased their value as conserved areas for habitat for unique organisms, for scientific curiosity, and tranquil areas of introspection.

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Appendix D. Earth Sanctuary Wildlife Report

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January 2001

The Earth Sanctuary Wildlife Report – Draft

Within the Earth Sanctuary boundaries lies a rich and unique habitat that provides refuge for a diverse community of animals. The occurrence of three ponds bordered by mixed conifer and deciduous forest creates a combination of wildlife resources that is scarce in this region. In the last 150 years, nearly 90% of the ponds and wetland systems in Washington State have been degraded; 50% have been filled or otherwise destroyed (Washington Department of Wildlife). In the Puget Sound basin wetland losses reach nearly 70% of the estimated wetlands present before settlement (Frost 1991). Most remaining wetlands are not forested, found within a matrix of lands developed for agriculture or housing. The integrity of the wildlife community served by these ponds depends on the continued protection of the surrounding forest.

A formal survey of all species found in the sanctuary is not a necessary action at this time. Collecting quantitative data in a systematic and objective manner would take more than a year to complete and require a substantial financial investment to support field personnel and materials. Instead, reviews of wildlife species lists from the Audubon Society, various field guides, and historical county guides can provide land managers and decision makers with enough information to make sound choices with regard to wildlife habitat and the wildlife community. I have composed lists, by animal taxa, of species known to occur in Island County (Tables 2, 3, 4, 5). Included are rough measures of the likelihood of a species occurring and breeding on the Earth Sanctuary property. Species known to breed on the property (i.e. observed by a reputable source) have been identified as well.

This report addresses four aspects regarding wildlife management at the Earth Sanctuary. First, I discuss habitat resources present within the property boundaries and wildlife species associated with these habitat types. This includes discussions of critical habitat resources that limit the number of individuals the area can support. Critical habitat areas include types that are rare in the regional matrix or that if degraded or removed, would lead to the demise of certain species. Second, I discuss possible actions to improve the habitat for certain species. This includes suggestions for restoring degraded areas and improving the habitat value of existing features. Third, I speculate on the impact of human uses within the property on the wildlife community. Finally, I recommend species for continued monitoring of the wildlife community. These species, also known as indicator species, function effectively as a barometer, indicating general population trends in species occupying a similar niche.

Habitat Resources and Wildlife

The Earth Sanctuary property is characterized primarily by pond, mixed conifer forest, and alder forest. Each habitat type will be addressed separately and with respect to bird, mammal, amphibian, and reptile species. Complete species lists can be found in Tables 2-5.

Ponds

The three ponds, including the bog island, comprise approximately 25% of the Earth Sanctuary property (Miller and Fetherston 2000). Forest habitat surrounds the ponds on nearly all sides. This creates a unique arrangement that is rare on Whidbey Island as well as the largely developed Puget Sound lowlands. The combination of forest and freshwater ponds attracts wildlife species that would not be present without the occurrence of both habitat types.

Birds

Bird watchers have documented over 200 species of birds on Whidbey Island, its shoreline, and near shore waters (Naval Air Station, Whidbey Island pamphlet). Most of these species could conceivably be seen at the Earth Sanctuary. Those species dependent on freshwater habitat include Loons, Grebes, Cormorants, Herons, Waterfowl, Kingfishers, Osprey, Cranes, Shorebirds, Owls, and Perching birds (Table 2). The presence of any species depends on availability of suitable habitat and time of year. Species observed only in Spring and Fall are migrants. Many stop over on Whidbey Island on their way to and from northern breeding grounds (e.g., Dunlin, Sanderling, Short- and Long-billed Dowitchers). Other species breed further north and winter in the Puget Sound region (e.g. Northern Shoveler, American Wigeon, and Common Goldeneye). Those that are known to breed on Whidbey Island are generally present all year or spring, summer, and possibly fall (e.g., Osprey, Spotted Sandpiper, Killdeer, Mallard).

Waterfowl species benefit the most from pond habitat. Ducks and geese thrive in open waters, accessible shorelines, and areas of emergent vegetation. Although Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Common Merganser, and Hooded Merganser are common visitors to many ponds, they nest primarily in cavities found in dead and dying trees. The forest habitat surrounding the Earth Sanctuary ponds greatly increases the likelihood of these species finding suitable nesting sites. The snags or dead trees within one tree length (roughly 75-100 feet) of the pond edge represent critical breeding habitat for these species. The orientation of the snag and opening is important to different species. Some species avoid using cavities where the opening is exposed to frequent winds. Others prefer cavities with an opening that provides solar exposure.

Great Blue Herons have been observed at the Earth Sanctuary. They construct nests in live deciduous trees near water. Great Blue Herons generally nest in colonies, called rookeries, and nests are usually 10 - 20 meters (30-70 feet) from the ground (Ehrlich 1988). Great Blue Herons consume fish which they capture while wading through shallow water. They may also benefit from the abundant population of bullfrog tadpoles.

Many bird species that live and breed at ponds are ground nesters. These include Loon, Grebe, Sora, Rail, Wigeon, Mallard, Pintail, Teals, Gadwall, Northern Shoveler, Ruddy Duck, and Scoters. Ground-nesting birds generally build nests near or floating on the water in clumps of vegetation. The vegetation helps conceal the nest from predators. Providing shoreline with abundant vegetation both on the shore and in shallow waters will facilitate nesting at the Earth Sanctuary ponds. The bog island provides a well-protected nesting area for waterfowl as the pond functions as a moat to keep many mammalian predators away.

Osprey, Bald Eagle, Northern Harrier, and Cooper's Hawk depend on aquatic habitat for food and/or breeding resources. Currently, an Osprey pair has built a nest in a **Douglas fir tree (???)** on the north side of the bog pond. Osprey nest on human-made platforms or in large trees that provide fairly unobstructed views of the surrounding area. Nests are built in conifer or deciduous trees, usually 3 - 20 meters (10 - 60 feet) from the ground. Nesting and successfully raising young are dependent on the presence of an ample food supply. Osprey feed primarily on fish but also take rodents, birds, and crustaceans. A brood of 3 young Osprey requires nearly 3 kg. (6 lb.) of meat daily (Ehrlich 1988).

Many studies document correlations between Osprey reproductive success (number of young raised successfully) and environmental characteristics. In the Long Valley of west central Idaho, Osprey were significantly more successful raising young in nests that were more than 1500 meters (4875 feet) from any type of human disturbance than those nesting within 500 meters (1625 feet) of human disturbance (Van Daele and Van Daele 1982). Human disturbance included the presence of a major road or an occupied house. The authors observed that Osprey do adjust and habituate to human presence. Osprey less than 500 meters (1625 feet) from human development did successfully raise young. However, if human disturbance comes during the early nesting stages when Osprey are incubating eggs, the disturbance can jeopardize their nesting success. A study in North Carolina reports that Osprey eggs hatch five weeks after eggs are laid and young birds fledge seven to eight weeks after hatching (Hagan 1986). A Maine study also found that Osprey young fledge seven to eight weeks after hatching (Stotts and Henny 1975). In North Carolina, the greatest mortality rates were found in nestlings two and a half weeks old, a time of very fast growth. Once the young birds reach four and a half weeks, their probability of survival increased. These studies suggest that human activity around the existing Osprey nest should be limited to late summer, fall, and winter to avoid disturbing the Osprey during periods of incubation and nestling development.

Kingfishers are commonly seen along watercourses. Their diet consists primarily of fish but they occasionally take aquatic invertebrates, amphibians, reptiles, young birds, and rodents. Nests are usually burrows found in steep banks. Some kingfishers have been known to use tree and snag cavities when steep banks are not available. Because of the propensity for nesting in steep banks, the likelihood of Kingfishers nesting at the Earth Sanctuary is very low.

The Earth Sanctuary does not provide suitable habitat for most of the Cormorants, Shorebirds, Gulls, and Alcids. These birds require extensive sandy shorelines or seacoast cliffs, and many do not stray far inland. There are, however, exceptions. The Double-crested Cormorant is a common visitor to inland lakes, such as Lake Washington and Green Lake in the Seattle area. They are commonly seen in their spread-wing posture, presumably drying their wings (Ehrlich et. al. 1988). Maintaining fish in the ponds and low-level perches for cormorants could draw them to the Earth Sanctuary. However, cormorants at the pond would compete with the Osprey for fish, potentially having a negative impact on the Osprey. The Killdeer, Spotted Sandpiper, Least Sandpiper, Long-billed Dowitcher, and several gull species are likely visitors to the Earth Sanctuary ponds. Providing sandy, shallow shorelines for wading and insect foraging will increase the habitat value of the ponds to these species.

Mammals

Approximately 45 species of mammals are likely to occur on the Earth Sanctuary property (Table 3). Of these, bats, beaver, and river otter are most dependent on the pond habitat.

All of the coastal Washington bats are insectivores and ponds provide a plentiful source of insects for bats. Bats roost in many structures, including buildings, snags, and living trees. They are capable of flying considerable distances. Consequently, roosting and feeding areas do not need to be in close proximity. Most of the western Washington bat species are active when nighttime air temperatures are warm, late spring through early fall. During the colder months they either migrate south or hibernate. Little is known about western Washington bats, although many studies have been completed in the last 10 years. Identification of the bats and their numbers using the Earth Sanctuary ponds would provide visitors and managers with a better understanding of bat activity and it would provide a UW undergraduate wildlife student with an interesting senior project.

Ponds provide habitat for beaver, muskrat, and river otter. These animals spend most of their time in the water. Only the river otter is carnivorous, and supplements a diet of fish with frogs, turtles, crayfish, insects, and occasionally young birds. Several visitors to the Earth Sanctuary ponds have reported seeing a river otter (K. Fetherston, personal communication).

