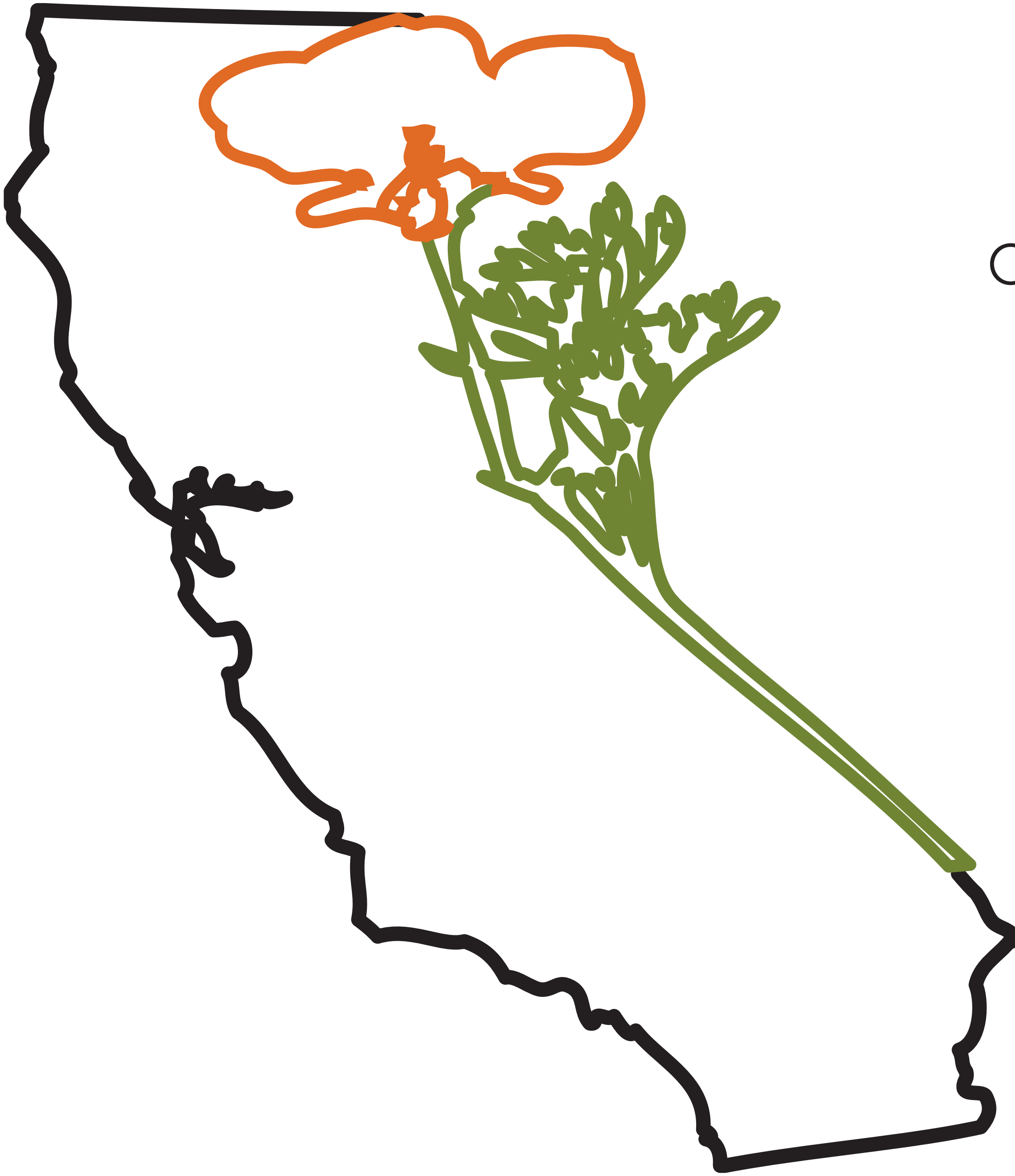

CAPIS

california plant information systems

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abstract

The landscape architect's plant selection process is complex, considering many factors from site and climate requirements to design and aesthetic qualities; but a comprehensive searchable listing of all such relevant information is not available, so the plant selection process is complicated by cross-referencing of many different sources. This is especially true for California native plants – where there is a growing trend to design with natives, there is not a comparable improvement in resources to make information about these plants accessible to landscape architects. This project analyzes the plant selection process, identifying goals of plant selection and how California natives meet these goals, and applying these goals to understand where existing resources fall short. This analysis is applied to create a new database entitled CAPIS: California Plant Information Systems, which is accessed through a dynamic website to improve accessibility of information about California native plants by landscape architects. CAPIS is intended as a tool to aid in plant selection, compiling relevant information into one resource; it facilitates the landscape architect's plant selection process and the use of California natives in the landscape.

dedication

For:

My parents and my sister, whose love and support are always there when I need it and even when I don't.