Amphibians

Only nine species of amphibians are likely to be found at the Earth Sanctuary. Of these nine, seven require aquatic habitat for breeding. These include the roughskin newt, northwestern salamander, long-toed salamander, western toad, Pacific tree frog, red-legged frog, and the non-native bullfrog. The northwestern salamander, Pacific tree frog, and bullfrog have all been observed at the Earth Sanctuary during 2000. Spot aquatic trapping using funnel traps found northwestern salamander larvae in the smallest pond at the northwest corner of the property and in the largest pond at the southern end of the property (Table 1). Bullfrog tadpoles were captured on the east side of the middle pond and adult bullfrogs were observed at all three ponds.

Table 1. Amphibian Species Observed in Earth Sanctuary Ponds September 2, 2000.

Species	Location	Number	Developmental Stage	Size
Northwestern Salamander	NW Pond, E side	1	Larva	55mm
	S Pond, N side	1	Larva	45mm
Bullfrog	NW Pond, N side	2	Adult	
	NE Pond, W side	1	Larva	105mm
	NE Pond, W side	1	Larva	95mm
	NE Pond, W side	Numerous	Adult	
	NE Pond, N side	Numerous	Adult	
	S Pond, N side	Numerous	Adult	

It is unlikely that the native frogs, roughskin newt, and long-toed salamander would be captured in early September. These species complete their development from egg to larva to adult in one summer. The larvae of both the bullfrog and northwestern salamander spend one winter in ponds before they undergo metamorphosis to become adults. The clear, dry weather on September 2nd, 2000, when observations were made, also reduced the chances of observing these species in terrestrial habitats.

The large bullfrog population provides a food source for a variety of vertebrates, namely fish, wading birds, garter snakes, mammals, and other bullfrogs. In turn, adult bullfrogs consume nearly any animal they can swallow, including insects, fish, amphibians, reptiles, small mammals, and birds. The extent that bullfrogs impact native fauna has not been well documented. Bullfrog predation has been blamed for the extirpation of spotted frog *(Rana pretiosa)* populations in the Puget Sound lowlands. Their impact on other species is not fully understood. Without this information, it is advisable to manage the bullfrog population conservatively by trying to reduce their numbers. This can be done by trapping tadpoles throughout the year and removing them from the pond. During winter months, it may be possible to locate and capture large numbers of adult frogs that are sluggish due to colder temperatures.

Frogs and salamanders attach eggs to emergent vegetation, protruding sticks, and logs. Management practices should assure the continued presence of these structural features. The adjacent forest will naturally contribute materials suitable for egg attachments to the ponds.

It is possible that salamanders and frogs cross Newman Road to go to and from the ponds during breeding migrations. Road activity can be monitored during wet evenings in the spring. Light traffic on the road at these times does not pose much of a threat to the amphibians. If, however, the road traffic increases and roadkill becomes a problem, this issue will have to be addressed. A program in Amherst, Massachusetts routed migrating spotted salamanders under a busy road to reduce mortality rates.

Reptiles

Five species of reptiles and various introduced turtle species are likely inhabitants of the Earth Sanctuary. Of these, only introduced turtles are dependent on pond habitat. Two native turtles, western pond turtle *(Clemmys marmorata)* and painted turtle *(Chrysemys picta)* have not been found on Whidbey Island. Other turtle species, former pets, do thrive in area ponds. To my knowledge, there have been no reports of turtles in the Earth Sanctuary ponds.

Mixed Conifer Forest/Alder Forest

Approximately 60% of the Earth Sanctuary property is mixed conifer and red alder forest. Conifer tree species present in the mixed forest include Douglas fir *(Pseudotsuga menziessi),* western hemlock *(Tsuga heterophylla),* western red cedar *(Thuga plicata),* grand fir *(Abies grandis),* and Sitka spruce *(Picea sitchensis)* (Miller and Fetherston 2000). Deciduous tree species present are dominated by red alder *(Alnus rubra),* and include big-leaf maple *(Acer macrophyllum)* and willow *(Salix spp.)* (Miller and Fetherston 2000).

Birds

The forested areas of the Earth Sanctuary could provide habitat resources to nearly 90 species of birds (Table 2). Most of these species are Perching Birds, Woodpeckers, Hummingbirds, Owls, and Hawks.

The Perching birds are more formally known as passerines. Roughly 60% of all bird species are passerines, which is a large portion of bird diversity (Ehrlich et. al. 1988). Singing is more highly developed in these species than any other birds and they are therefore the objects of much interest and study. The diversity in perching birds suggests that they have effectively partitioned resources to reduce competition among species. As a diverse group, their habitat needs are quite diverse. Some nest in tree cavities; others nest in abandoned holes. Some build nests on the ground; others construct nests in evergreen or deciduous trees and shrubs. Dietary habits are equally diversified. Many people consider the perching birds to be primarily seed eaters, as this is the fare offered at backyard birdfeeders. However, many species eat a combination of seeds, fruit, and insects throughout the year. During the breeding season, when adults work hard to feed themselves and their young, the diet is composed primarily of insects. Insects provide more protein than seeds and fruit during the intensive growth period of the young. During winter months when insects are less plentiful, many species rely on berries and seeds to sustain them. Foraging strategies are also very diverse. Some species forage for insects under tree bark; others forage on the ground or in the air. The sight of barn swallows swooping over a field or pond engulfing small flying insects captures attention. Thirty-eight (50%) of the perching birds likely to be found at the Earth Sanctuary are migratory species. Consequently, they may be observed only on stopovers during breeding migrations or when they are breeding in this area. These migrants are rarely seen during winter months in the Pacific Northwest.

Habitat resources at the Earth Sanctuary that are critical to perching birds include structurally complex forest structure, developed understory, and standing dead trees (snags). Perching birds are fairly specific in their habitat use, foraging in often well-defined territories and nesting in predictable locations. Providing a structurally diverse forest, with different tree species, sizes, ages offers a greater range of habitat resources for the perching birds. While some species spend most of their time in the upper canopy of the forest, others are more commonly observed in low-level shrubs and on the ground. Providing an understory of evergreen and deciduous shrubs will provide nesting materials, food, and cover for understory bird species. Berry-producing shrubs such as Oregon grape *(Berberis spp.),* salmonberry, blackberry, raspberry, thimbleberry, and other *Rubus* species, and blueberry and huckleberry *(Vaccinium spp.)* provide an important food resource to perching birds, especially before and after the breeding season. Snags are an important habitat resource as they provide a plentiful source of insects and cavities and crevices for cavity-nesting species. The scarcity of snags on a landscape has often been blamed for the absence of certain species. Nuthatches and chickadees are common cavity nesting perching birds in western Washington.

Woodpeckers primarily use forest habitat. These birds have unique bills and tongues designed for drilling into tree trunks and extracting insects. Woodpeckers are important members of the forest community because many other bird species use their excavated holes fore nesting sites. Snags are a critical habitat resource for woodpeckers. Increasing the number of snags will likely increase the woodpecker population as well as the population of cavity-nesting perching birds.

Numerous species of raptors reside in forest habitat. These larger species of hawks and owls require forest habitat with low tree density or near a forest edge that borders meadow or marsh habitat. Raptors are carniverous and depend on ample supplies of small mammals and birds. Consequently, the presence of owls and hawks in a forest indicates an abundant prey base and an ecologically sound food web. In January of 1999, a dead juvenile Northern Spotted Owl was found at Fort Ebey State Park. The owl appeared emaciated and was most likely searching for suitable habitat. Breeding Spotted Owl pairs require home ranges roughly 20 times that of the Earth Sanctuary property. It is not likely that Northern Spotted Owls will ever find suitable habitat on Whidbey Island.

Mammals

Mammals tend to be very inconspicuous members of the forest community especially when compared to the birds. Most Whidbey Island mammals are nocturnal, active only at night, and are secretive to avoid detection by predators. The moles, shrews, squirrels, chipmunks, mice, rats, and voles constitute a large part of the prey base for carnivorous birds, mammals, and snakes. The small mammals comprise roughly 50% of the mammal community expected to inhabit the Earth Sanctuary property. On the forest floor, the small mammals burrow into litter and loose, well-drained soils. Understory plants, logs, and other pieces of down wood provide cover for small mammal movements. Forests maintain these resources as a natural process of tree growth and death. Thus, a dead tree or snag is a very important wildlife resource and should be left to decompose unless it poses a significant safety threat. Removal of dead trees for purely aesthetic reasons is not an ecologically advisable practice.

Forest habitat provides thermal cover for deer, particularly during periods of extremely hot or cold temperatures. Forest thickets also provide secluded calving areas. Deer easily adapt to living in close proximity to human dwellings as long as there is no hunting threat.

Amphibians

The Ensatina and western redback salamanders are two species of terrestrial-breeding amphibians commonly found in forest habitat. These small, lungless salamanders breed and develop terrestrially, without ever using aquatic breeding habitats. They are found in loose, well-drained soils, talus slopes, under bark piles, loose rocks, and other cover objects. During periods of drought or extreme temperatures, Ensatina and western redback salamanders burrow deeper into the soil. Western redback salamanders are not commonly found on Puget Sound Islands and are unlikely inhabitants of the Earth Sanctuary. Records of Ensatina salamanders on Whidbey Island do exist (Slater).

The other pond-breeding salamanders, rough-skinned newts, northwestern salamanders, long-toed salamanders, inhabit forest areas when they are not breeding. They migrate from the forested wintering grounds to breeding ponds in late winter and spring and return to the forest after breeding. Forest habitat important for maintaining amphibian diversity include decomposing down wood, bark piles, loose soils, forest litter, and understory plants, especially sword fern.

Reptiles

Three forest-dwelling reptile species could be found at the Earth Sanctuary, the northern alligator lizard, rubber boa, and common garter snake. The northern alligator lizard and common garter snake are frequently seen basking in sunny areas. Rubber boas are secretive and remain under cover objects during the day. At night they may be found actively foraging or dispersing to new areas. Rubber boas are most commonly found within several hundred meters (yards) of water (Brown et. al. 1995).

Wildlife Habitat Enhancement

Wildlife biologists frequently alter or manipulate habitat characteristics of an area as a means of enhancing lands for certain species. In the Douglas fir and western hemlock forests of the western Cascades, the goal is often to drive forest structure to more closely resemble old-growth forest structure. Other times, certain species are targeted and habitat manipulations are designed to benefit those certain species. Within the boundaries of the Earth Sanctuary, the wildlife community would benefit from both strategies. Following are my recommendations.

1. Girdle or remove alder surrounding suppressed western hemlock and Douglas fir within the red alder stand. This will release these already established conifer trees, allowing them to grow above the alder canopy. Allowing these trees to become dominant forest structures increases tree age and size diversity in the overall forest, a characteristic more common to old-growth than second growth forests. These tall trees will provide perches and roosts for eagles, hawks, osprey, and bats. Girdled trees will form snags and can provide nesting cavities and a source of insects. If tree removal is preferred, leave felled trees on forest floor. These provide cover and insects for wildlife as well as return nutrients to the soil.
2. Preserve all snags unless they present a significant threat to human lives and property. Existing snags can be protected by buffer trees if they are near heavy use areas. Labor and Industry guidelines present strategies for buffering snags at different stages of decay. Imperfect trees are good candidates for becoming snags and can be designated as wildlife trees. Do not remove them.
3. Replace invasive, non-native species with structurally similar native species. For example, removal of Himalayan blackberry allows space to increase the *Rosa, Rubus,* and *Vaccinium* species native to this area. Reintroducing these native species will increase the diversity in the forest understory and provide berries, nesting materials, and cover for birds and mammals.
4. Remove bullfrogs, another invasive, non-native species. This may reduce the competition with native amphibian species for food and cover as well as reducing predation. Ideally, removal of the bullfrogs will lead to an increase in native, pond-breeding amphibians and fish. If native amphibian and fish populations don't rise, this action may reduce prey for animals such as herons, Osprey, and garter snakes.
5. Install nest boxes at pond for Wood Ducks. Install bat boxes in the forest. Install nest boxes in leave tree area for American Kestrel. Nesting and roosting boxes for these animals are fairly common and have been used across the country.

Reduction of Human Impacts on Wildlife

Optimizing an aesthetic and natural experience for Earth Sanctuary guests should, at the same time, adequately limit impacts on wildlife species. If the Earth Sanctuary is to be a peaceful refuge for people as well as wildlife, then the guidelines imposed to preserve the natural beauty and quiet of the environment will also preserve the habitat quality for wildlife. Sanctuary planners need to consider the following issues specifically.

1. Trails – Do not ring the ponds with trails. Shoreline property is critical to many bird and amphibian species. Protect the emergent vegetation and sand or mud bars. Select one or two locations at each pond where you can bring the trail down to the water, or even into the pond with a small dock. Construct a boardwalk or dock so people can walk without trampling shoreline vegetation. Design one dock as a duck blind with benches so people can sit and observe the birds without disturbing them. The docks can allow access to the water to monitor water quality.

   Forest trails should be spaced so that people on one trail do not disturb others on a different trail. By limiting trail use so visitors enjoy a peaceful and relatively solitary experience, wildlife species are also respected. It would not degrade habitat quality to pave a short trail and provide access to guests with physical limitations.

Constructing a tree house or suspended walkway through a small portion of the canopy could provide visitors with an exciting and educational experience. For liability reasons, access would have to be regulated.

2. Reserve ponds for wildlife use only; no swimming, boating, or fishing in the ponds.
3. A minimum of 200m should remain forested around the ponds. Clearing of trees to less than 200m of the pond edge can impact air temperature, wind speeds, amount of sunlight, and species presence. By creating an area with interior forest conditions, the sanctuary will provide habitat for certain species of birds, such as the Townsend's warbler, Pacific-slope Flycatcher, and Winter Wren. It also inhibits access by Cowbirds, Crows, and other aggressive species.
4. Limit major clearing, building, and invasive work to late summer, fall, and winter, outside the breeding season for the majority of species. Intrusions during the breeding season may cause some bird species to abandon their nests. This is particularly important for work within 50m of the Osprey nest to provide a buffer for the Osprey pair. Osprey aren't generally sensitive to human presence except near the nest. Construction work that could cause erosion and run-off into the ponds should be done in a manner and time of year that limits this, even if this means working in the summer when soil is drier
5. Place buildings in areas where the fewest number of trees must be removed and in a place that limits driving on the property. This will maximize forest interior habitat. Natural landscaping can be done around the buildings so that in the future, the buildings blend well with the landscape.

Monitoring Wildlife Species

No single method can survey or identify all species of wildlife in a given ecosystem. In fact, wildlife surveys are quite complex and require thorough planning and systematic implementation to assure statistically valid results. They can therefore be quite expensive to implement. A landowner can have a rough idea of what species are present through observations and careful record keeping. For example, anyone living at the Earth Sanctuary can make note of the date the Ospreys return each spring and whether any young are observed. General observations can be supplemented by formal surveys of individual species or groups of species that may indicate the presence of other species or the general functioning of the habitat. Here I include suggestions for monitoring specific groups or species in both the pond and forest habitat types.

Monitoring the abundance and breeding success of cavity-nesting ducks, such as Wood Ducks, Hooded Mergansers, or Buffleheads can provide an indication of the health of the waterfowl community at the Earth Sanctuary ponds. These ducks have specific habitat and food needs. If they drop out of the pond avian community, it is a good indication that something is amiss. On the other hand, their continued presence can be interpreted as an indication that the pond ecosystem is functioning satisfactorily with regard to waterfowl.

The best indicator of diversity and abundance of forest wildlife is the songbird activity. Perching birds are easily counted by a birder trained to recognize species by the male's song or call. Monitoring of this type takes place in the spring just after dawn. Using a point count method, the observer establishes stations at 75 - 100m intervals and listens at each station for a specified amount of time, usually 6-8 minutes. The observer records the number of individuals of each species heard within a specified distance from the station. Observers are trained to avoid double counting birds and estimating the distance from the station by the sound of the call.

Participating in the Christmas Bird Counts that occur at the end of every year provides a yearly record of winter birds and can be compared to other Christmas Bird Counts completed on Whidbey Island.

Mammal population surveys generally require a lot of equipment and consequently can be expensive. The small mammals on Whidbey are common inhabitants of western Washington forests and are not regarded as species of special concern. I do not recommend efforts to monitor their numbers. Because so little is known about bat populations around the state, it would be interesting to have someone do some trapping and recording of echolocation calls at the ponds. The University of Washington's Wildlife Science program in the College of Forest Resources has the necessary equipment. An undergraduate student in the program might be willing to do initial surveys for a senior project.

To monitor the pond-breeding amphibian population, I recommend counting northwestern salamander egg masses every spring. These egg masses are easy to find and identify and will provide an idea of breeding activity every year. To identify other pond-breeding amphibian species, funnel traps could be placed in the ponds throughout the spring, beginning in February. Although not all ponds can support breeding populations of all seven species, the three Earth Sanctuary ponds and adjacent forest habitat provide abundant resources both during and after breeding.

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Table 2. Bird Species Known to Occur on Whidbey Island and It's Shorelines

General habitat descriptions, likelihood of being seen on Earth Sanctuary property, seasonal presence, likelihood of nesting on Earth Sanctuary property, and sensitivity to humans are given. The following abbreviations are used in the table:

Habitat: P – Ponds, L – Lakes, S – Streams, R – Rivers, E – Estuaries, SC – Seacoasts, CF – Conifer Forest, DF – Deciduous Forest, FE – Forest Edge, O – Open, U – Urban

Presence at Earth Sanctuary: VL – Very Likely, L – Likely, U – Unlikely

Seasonal Presence: YR – Year Round, Spr – March/April/May, S – June/July/August, F – September/October/November, W - December/January/February

Nesting Probability: K – Known to breed at Earth Sanctuary, VL – Very Likely, L – Likely, U – Unlikely

Sensitivity to Humans and Development: H – High, M – Moderate, L – Low

Species	Habitat	Presence at E.S.	Seasonal Presence	Nesting Probability	Sensitivity to Humans	Additional Notes
Loons						
Red-throated Loon	P/L	U	Spr, F, W	U	M	
Pacific Loon	L	U	Spr, F, W	U	M	
Common Loon	P/L	U	YR	U	M	
Grebes						
Pied-billed Grebe	P/L/S	L	YR	L	M	
Horned Grebe	P/L/S	L	Spr, F, W	U	M	
Red-necked Grebe	P/L	L	Spr, F, W	U	M	
Eared Grebe	P/L	L	Spr, F, W	U	M	
Western Grebe	P/L	L	Spr, F, W	U	M	
Pellicans and Allies						
Double-crested Cormorant	P/L/R/SC	U	YR	U	L	
Brandt's Cormorant	SC	U	YR	U	M	
Pelagic Cormorant	SC	U	YR	U	M	
Herons and Allies						
American Bittern	P	L	Spr, S, F	L	M	
Great Blue Heron	P/L/R	L	YR	L	L	
Waterfowl						
Tundra Swan	P/L	U	Spr, F, W	U	M	
Trumpeter Swan	P/L	U	Spr, W	U	M	
Greater Wht-frntd. Goose	P/L/E	U	Spr, F	U	L	
Snow Goose	P/L	U	Spr, F, W	U	M	
Brant	R/E/SC	U	Spr, F, W	U	M	
Canada Goose	P/L/M	VL	YR	L	L	
Wood Duck	P w/CF, DF	VL	YR	K	M	Obs. by S.R.
Northern Pintail	P/L	L	Spr, F, W	U	L	
Mallard	P/L	VL	YR	VL	L	
Blue-winged Teal	P/L/S	U	Spr, S, F	U	L	
Green-winged Teal	P/L/S	L	Spr, F, W	L	L	
Cinnamon Teal	P/L/S	U	Spr, S, F	L	M	
Northern Shoveler	P/L	L	Spr, F, W	L	L	
Gadwall	P/L	U	YR	L	L	
American Wigeon	P/L	VL	Spr, F, W	L	L	
Canvasback	P/L/R	U	Spr, F, W	U	M	
Redhead	P/L	U	Spr, F, W	U	L	