My friends, classmates, and peers, who told me to go for it, and whose company late at night kept me inspired and sane. My studio family.

And Anna.

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table of contents

list of images

preface

This project was conceived out of frustration. As a landscape architecture student, I have created plant palettes for many projects including design development projects and construction documents, but found myself unsure of the best way to go about doing so. Studies of horticulture and plant biology familiarize students with the range of plants available for use in the built landscape, but few resources are available to students to aid in the plant selection process. I became very familiar with what resources I did have access to, including botanical databases and horticultural plant lists, but a fair amount of cross-referencing and searching made it obvious that a more refined plant selection tool was needed. My own personal studies of plant biology, California floristics, and horticulture have taught me that the California flora is broad, diverse, and beautiful, but when the time came to put together a plant palette, the right plant never came to mind. A searchable database, full of information important to me as a landscape architecture student and future professional, would put all this information at my fingertips. Having taught myself basic web design during my preteen years, I felt comfortable building a simple website to serve as the platform for accessing the database, making the information accessible not only for myself but also for landscape architecture students, professionals, and anyone hoping to learn more about the plants of California.

-Brenna Castro

introduction

The CAPIS project, short for California Plant Information Systems, is a searchable online database of California native plants, intended for use by landscape architects and landscape architecture students to aid in plant selection. In order to meet the needs of this profession, the database is searchable by both site-specific and design-specific criteria. In addition to providing database access, the CAPIS website, www.california-plant.com, creates an information network by linking users to other databases, plant images, care information, and commercial availability. CAPIS is a tool for designers intended to aid in the plant selection process and encourage use of native plants in the landscape.

Goals

This project first necessitates a thorough understanding of the plant selection process, both to help understand how our current resources fall short, and also to help build a tool optimized for use by the landscape architect, providing as much information as possible without including unnecessary or unhelpful information. The project analyzes plant selection as a part of the landscape architect's design process and identifies a set of plant selection goals, then further analyzing how California native plants meet these goals. This analysis of plant selection goals is applied in a review of existing resources to identify gaps in the available databases and lists, categorizing these resources into several main groups by their primary use. This allows for a comparison of similarities and differences between the databases, and illustrates how the CAPIS project can serve to fill these gaps and draw on existing resources.

Having identified plant selection goals and where the current plant selection tools fall short, the CAPIS database was developed to respond to these needs. The database provides information about plant characteristics relevant to the landscape architect as well as images and links to plant listings on other websites. Next, to make the database publicly available, a dynamic website, www.california-plant.com, was built to serve as a simple access platform, allowing users to query the database, returning lists of plants and data for each listed entry. The website also links to other resources to build a network of information – the information system – that directs users to other websites pertaining to California native plants, including other databases, care and maintenance guides, and nursery availability listings. The project draws on a wide range of resources with the aim of making this information more easily accessible to landscape architects, students, and related professionals, improving the way we learn about California native plants.

Basic Definitions

California Native Plant: a plant that grew naturally in California before 1769, when the first foreign settlers began to introduce and naturalize new species into the California flora (Potter, 2011).

Database: a collection of related data, organized and classified in a structured format called metadata (Sheldon and Moes, 2005).

Dynamic website: a website that generates content in response to user inputs, which the user specifies using HTML forms to perform searches or other interactive activities (Ullman, 2012).

For a comprehensive lists of terms used in this report, see Appendix A: Glossary on page 47.

understanding plant selection

Planting design philosophy

Planting design is a two-part process, consisting of planting layout and plant selection. Planting layout, determining where on the site plants will be placed, uses plants as functional elements to create spaces for human use (Robinson, 2004). The landscape architect's mantra of "form follows function" describes the intentionality of this process – spaces are created to meet a certain need or design goal, and the specific forms chosen reflect that need. This can be described as the creation of an architectural framework for outdoor spaces – floors, walls, openings, hallways, and ceilings are created during the process of planting design and rely on plant form. The shape of the space under a tree canopy is one example of how plant form affects space, as is the ability of a shrub to screen views based on size and foliage density (Leszczynski, 1999). In this use, plants are "green building blocks" (Robinson 2004) that are regarded as more or less static, with less attention to the specific character of each plant and more to its most basic and general qualities – form and size.