Species	Habitat	Presence at E.S.	Seasonal Presence	Nesting Probability	Sensitivity to Humans	Additional Notes
Ring-necked Duck	P/L	VL	Spr, F, W	U	L	
Greater Scaup	P/L	L	Spr, F, W	U	L	
Lesser Scaup	P/L	L	Spr, F, W	U	L	
Harlequin Duck	S/SC	L	YR	U	L	
Oldsquaw	L/SC	U	Spr, F, W	U	L	
Black Scoter	P/L/SC	U	Spr, F, W	U	L	
Surf Scoter	P/L/S	L	YR	U	M	
White-winged Scoter	P/L/S	VL	YR	U	M	
Common Goldeneye	P/L/R/SC	L	Spr, F, W	U	L	
Barrow's Goldeneye	P/L/R/SC	L	Spr, F, W	U	L	
Bufflehead	P/L	L	Spr, F, W	L	L	
Hooded Merganser	P/L/E	VL	YR	K	L	Obs. by S.R.
Common Merganser	L/R	L	YR	U	L	
Red-breasted Merganser	P/L/R/SC	U	Spr, F, W	U	L	
Ruddy Duck	P/L/R/E	L	Spr, F, W	L	L	
Vultures, Hawks, and Falcons						
Turkey Vulture	CF/DF/O	U	Spr, S, F	U	L	
Osprey	L/R/SC	VL	Spr, S, F	K	M	Obs. by K.F.
Bald Eagle	L/R/SC/CF/DF/O	L	YR	L	M	
Northern Harrier	P/M	U	YR	L	L	
Cooper's Hawk	P/L/R/CF/DF	U	YR	L	M	
Sharp-shinned Hawk	CF/DF	L	YR	L	L	
Northern Goshawk	CF/DF	U	W	U	H	
Red-tailed Hawk	CF/DF/O	L	YR	L	L	
Rough-legged Hawk	CF/O	U	Spr, F, W	U	M	
Golden Eagle	O	U	YR	U	M	
American Kestrel	O/U	L	YR	L	L	
Merlin	DF/O	U	Spr, F, W	U	M	
Peregrine Falcon	SC/DF/O/U	U	Spr, F, W	U	L	
Gallinaceous Birds						
Ring-necked Pheasant	P/CF/DF/FE/O	U	YR	L	L	
Wild Turkey	CF/DF	U	YR	U	M	
California Quail	M/DF/O	L	YR	VL	L	
Cranes and Allies						
Virginia Rail	P	L	YR	L	L	
Sora	P	L	Spr, S, F	L	L	
American Coot	P/L/R	VL	YR	L	L	

Species	Habitat	Presence at E.S.	Seasonal Presence	Nesting Probability	Sensitivity to Humans	Additional Notes
Shorebirds, Gulls, and Alcids						
Black-bellied Plover	SC	U	YR	U	M	
Lesser Golden-Plover	SC	U	F	U	M	
Semipalmated Plover	P/L/SC	U	Spr, S, F	U	M	
Killdeer	P/L/M	VL	YR	L	L	
Black Oystercatcher	SC	U	YR	U	M	
Greater Yellowlegs	P	L	Spr, F	U	M	
Lesser Yellowlegs	P	U	F	U	M	
Spotted Sandpiper	P/L/SC	L	YR	L	M	
Solitary Sandpiper	P/L/S	U	Spr, F, W	U	M	
Whimbrel	P/M	U	Spr, S, F	U	M	
Long-billed Curlew	P/M	U	S	U	M	
Ruddy Turnstone	P/SC	U	Spr, S, F	U	M	
Black Turnstone	SC	U	YR	U	M	
Surfbird	SC	U	S	U	M	
Sanderling	SC	U	YR	U	M	
Semipalmated Sandpiper	SC	U	S, F	U	M	
Least Sandpiper	P/R/E/SC	L	Spr, S, F	L	M	
Western Sandpiper	P/SC	U	YR	U	M	
Baird's Sandpiper	P/L/SC	U	Spr, F, W	U	M	
Pectoral Sandpiper	P/M/SC	U	S, F	U	M	
Rock Sandpiper	P/SC/M	U	Spr, F, W	U	M	
Dunlin	SC	U	YR	U	M	
Short-billed Dowitcher	P/M/SC	U	Spr, S, F	U	M	
Long-billed Dowitcher	P/M	L	Spr, S, F	L	M	
Common Snipe	P/R/M	U	YR	U	M	
Wilson's Phalarope	P/L/S/M	U	Spr, S, F	U	M	
Red-necked Phalarope	P/L	U	S, F	U	M	
Parasitic Jaeger	SC	U	Spr, F	U	M	
Bonaparte's Gull	P/L/SC	L	YR	L	M	
Heermann's Gull	SC	U	S, F	U	M	
Mew Gull	L/R/SC	L	YR	U	M	
Ring-billed Gull	P/L/SC	L	YR	L	L	
California Gull	P/L/SC	L	YR	L	M	
Herring Gull	L/R/SC/U	L	Spr, F, W	U	L	
Thayer's Gull	SC	U	Spr, F, W	U	M	
Glaucous-winged Gull	L/SC/U	L	YR	U	L	
Western Gull	SC	U	YR	U	M	
Caspian Tern	SC	L	Spr, S, F	U	M	
Common Tern	SC	U	Spr, F	U	M	
Common Murre	SC/Cliffs	U	YR	U	M	
Pigeon Guillemot	SC	U	YR	U	M	

Species	Habitat	Presence at E.S.	Seasonal Presence	Nesting Probability	Sensitivity to Humans	Additional Notes
Marbled Murrelet	L/SC/CF	U	YR	U	H	
Ancient Murrelet	SC	U	F, W	U	M	
Rhinoceros Auklet	SC	U	YR	U	M	
Tufted Puffin	SC	U	S	U	M	
Pigeons and Doves						
Rock Dove	O/U	L	YR	L	L	
Band-tailed Pigeon	CF/DF	L	YR	L	M	
Mourning Dove	DF/U	L	YR	L	L	
Owls						
Barn Owl	M/DF/O	U	YR	U	L	
Western Screech-Owl	P/L/R/DF	L	YR	L	L	
Great Horned Owl	P/R/CF/DF	L	YR	L	M	
Snowy Owl	O	U	W	U	L	
Northern Pygmy-Owl	CF/DF	U	Spr, F, W	U	M	
Barred Owl	P/R/CF/DF	U	YR	U	L	
Short-eared Owl	P/M	L	YR	L	M	
Northern Saw-whet Owl	P/L/CF/DF	L	YR	L	L	
Northern Spotted Owl	CF/DF	U	YR	U	H	
Goatsuckers						
Common Nighthawk	M/O/U	L	Spr, S	L	L	
Swifts and Hummingbirds						
Black Swift	SC, Cliffs	U	Spr, S	U	M	
Vaux's Swift	CF/DF	L	Spr, S	L	L	
Anna's Hummingbird	DF	U	YR	U	L	
Rufous Hummingbird	CF/DF/M	VL	Spr, S, F	L	L	
Kingfishers						
Belted Kingfisher	P/L/S/R/SC	L	YR	U	M	
Woodpeckers						
Red-breasted Sapsucker	CF/DF	L	YR	L	L	
Downy Woodpecker	CF/DF	VL	YR	L	L	
Hairy Woodpecker	P/CF/DF	VL	YR	L	L	
Northern Flicker	CF/DF/M/U	VL	YR	VL	L	
Pileated Woodpecker	CF/DF	VL	YR	VL	L	
Perching Birds						
Olive-sided Flycatcher	CF/DF	VL	Spr, S	VL	L	
Western Wood-Pewee	CF/DF	L	Spr, S	L	M	
Willow Flycatcher	P/L/DF	L	Spr, S	L	M	cowbird host
Hammond's Flycatcher	CF/DF	L	Spr, S	L	M	
Pacific-slope Flycatcher	P/L/S/R/DF	VL	Spr, S	VL	M	