Figure 1.1 The wide, low-ceilinged space under a Blue Oak (*Quercus douglasii*).

Plant selection goes hand-in-hand with planting design; plants must first satisfy functional needs of the design. Their basic form must occupy the correct spatial volume – they must be the right sized and shaped "green building block." The horticultural saying, "right plant, right place" means that plants must also be well suited to the site's ecology – a plant selection is successful only if it can thrive in its intended home. (Robinson, 2004). Careful selection of plants for the site can reduce intervention needed to keep plant thriving – irrigation, pesticides, fertilization, etc. (California Native Plant Society [CNPS], 2012). Garden designer Piet Oudolf notes that "a planting scheme will be much stronger if all possibilities are considered rather than just a few" (Oudolf 2005); whereas one plant may meet the minimal functional needs of the site – size, shape, and ability to survive – the goals of plant selection extend far beyond these bare bones requirements, and if the many varied goals of the designer are considered during plant selection, the result will be more interesting, dynamic, and successful. Oudolf recommends a strategy in which separate lists are made up of plants that suit different needs; for instance, a list could be drawn up of plants that will thrive under the given site ecology, those that meet the designer's aesthetic goals, and those that meet pragmatic goals such those that are attractive to pollinators. The overlap of these lists is the jumping-off point for the overall plant palette (Oudolf 2005). This process of drawing up and cross-referencing lists is analogous to searching a database for plants that meet all the desired criteria; however, before any such search or list can be made, the criteria in question must be better understood.

Goals of plant selection

Aesthetics

The landscape architect is interested in creating spaces that are not only functional but also beautiful, creating visual interest, dynamic user experience, and an intended mood, feel, or look to the site. Because of the wide range of plants' visual character, different combinations create different moods based on such aspects as visual continuity, interaction with light, harmony, and mysticism. Combinations of plants with like character create a harmonious feel, and combining plants with unlike character "generates a creative tension that keeps both the eye and the imagination interested"; a balance, then, between tension and harmony contributes to the overall mood of the site. Oudolf advocates for

Figure 1.2 Harmonious color scheme.

Figure 1.3 Complementary color scheme.

selecting plants based “firstly, for the shapes of their flower- and seedheads, then for their leaf shape and texture, and only then for colour” (Oudolf, 1999), these being the three most important parts of a plant’s appearance that contribute to its visual character. While Oudolf’s work in garden design is mostly with perennials (Oudolf, 1999) these characteristics can be applied to any plant, woody or herbaceous; however, since the vegetative body of woody plants persists and grows for many years, these plants develop an important vegetative structural character in addition to their floral structure. This includes characteristics such as foliage texture as well as canopy shape, fall color, bark color and texture, and branching structure (Robinson, 2004).

Some of these visual qualities are based on ephemeral traits – flower shape and color, fall color, foliage texture on deciduous plants – and some are more or less permanent – foliage texture on evergreen plants, bark color, canopy shape – but plants as living organisms undergo a constant change, and their visual character varies on an annual

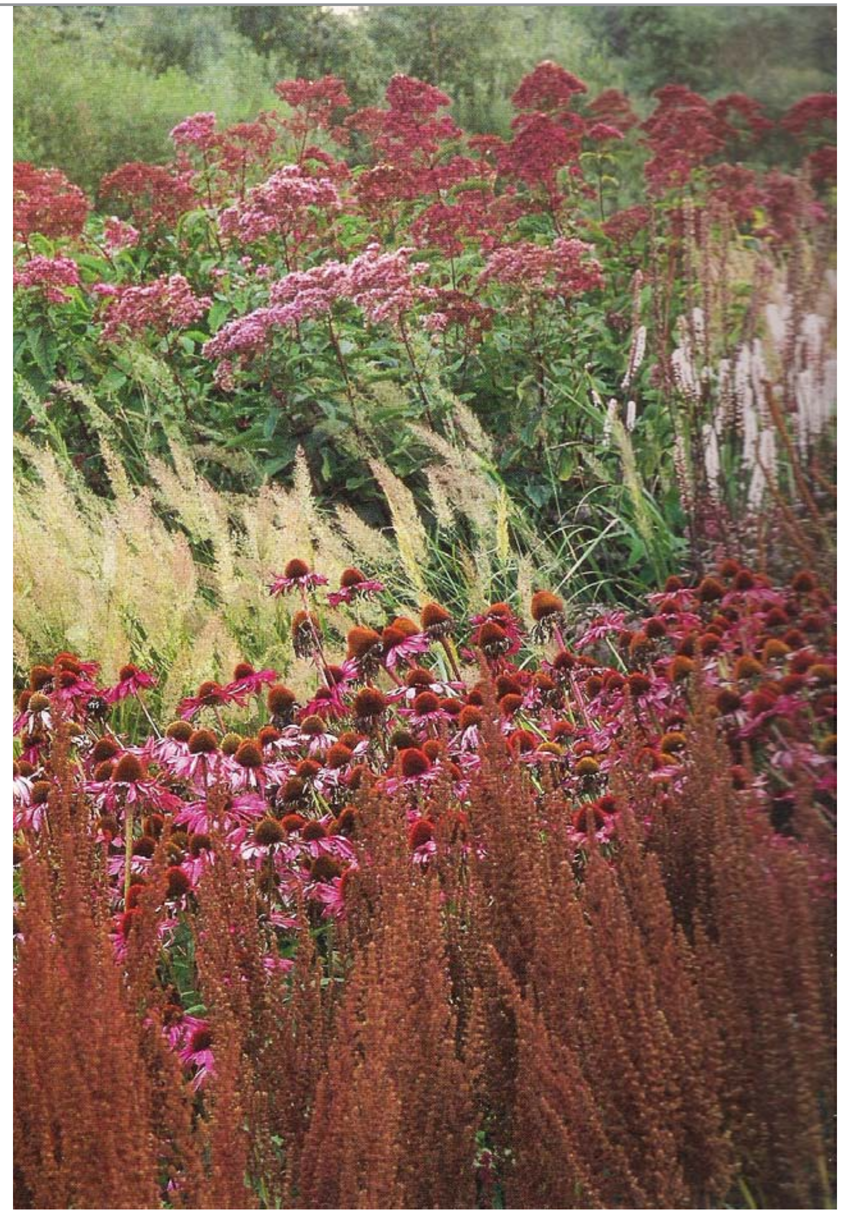


Figure 14 Combining forms - plumes, spires, umbels, and daisy-like flowers.

cycle (as in ephemeral traits) as well as a longer lifetime cycle of growth, maturity, and senescence. Understanding these cycles and how changes in visual character change the overall aesthetic of the site can help to produce designs that have year-round interest, and that furthermore produce a dynamic user experience with each visit as the site as a whole matures (Oudolf, 2005). Attractiveness to wildlife adds a further dynamic quality to the garden, enhancing the liveliness and interest of the built environment (Austin, 2002) and contributing to another important aspect of plant selection: ecology.

Ecology

According to Oudolf, the ecology of a planting design "refers to process, or how the planting actually functions" (Oudolf 2005). For a plant to serve its intended purpose in the landscape, it must thrive in its new environment; therefore, climate is an important consideration to ensure survival of the planting. Climatic considerations include temperature, rainfall, and exposure; site-specific conditions include soil and light (Austin 2002). Understanding the ecology of the planting site, including climate and site-specific conditions, is an important step in selecting plants that will require a minimal amount of human intervention; it can in this way reduce the amount of input, both in effort and in physical material, required to maintain a successful space. Landscapes that require less water, fertilizer, pesticide, and soil treatment interact positively with the environment as a whole, reducing the impact of that site on the larger ecology (Robinson, 2004). Interactions with a regional ecology can also happen as a result of interactions with local fauna, including insects, birds, small mammals, and other important wildlife species. Sites that are attractive to these species may serve as bridges between other nearby wildlands, enhancing the local environment (CNPS, 2012) as well as improving the function of the site and its aesthetic interest. Oudolf asserts that planting design is "very much concerned with ecology, both as a science and as an aesthetic ideal…gardening is based on a sympathy with nature and an understanding of natural processes" (Oudolf 2005). Selecting plants that interact positively with site and local ecology is an important goal in planting design and requires and understanding of abiotic and biotic interactions between plants and their environment.

Characteristics of Interest

In order to meet the aesthetic and ecological goals of plant selection, a designer must have access to information about a breadth of information about each species they consider. Below is a list of some of the most important characteristics for this process, along with an explanation of what some of the less self-explanatory qualities mean, or how they can be described. This list is not only important for understanding plant selection, but also informed the CAPIS project as a whole in determining important database search critieria.

- Habit: the most basic piece of information about a plant, which can be broken down into five main categories: Trees, shrubs, herbaceous plants (annuals and perennials), groundcovers and vines (Leszczynski, 1999; Oudolf, 2005).