Species	Habitat	Presence at E.S.	Seasonal Presence	Nesting Probability	Sensitivity to Humans	Additional Notes
Western Kingbird	P/L/S/R/DF	U	Spr, S	U	L	
Horned Lark	M/O	U	Spr, F, W	U	L	
Purple Martin	P/L/O	U	S	U	L	
Tree Swallow	P/L/FE/O	VL	Spr, S, F	VL	L	
Violet-green Swallow	CF/DF	VL	Spr, S, F	VL	L	
Rough-winged Swallow	S/R/O	L	Spr, S, F	L	L	
Bank Swallow	S/R/O	U	Spr, S, F	U	L	
Cliff Swallow	S/R/O	VL	Spr, S, F	U	L	
Barn Swallow	P/L/S/R/O	VL	Spr, S, F	VL	L	
Steller's Jay	CF/DF	L	YR	L	L	
American Crow	P/L/SC/DF/U	VL	YR	L	L	
Northwestern Crow	SC	L	YR	L	L	
Common Raven	CF/DF	L	YR	L	L	
Black-capped Chickadee	CF/DF	VL	YR	VL	L	
Chestnut-backed Chickadee	CF/DF	VL	YR	VL	M	
Bushtit	DF/U	VL	YR	VL	M	
Red-breasted Nuthatch	CF/DF	VL	YR	VL	L	
Brown Creeper	CF	VL	YR	VL	L	
Bewick's Wren	DF/U	VL	YR	VL	L	
House Wren	DF/U	L	Spr, S	L	L	
Winter Wren	CF/DF	VL	YR	VL	L	
Marsh Wren	P	VL	YR	VL	L	
Golden-crowned Kinglet	CF	VL	YR	VL	L	
Ruby-crowned Kinglet	CF/DF	VL	Spr, F, W	VL	L	
Swainson's Thrush	P/L/CF/DF/FE	VL	Spr, S, F	VL	L	
Hermit Thrush	CF/DF/FE	L	Spr, F	U	L	
American Robin	CF/DF/U	VL	YR	VL	L	
Varied Thrush	CF/DF	VL	YR	VL	L	
American Pipit	P/L/M	L	Spr, F	U	L	
Bohemian Waxwing	CF/DF	L	Spr, W	U	L	
Cedar Waxwing	DF/FE	VL	YR	VL	L	
Northern Shrike	CF/DF	U	Spr, W	U	L	
European Starling	DF/O/U	VL	YR	VL	L	
Solitary Vireo	CF/DF	L	Spr, S	L	M	cowbird host
Hutton's Vireo	CF/DF	L	YR	L	L	
Warbling Vireo	CF/DF	L	Spr, S	L	M	cowbird host
Red-eyed Vireo	CF/DF	L	Spr, S	L	M	cowbird host
Orange-crowned Warbler	CF/DF	VL	YR	VL	L	
Yellow Warbler	CF/DF/U	VL	Spr, S	VL	L	cowbird host
Yellow-rumped Warbler	CF/DF	VL	YR	VL	L	
Blk.-throated Gray Warbler	CF/DF	VL	Spr, S	L	L	

Species	Habitat	Presence at E.S.	Seasonal Presence	Nesting Probability	Sensitivity to Humans	Additional Notes
Townsend's/Hermit Warbler	CF/DF	VL	Spr, S, F	VL	L	
MacGillivray's Warbler	DF/FE	L	Spr, S	L	M	
Common Yellowthroat	P/DF/FE	VL	Spr, S, F	VL	L	cowbird host
Wilson's Warbler	P/L/S/R/DF	VL	Spr, S, F	VL	L	
Western Tanager	CF/DF	L	YR	L	M	
Black-headed Grosbeak	P/DF	L	Spr, S	L	L	
Rufous-sided Towhee	P/L/S/R/DF/FE	VL	YR	VL	L	
Chipping Sparrow	CF/DF/FE	U	Spr, S	U	L	cowbird host
Savannah Sparrow	P/M	L	YR	L	L	
Fox Sparrow	CF/DF/FE	L	Spr, F, W	U	M	
Song Sparrow	P/L/S/R/SC/FE	L	YR	L	L	cowbird host
Lincoln's Sparrow	P/M/DF	U	Spr, F, W	U	M	
Golden-crowned Sparrow	DF	U	Spr, F, W	U	M	
White-crowned Sparrow	M/DF	L	YR	VL	L	
Dark-eyed Junco	P/CF/DF/FE	VL	YR	VL	L	
Lapland Longspur	M	U	Spr, F, W	U	M	
Snow Bunting	SC/Cliffs	U	F, W	U	M	
Red-winged Blackbird	P/L	VL	YR	VL	L	cowbird host
Yellow-headed Blackbird	P/L	U	Spr, S, F	U	L	
Western Meadowlark	M	U	YR	U	L	
Brewer's Blackbird	P/DF	VL	YR	VL	L	cowbird host
Brown-headed Cowbird	DF/FE	L	YR	L	L	
Purple Finch	CF/DF/FE	L	YR	L	L	
House Finch	DF/U	VL	YR	VL	L	
Red Crossbill	CF/DF	L	YR	L	M	
Pine Siskin	CF/DF/U	VL	YR	VL	L	
American Goldfinch	M/DF	VL	YR	VL	L	cowbird host
Evening Grosbeak	CF/DF/FE	L	YR	L	L	
House Sparrow	DF/FE/U	VL	YR	VL	L	

***Table 3.** Mammals Known to or Could Occur on Whidbey Island and at the Earth Sanctuary*

General habitat descriptions, likelihood of presence at Earth Sanctuary, and sensitivity to humans are given. The following abbreviations are used in the table:

Habitat Requirements: G – Habitat Generalist, H – Hollow Trees and Logs, NW – Near Ponds, Lakes, Streams, or Rivers, RF – Riparian Forest, B – Building Structures, CF – Conifer Forest, DF – Deciduous Forest, M – Meadows or Clearings

Presence at Earth Sanctuary: K – Known, VL – Very Likely, L – Likely, U – Unlikely

Sensitivity to Humans and Development: H – High, M – Moderate, L – Low

Species	Common Name	Habitat Requirements	Presence at E.S.	Sensitivity to Humans	Additional Notes
Marsupials					
Didelphis virginianus	Opossum	G/H/B	L	L	
Insectivores					
Sorex bendirii	Marsh Shrew	NW/CF/DF	VL	L	
Sorex cinereus	Masked Shrew	DF/CF	U	H	
Sorex monticolus	Montane Shrew	NW/CF/DF	L	L	
Sorex vagrans	Vagrant Shrew	CF/DF	L	L	
Sorex trowbridgii	Trowbridge's Shrew	HG/CF/DF/M	VL	L	
Sorex palustris	Water Shrew	NW/CF	U	L	
Scapanus orarius	Coast Mole	CF/DF	L	L	
Neurotrichus gibbsii	Shrew-mole	CF/DF	VL	L	
Scapanus townsendii	Townsend's Mole	HG/CF/DF/M	VL	L	
Bats					
Eptesicus fuscus	Big Brown Bat	P/CF/DF/M/B	L	L	
Myotis californicus	California Myotis	P/CF/DF/M/B	L	L	
Lasiurus cinereus	Hoary Bat	P/CF/DF/M/B	U	L	
Myotis keenii	Keen'sMyotis	P/CF/DF/M/B	L	L	
Myotis lucifugus	Little Brown Bat	P/CF/DF/M/B	L	L	
Myotis evotis	Long-eared Myotis	P/CF/DF/B	L	L	
Myotis volans	Long-legged Myotis	P/CF/DF/M/B	L	L	
Lasionycterus noctivagans	Silver Haired Bat	P/CF/DF/M/B	L	L	
Plecotus townsendii	Townsend's Big-eared Bat	P/CF/DF/M/B	L	L	
Myotis Yumanensis	Yuma myotis	P/CF/DF/B	L	L	
Rabbits					
Lepus americanus	Snowshoe Hare	CF/RF	U	M	
Squirrels and Chipmunks					
Tamiasciurus douglasii	Douglas' Squirrel	CF	L	L	
Glaucomys sabrinus	Northern Flying Squirrel	CF	U	M	
Tamias townsendii	Townsend's chipmunk	CF	L	L	
Castor canadensis	Beaver	P/L/S/R/RF	U	L	

Species	Common Name	Habitat Requirements	Presence at E.S.	Sensitivity to Humans	Additional Notes
Mice, Rates and Voles					
Peromyscus maniculatus	Deer Mouse	HG/CF/DF/M	VL	L	
Peromyscus oreas	Forest Deer Mouse	CF	VL	L	
Neotoma fuscipes	Dusky-footed Wood Rat	CF/DF	L	L	
Clethrionomys gapperi	Southern Red-backed Vole	CF	U	M	
Microtus longicaudus	Long-tailed Vole	CF/DF/RF	L	L	
Microtus townsendii	Townsend's Vole	CF/DF	L	L	
Ondatra zibethica	Muskrat	P/L/S	L	L	
Rattus norvegicus	Norway Rat	G/B	L	L	non-native
Rattus rattus	Black Rat	G/NW/B	L	L	non-native
Mus Musculus	House mouse	G/B/M	VL	L	non-native
Zapus trinotatus	Pacific jumping mouse	FM/S	L	L	
Carnivores					
Canus latrans	Coyote	HG	L	L	
Procyon lotor	Racoon	HG/NW	VL	L	
Mustela frenata	Long-tailed Weasel	HG/NW	U	M	
Mustela erminea	Ermine (Shorttail Weasel)	NW/CF/DF	U	L	
Mephitis mephitis	Striped Skunk	G/NW/DF	L	L	
Spilogale putorius	Spotted Skunk	G/S/DF/B	U	M	
Lutra canadensis	River Otter	P/L/R	L	M	
Ungulates					
Odocoileus hemionus	Mule deer	G	VL	L	

Table 4. Amphibians Likely to Occur on Whidbey Island and at the Earth Sanctuary.

General breeding habitat descriptions, likelihood of presence at Earth Sanctuary, and sensitivity to human activity are given. The following abbreviations are used in the table:

Breeding Habitat: E – Ephemeral Ponds, P – Ponds, L – Lakes, CF – Conifer Forest, DF – Deciduous Forest

Presence at Earth Sanctuary: K – Known, VL – Very Likely, L – Likely, U – Unlikely

Sensitivity to Humans and Development: H – High, M – Moderate, L – Low

Species	Breeding Habitat	Presence at E.S.	Sensitivity to Humans	Additional Notes
Taricha granulosa Rough-skinned newt	E/P/L	L	L	
Ambystoma gracile Northwestern salamander	P/L	K	M	obs. by KK '00
Ambystoma macrodactylum Long-toed salamander	E/P/L	VL	L	
Plethodon vehiculum Western red-backed salamander	CF/DF	U	L	
Ensatina eschscholtzi Ensatina salamander	CF/DF	VL	L	
Bufo boreas Western toad	E/P/L	L	M	
Hyla regilla Pacific tree frog	E/P/L	K	L	
Rana aurora Red-legged frog	E/P/L	VL	L	
Rana catesbeiana Bullfrog	P/L	K	L	obs. by KK '00 Non-native, invasive species

Table 5. Reptiles Which Could Occur on Whidbey Island and at the Earth Sanctuary

General habitat descriptions, likelihood of presence at Earth Sanctuary, and sensitivity to humans are given. The following abbreviations are used in the table:

Habitat Requirements: O – openings for basking and foraging, C – cavities and cracks within large stumps, logs, rocks, EP – Elevated Perches, P – Ponds, L – Lakes, S – Streams, R - Rivers, PW – Proximity to Water, CF – Conifer Forest, DF – Deciduous Forest, M – Meadows or Clearings

Presence at Earth Sanctuary: K – Known, VL – Very Likely, L – Likely, U – Unlikely

Sensitivity to Humans and Development: H – High, M – Moderate, L – Low

Species	Habitat Requirements	Presence at E.S.	Sensitivity to Humans	Additional Notes
Elgaria coerulea Northern Alligator Lizard	O/C/CF/DF	L	L	Live-bearing
Sceloporus occidentalis Western Fence Lizard	O/EP	U	L	Scattered distribution in Puget Sound region
Charina bottae Rubber Boa	O/C/PW/CF/DF	L	L	
Thamnophis ordinoides Northwestern Garter Snake	C/M	L	L	ID: 7 upper labial and 8-9 lower labial scales
Thamnophis sirtalis Common Garter Snake	O/C/P/L/S/R/CF/DF	VL	L	ID: 7 upper labial and 10 lower labial scales
Introduced turtles	P/L	L	L	Various pet-store species

Appendix E. Earth Sanctuary Fish Assessment

Ann Garrett
September 2001

Earth Sanctuary Fish Assessment

September 29, 2001

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Introduction

The purpose of this report is to describe the fish community in three small freshwater ponds on Whidbey Island. Field surveys were conducted in the fall and summer in three ponds on the Earth Sanctuary property near Freeland, Washington. Although the surveys were inconclusive, some information exists to suggest warm water (nonnative) fishes inhabit the ponds presently.

This report examines the role of the Earth Sanctuary drainages in native fish production and the role of pond fishes in the local food web. Similar ponds and bog/fen complexes within the Puget Sound region are discussed for comparison.

Finally, three general alternatives are proposed for enhancing the local fish community. These are the rehabilitation of historic processes, conservation of the existing processes, and supplementation. Each alternative is explored in detail, including the potential affect altering fish habitat and abundance could have on the local biota such as osprey *(Pandion haliaetus)*, otter, and macroinvertebrates.

Site Description

The Earth Sanctuary site has three ponds, which drain two basins to Useless Bay on the southern end of Whidbey Island. The ponds are listed as a habitat of local importance in the Island County critical areas plan. The Whidbey Audubon Society nominated the ponds for this status because they provide unique waterfowl habitat. Osprey and bald eagle (*Haliaeetus leucocephalus*), as well as, otter, salamanders and other animals, have been observed on the site.

Two of the ponds were enhanced years ago to promote a warm water fishery. The northwest pond, Pond One, is the smallest pond on the site. Weirs control the water levels in Pond One and Two, which are hydrologically linked. The hydrology of Pond Three, the Fen, is controlled in part by a roadway culvert.

Drainages entering the ponds and fen are very small and contain limited gravels. The ponds and upland areas are well vegetated, although there is room to enhance pond buffer function through planting native vegetation. The surrounding area is rapidly urbanizing, and the forest cover at the site helps protect pond hydrology, as well as water quality. Additionally, the riparian buffer provides many other functions such as nest and forage cover for birds, and a recruitable source of wood/structure to the waterways, where fish, insects, salamanders and other animals can use it.

Osprey and bald eagle are a few of the birds that frequent the Earth Sanctuary site, occasionally perching on snags in or around the ponds. In fact, an osprey pair has been returning to nest at the Earth Sanctuary property for several years. The foraging habits of the pair are uncertain. Observations of the pair could help determine forage area preferences and the role that pond fish play in the ospreys' diet.

Methods and Results

The three Earth Sanctuary ponds were by sampled with minnow traps on November 17 and 18, 2000. Underwater observation was also attempted on November 17, but poor water clarity hampered successful detection. On June 23, 2001 ponds were sampled using a variety of methods including gill nets, minnow traps, and cast nets. The gill net was set and baited in Pond One and the Fen. Minnow traps were set and baited in all three ponds in November and June, whereas multiple cast nets were set in all three ponds in June only. Although, survey efforts were inconclusive, as no fish were captured during either sampling period, four brown bullhead *(Ictalurus nebulosus)* were captured during amphibian trapping in Pond One, and the remains of two largemouth bass *(Micropterus salmoides)* were found on the shoreline of the Fen in November 2000.

Efficiency of sampling gear was considered before sampling began in the Earth Sanctuary ponds. Trap types were selected and deployed to target warm water and pond fish species. Typical methods used to survey ponds and lakes include baited minnow traps, snorkel surveys, fyke netting, gill netting, hook and line, and electrofishing (Murphy and Willis 1996; Downen et al. 1999; B. Pfeifer pers. comm.). Where sufficient water exists at the pond outlet, weirs or other types of full spanning fence traps provide opportunity for complete enumeration of all migrating fishes (Hubert 1996; Garrett 1998). Electrofishing, fyke netting, and weir trapping were dismissed as potential survey methods due to cost, low flow conditions, and dense aquatic vegetation and woody debris.

For the Earth Sanctuary project, a gill net was special ordered with mesh openings sized for large mouth bass. Gill net sets were chummed with bait to increase catch success (B. Pfeifer, pers. comm.). Minnow traps baited with tuna and cat food were used to target smaller fishes and bottom feeders, such as brown bullhead. Even so, surveys were inconclusive and may have been hampered by site conditions (dense aquatic vegetation), sampling regime (time of day, duration of set and location), and low fish productivity. Catch success could increase by extending gill net and minnow trap set duration or through hook and line techniques, although low fish productivity would likely limit catch per unit effort.

Discussion

The Earth Sanctuary ponds appear to contain two warm water nonnative fish species, large-mouth bass and brown bullhead. Although large-mouth bass can live for as long as 16 years, few live as long as 10 years and brown bullhead seldom live past age 5. Therefore, these species are likely spawning within the ponds, since anecdotal information suggests that the ponds have not been stocked with these species for many years. Fish productivity in the ponds is likely limited by the amount of suitable spawning areas, prey density, and presumably high predation by birds and small mammals like otters. High mortality likely limits the number of fish that survive to reproductive size.

In general, natural freshwater fish production is limited on Whidbey Island. The majority of the Island's streams are very small and are typically dry through the summer months, limiting native fish diversity (Williams et al. 1975). Only about 7 streams on the Island are believed to support salmon, the region's most abundant freshwater fish (Williams et al. 1975; Wydoski and Whitney 1979). Salmon species that use the Island's streams are primarily limited to coho *(Oncorhynchus kisutch)* and chum salmon *(O. keta)* (Williams et al. 1975), and coastal cutthroat trout *(O. clarki clarki)*.

Coho salmon and cutthroat trout frequent ponds and small streams, and could have used the site on an intermittent basis. Both species have a tendency to migrate to small streams and ponds as juveniles where they forage and rear until outmigrating (Cederholm and Scarlett 1982). Cutthroat trout tend to be found in a wider variety of habitats than many other salmonids, including very small streams sometimes only a foot or two wide (Johnson et al. 1999). Frequently, such small streams support freshwater resident forms of coastal cutthroat trout that do not undertake extensive migrations (Garrett 1998). Such habitats include ephemeral streams, which may flow only during the wet season and may consist of only seeps and discontinuous pools in the dry season, and others that are totally devoid of water during the dry season (Hartman and Brown 1987).

Fish species and size largely govern minimum water depth requirements. Adult coastal cutthroat trout can spawn in water depths as low as 2 to 4 inches and adult coho salmon have been observed spawning in water depths as low as 3 inches (Burner 1952; Hunter 1973). Due to the their smaller size juvenile fish can typically tolerate shallower waters than adult fish, and may even be found in areas were stream surface waters are dry, but where hyporheic water flows are sufficient to avoid desiccation (R. Edwards, Hyporheic Zone seminar, 2000).

Other native fish that may have inhabited the Earth Sanctuary drainages include red-side shiner *(Richardsonius balteatus),* three-spine stickleback *(Gasterosteus aculeatus),* and possibly western brook lamprey *(Lampetra richardsoni).* Red-side shiner (a native minnow) and sticklebacks are both pelagic fishes that are widely distributed in the region and have been found in swamps, ponds, and irrigation ditches (Wydoski and Whitney 1979; Link 1999). The red-side shiner can tolerate a wide range of temperatures (44ºF to 75ºF). Shiners spawn in gravel in pond ingress and egress channels and in vegetation along shorelines. Sticklebacks also build nests in vegetation and on the bottom of streams and ponds, and are one of the most widespread fishes worldwide (Wydoski and Whitney 1979). Western brook lamprey, on the other hand, are bottom dwellers with an eel-like appearance. The western brook lamprey is the smallest-bodied lamprey and the only lamprey that spends its entire life in fresh water (Wydoski and Whitney 1979). Adult western brook lamprey are usually less than 6 or 7 inches long, spawn in small gravel, and the larvae (ammocetes) inhabit silty substrates where they filter feed. The site has limited gravels suitable for spawning however, which may limit lamprey production.

Pond enhancement to promote a warm water fishery, like that at the Earth Sanctuary property, was commonplace 15 or more years ago, particularly in lowland drainages. Such ponds were typically stocked with native trout or introduced species like bass and bullhead. Sometimes the introduction of nonnative fishes occurred to the detriment of the native fish population, and other times the stocking occurred in fishless ponds and lakes (Temple et al. 1998; Wydoski and Whitney 1979).

The Earth Sanctuary site, however, likely provided marginal habitat for native fishes historically. Although recent surveys were inconclusive, present habitat conditions appear to restrict native fish use of the ponds while empirical evidence suggests that warm water fishes may occupy the ponds today. In the past, the Earth Sanctuary ponds may have been dominated aquatic insects and amphibians, rather than fish. These drainages however, may have contributed to fish habitat in the lower basin by maintaining functional hydrological and nutrient conditions downstream. The importance of these upper drainages to fish production and the maintenance of suitable native fish habitat in the basin could be better understood by identifying fish species distribution and abundance within the watershed.

Although native freshwater fish production is limited on the Island, the surrounding marine waters and the shorelines are used by large numbers of juvenile salmonids outmigrating from other areas (Williams et al. 1975). Osprey, bald eagle, and other fish-eating animals may be attracted to these large concentrations of fish. It seems unlikely that fish in the Earth Sanctuary ponds provide a primary food source for these birds. Osprey feed almost exclusively on fish (NGS 1992) and may need a more abundant primary food source, such as saltwater fishes. Even so, the stocking of warm water fishes to the Earth Sanctuary ponds introduced a supplemental prey source for these birds and other animals, like otters. Observations on osprey feeding patterns are necessary to evaluate foraging preference and foster an understanding of their use of the ponds. Other suitable habitat characteristics at the Earth Sanctuary property, such as adequate nesting sites in close proximity to Useless Bay, may attract the birds.

New goals for the Earth Sanctuary property include constructing a long-term plan (500 year) for the protection of the site, while enhancing biodiversity (C. Pettis, pers. comm.), and carefully shaping a self-sustaining ecosystem. The next sections of this report discuss three general alternatives for enhancing the local fish community and food web at the Earth Sanctuary property. The first alternative emphasizes rehabilitation of historic site function, diversity, and dynamics so that the ponds will operate without continued reliance on engineered structures (a low maintenance or self-sustaining 500-year plan). The second alternative is to maintain current processes whereby avoiding changes that could significantly alter the local biota, and the final alternative is to supplement the local food web by stocking fish in the ponds.

Rehabilitation of Historic Processes

The 500-year plan for the Earth Sanctuary ponds might include reducing reliance on engineered structures to maintain the hydrology of the site. Human engineered structures, like the weirs, will fail in time, although the structural life is typically 30 to 50 years or more. Rehabilitation of the hydrology could result in an increase in native wildlife species that are dependent upon seasonal waterways, although this alternative may be less favorable in the short-term due to uncertainty with how the existing ecosystem may respond and because confining factors like undersized roadway culverts may need to be upgraded by local agencies. Furthermore, Island County personnel and Whidbey Island Audubon Society may cautiously evaluate such alterations to the ponds as a result of their status.

Nevertheless, recreating the pre-disturbed hydrological conditions could promote seasonal use of the site by native fishes, amphibians, and increase aquatic insect habitat. Similar ponds and headwater wetlands provide important winter refuge habitat to native fish. However, usage will depend largely on accessibility during fall and winter rains. Weir removal would require careful planning to ensure largemouth bass and brown bullhead are not released downstream.

Rehabilitating the hydrologic conditions on site might also promote increases in native amphibian abundance, while reducing habitat conditions favorable to nonnative species like bullfrogs (*Rana catesbeiana*). Bullfrogs are voracious and opportunistic predators that eat a wide variety of animals, including native frogs, turtles, fish, ducklings and mice. The predatory nature of both bullfrogs and bass may limit aquatic biodiversity on the site. Where bass and juvenile native fish overlap, studies have shown that rearing success of native fish is significantly reduced through bass predation (Temple et al. 1998). Similarly, there is evidence to suggest that in some areas declines in waterfowl production correspond with the introduction of bullfrogs (Leonard et al. 1993). Bullfrogs, however, cannot survive in seasonal wetland habitats (Link 1999) and suitable habitat for bass would be seriously reduced with a return to a pre-disturbed hydrological regime.

To recreate a close approximation of the pre-disturbed condition on the site it may be desirable to fill portions of Pond One, where native soils have been excavated. Recreating historic hydraulic processes does not necessitate restoration of all historic site characteristics. That is, even though predisturbed conditions did not appear to include ponds, the site could be designed to reduce reliance on weirs and still provide pond habitat, while providing seasonal access to native fishes. Clean native fill could be added to Pond One to create gently sloped shorelines where there is currently a steep excavated edge. This steep edge provides poor conditions for wildlife and a gradual slope with varying water depths would promote enhanced use by wildlife including birds, mammals, native amphibians, and aquatic insects (Link 1999).

Flow-through conditions and the effects of altering these conditions should be thoroughly evaluated if this alternative is chosen. This alternative could actually reduce fish abundance at the site, particularly in Ponds One and Two. However, it could increase the abundance of aquatic insects and native amphibians. Additional observations of osprey activities at the site would be necessary to fully evaluate the potential effects of this alternative on the nesting osprey pair.

Preservation of Existing Processes

The exact time at which the Ponds were last stocked with bass and bullhead is uncertain, but is believed to have occurred sometime in the last 15 to 20 years. Bass and bullhead typically prefer warmer waters than native salmonids, are commonly found in ponds and lakes, and are infrequently found in streams. Their reproductive potential is typically quite high and they are able to survive in a wide variety of what are otherwise unfavorable conditions for most fish species, including low dissolved oxygen concentrations and high water temperatures (Wydoski and Whitney 1979).

Largemouth bass can live to an old age. In Washington, largemouth bass generally don’t live past 10 years of age, although some have lived as long as 14 years (Wydoski and Whitney 1979). Spawning likely occurs in the Earth Sanctuary ponds, although surveys were unable to find adult or juvenile fish. In general, largemouth bass spawn in shallow water over sand, or gravel, which appears limited at the site.

Brown bullhead on the other hand, spawn in shallow areas with mud or sand substrates. The four bullhead captured during amphibian sampling were all about 2 inches long, and based on average age at length data from other basins, were probably about one year old when captured. This suggests that brown bullhead are reproducing naturally in at least Pond One. Bullhead are bottom feeders, and prey primarily on plankton and midges when young. Adults however, feed on a wider variety of foods including large amounts of fish (Wydoski and Whitney 1979).

Limited spawning sites for bass, coupled with extensive predation of both bass and bullheads by birds and mammals may limit natural production at the Earth Sanctuary site. Nevertheless despite inconclusive survey data, it appears that the Earth Sanctuary site contains suitable habitat for these species to reproduce. Suitable spawning sites could be created or enhanced to further encourage bass spawning, in particular. As mentioned previously, gravel could be added along the shores of Pond One, which would create shallow habitat and provide suitable sites for spawning. Gravel cleaning or enhancement may be necessary to maintain suitable spawning conditions for bass, but would need to be evaluated over time. Adding submerged logs and brush to the excavated shores of Pond One would also provide additional habitat features preferred by largemouth bass.

Supplementation

This section explores supplementation or stocking of fish in the Earth Sanctuary ponds, without modifications to existing hydrology. Supplementation could be done on the site with native or nonnative fish species, or a combination of both. All of which should achieve the same goal of increasing prey abundance for fish-eating animals, at least temporarily. Heavy aquatic vegetation and organic loading, water temperatures, and dissolved oxygen levels are a few of the variables that influence fish production on the site, and likely favor warm water fishes like largemouth bass and bullhead.

The release of fish into any water of the state, including private, natural or man-made ponds requires a fish-stocking permit from the Washington Department of Fish and Wildlife (WDFW). Regulations and permits for stocking fish are addressed in the following section, however it bears mentioning that the WDFW will conduct a pond evaluation as part of this process. The spread of cultured fish, native and nonnative, can have serious adverse affects on the native biota and is the major reason for the pond evaluation. Biologists with WDFW will review water quality and quantity, outlet structures, connections to nearby waters, and the flooding potential of the Earth Sanctuary ponds. Limited information on downstream fish usage could be supplemented by surveys and would provide a better understanding of the potential risk of stocking fish in the Earth Sanctuary ponds. For instance, neighboring Lone Lake on Whidbey Island contains illegally introduced largemouth bass that have affected the survival of juvenile native trout (Pfeifer *in* Histata 1999). However, former management actions on the Earth Sanctuary site should weigh heavily into the agency's evaluation of the proposal.

Trout, such as rainbow (*O. mykiss*) and cutthroat trout, are more commonly stocked in private ponds in central and north Puget Sound counties, including Island County (Phillips 1997). As a result, it is easier to find local companies that specialize in trout stocking. In 1998, eleven applicants requested applications to stock fish in their private ponds. None of the requests however, were to stock warm water species in private ponds (Histata 1999). Requests for stocking warm water fish are less common, but do occur.

A limited number of species will succeed in the Earth Sanctuary ponds and fewer yet are likely to be self-sustaining due to site conditions. While trout may be the preferred fish for stocking by natural resource agencies, trout are less likely to establish a self-sustaining population because the site lacks suitable spawning habitat. There is a remote chance that a limited number of cutthroat trout could spawn in the ingress channels, where gravel exists. Trout could have a difficult time surviving in the ponds however, because of their preference for clean cool water. It is highly likely that an on-going stocking program would be necessary to maintain trout populations. Trout survival in the ponds could be hampered by unsuitable water quality conditions in the ponds. Water temperature profiles and dissolved oxygen concentrations should be sampled to determine if the ponds are suitable for trout survival. Late summer and early fall sampling would likely be the season of highest trout mortality, so water temperature profiles would be particularly helpful during this period. Water temperature tends to vary greatly by depth and in relation to thermal features such as groundwater seeps. Therefore, vertical profiles are recommended with exploratory sampling to detect thermal irregularities.

Another option for enhancing native fish species in the ponds is to expand the range of a native species like the red-side shiner and stickleback. This would require authorization from WDFW and it could take several introductions before these fish would become successful in the Earth Sanctuary ponds. Potential benefits to this approach include that state agencies may be more likely to permit the stocking of native fishes, but also small fishes like the shiner will provide forage for a wide range of species, including small birds and other animals. Introduction of small fish like shiners could also increase the success of both bass and bullhead in these ponds.

Species like largemouth bass, bullhead, carp (*Cyprinus carpio*), goldfish (*Carassius auratus*) and koi are tolerant of adverse water conditions and may become easily established in the Earth Sanctuary ponds. Introduction of these species is a lawful, permitable activity, although as mentioned previously, the introduction of these species will be carefully evaluated by WDFW.

The addition of these nonnative species to the Earth Sanctuary ponds would likely cause a decline in overall biodiversity on the property. Conspicuous, charismatic species, like birds and small mammals may increase in abundance after stocking, while aquatic vegetation, aquatic insects and zooplankton abundance would likely decline on the site, primarily through increased predation. Some fish like bass and trout may occasionally feed on young waterfowl, although it seems unlikely that pond fishes would seriously limit waterfowl production on the site. However, introduced fish can also carry diseases or parasites, and as such are generally not a desirable fish to introduce to Washington waters.

Typically, carp feed on algae, plants, zooplankton, midges, caddisflies, clams, animal fragments, and miscellaneous organic and inorganic matter. Carp rarely feed on fish, although they are suspected of competing for food with native fish (Wydoski and Whitney 1979). Goldfish and koi are closely related to carp, and will spawn on or near aquatic vegetation. Goldfish are most successfully established where a larger littoral zone with abundant vegetation occurs (Wydoski and Whitney 1979), whereas koi can spawn on mud substrates, as well as aquatic vegetation (Star Koi, pers. comm.). Both species should find suitable spawning areas in the Earth Sanctuary ponds. Another potential downfall of introducing koi to the Earth Sanctuary ponds is the high cost of stocking these fish, relative to other species. The price for large koi starts at about 25 dollars per fish (Star Koi, pers. comm.). Smaller koi and goldfish could be obtained from aquaria suppliers, although due to their small size significant losses from predation may occur shortly after introduction.

Regulations and Permits

Management activities that alter stream hydraulics, or involve stocking and transferring fish are regulated by the WDFW. Washington Administrative Code (WAC) addresses fish and wildlife management through: WAC 232.12.017, which defines deleterious exotic fish and wildlife; WAC 232.12.064 concerns taking from the wild, importation, possession, transfer, and holding in captivity live wildlife; and WAC 232.12.271 provides criteria for planting aquatic plants and releasing wildlife.

Alteration of the pond weirs and any other construction in or near the waters will likely trigger the need for a hydraulic project approval (HPA) from the regional WDFW habitat biologist. Adding fill to the shoreline of Pond One could also trigger the need for a permit under the Clean Water Act, which would be obtained from the U.S. Army Corps of Engineers. This requirement would be determined in part by whether the Earth Sanctuary ponds are considered Waters of the U.S. The need for federal permits or authorizations would in turn trigger a review under Section 7 of the Endangered Species Act. A biological evaluation of the project's proximity to suitable habitat for threatened and endangered species, and the potential effect on these species would satisfy this requirement.

Application for an HPA and Clean Water Act permit, if necessary, can be done together though the Joint Aquatic Resources Permit Application, which is found online at the WDFW website (http://www.wa.gov/wdfw). The permitting process can be lengthy, particularly if Corps approval and ESA approval by the National Marine Fisheries Service and US Fish and Wildlife Service are necessary. There is however, a streamlined process for projects that are meant to restore native habitats.

Fish stocking and transport of fishes to the Earth Sanctuary site requires a fish transport permit from the WDFW. An application for fish stocking can be obtained online at http://www.wa.gov/wdfw/fish/trnsport.htm. There is $24 application fee for this permit. Permits are approved according to the location of the stocking, and evaluation of screening requirements and source of fish.

Conclusion

It is difficult to provide clear recommendations for the site in terms of fish productivity due to some inherent conflict in some of the stated goals for the Earth Sanctuary property. Earlier communications regarding the project suggested that a primary goal was to restore a functional natural ecosystem, while more recently emphasis has been placed upon increasing fish biodiversity, particularly through the introduction of nonnative species, to enhance wildlife. Currently, the site has a functional but altered ecosystem that does rely upon engineered structures. Although reducing reliance on these structures might be conducive to a 500-year plan because it would reduce the need for maintenance, the owner could also make provisions in a long-term plan to ensure the structures receive care and maintenance overtime.

Of the three recommended alternatives reestablishing a more natural hydrological regime may be the most ambitious endeavor for the property, but over time this alternative has the potential to promote a more stable environment for native wildlife species, even waterfowl. Although restoring historic site conditions (e.g. restoration of ponds to ephemeral streams) would effectively remove most of the waterfowl habitat on-site, a smaller pond system (i.e., series of small ponds linked by an ephemeral stream [*see* Cederholm and Scarlett 1991) could be created reducing reliance on weirs. However, surface water area suitable for waterfowl would still be reduced under this option. Such a design would increase areas of flowing water, which in the ancient philosophy of Feng Shui, brings powerful energy, particularly if the waterway is shaped with numerous meander bends. However, koi too bring positive energy according to Feng Shui and is of great interest to the property owner (C. Pettis, pers. comm.). Like altering the existing hydrological conditions, introducing new species to the ponds will likely also have a profound effect on the local ecosystem. Too many fish can deplete dissolved oxygen levels, add an unhealthy amount of ammonia to the water from wastes, and adversely affect plants, frogs, salamanders, tadpoles and aquatic insects.

Any action taken on the site, whether to restore pre-disturbed hydrology, preserve existing processes, or stock new species should be viewed as an experiment replete with monitoring to evaluate the effects. A combination of the above general alternatives might be the most successful on the site for achieving enhanced biodiversity of aquatic life, not just fishes. Specifically, creating gentler slopes along the excavated shores of Pond One may improve the survival of bass that may already exist in the pond, while promoting increased carrying capacity for aquatic insects like dragonflies, and possibly waterfowl. A wildlife biologist should be consulted regarding the potential effect of this action on waterfowl. Lastly, before significant changes to ponds are designed or applications for fish stocking are submitted to WDFW it may be prudent to request a pre-application meeting on site with WDFW fisheries and habitat biologists. Such a meeting would provide an idea of the likely conditions of the permit, which are generally tailored specifically to the project.

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Appendix F. Plant List for Artwork Landscape, and Riparian and Forest Restoration Plantings

Trees	Common Name
Abies amabalis	Silver fir
Acer circinatum	Vine maple
Cornus nattalii	Pacific dogwood
Malus fusca	Western crabapple
Pseudotsuga menziesii	Douglas fir
Rhamnus purshiana	Cascara
Taxus brevifolia	Pacific yew
Thuja plicata	Western red cedar
Tsuga heterophylla	Western hemlock

Shrubs	Common Name
Amelanchier alnifolia	Serviceberry
Betula glandulosa	Bog birch
Cornus stolohifera	Red-osier dogwood
Corylus cornuta	Beaked hazelnut
Gaultheria shallon	Salal
Holodiscus discolor	Ocean-spray
Ledum groenlandicum	Labrador-tea
Lonicera involucrata	Black twinberry
Mahonia aquifolium	Mahonia
Mahonia nervosa	Oregon grape
Oemlaria cerasiformis	Indian plum
Pachistema myrsinites	Myrtle boxwood
Philadelphus lewisii	Mock orange
Physocarpus capitatus	Pacific ninebark
Rhododendron occidentale	Rhododendron
Ribes bracteosum	Stink currant
Ribes sanguineum	Blood currant
Rosa nutkana	Nutka rose
Rosa pisocarpa	Clustered wild rose
Rubus parviflorus	Thimbleberry
Symphoricarpus albus	Snowberry
Vaccinium ovatum	Evergreen blueberry
Vaccinium parvifolium	Red blueberry

Herbs	Common Name
Actaea rubra	Baneberry
Aruncus Sylvester	Goatsbeard
Carex obnupta	Slough sedge
Fleocharis sp.	Spike-rush
Juncus effusus	Common rush
Polysticum munitum	Swordfern
Scirpus acutus	Hardstem bulrush
Scirpus microcarpus	Small-fruited bulrush