Figure 1.5 Tree, *Quercus lobata.* Figure 1.6 Shrub, *Salvia clevelandii*. Figure 1.7 Herbaceous perennial, *Heuchera maxima*. Figure 1.8 Herbaceous annual, *Eschscholzia californica.* Figure 1.9 Groundcover, *Juniperus communis.* Figure 1.10 Vine, *Clematis pauciflora*.

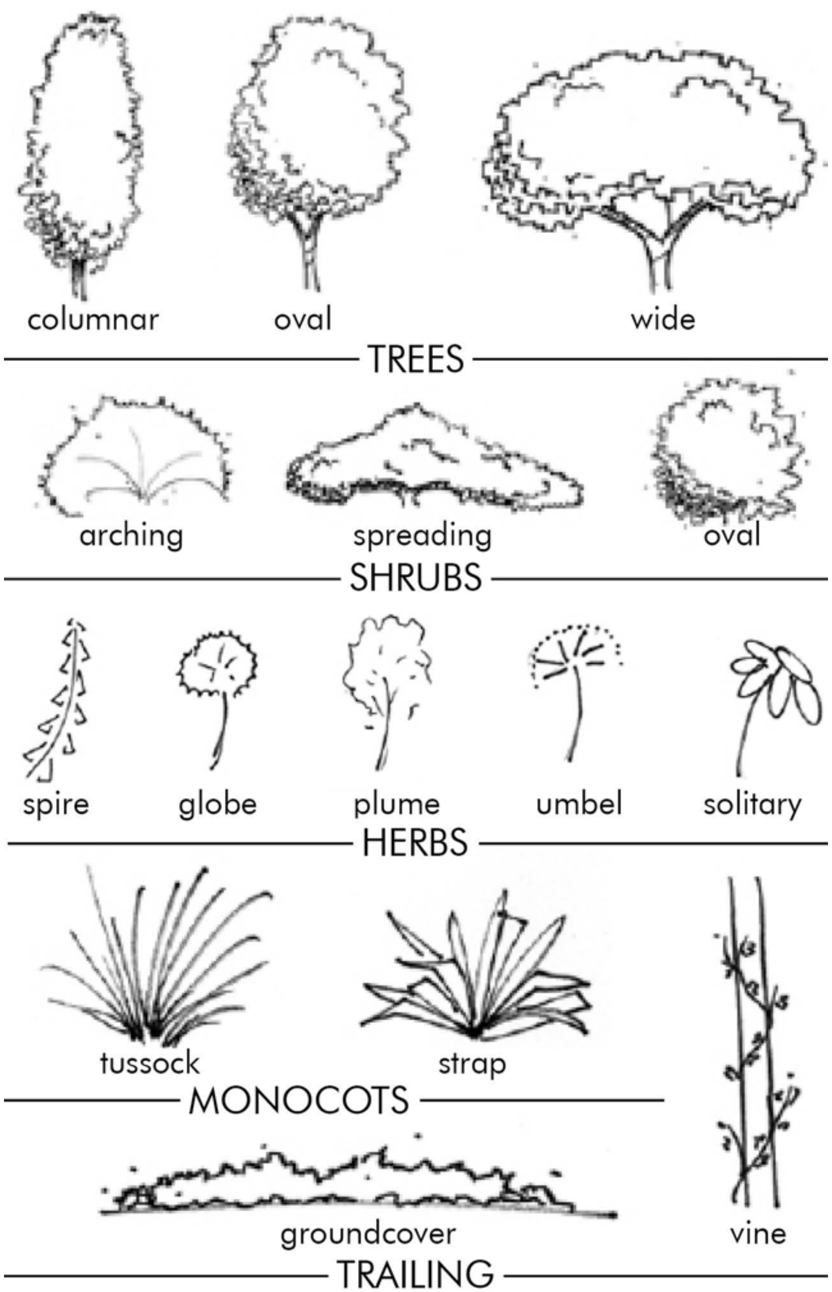


Figure 1.11 Plant forms.

- Form: a subdivision of habit, describing the overall shape a plant takes. For woody plants, this shape describes the canopy. Woody plant forms include columnar or cone-shaped trees, oval trees, wide trees, weeping trees, arching shrubs, spreading shrubs, dome-shaped shrubs, and ascending shrubs (Robinson, 2004). The form of herbaceous plants is mostly tied to the shape of flower- and seedheads, and includes spires, globes, plumes, umbels, and solitary flowers (Oudolf, 1999). Grasses and other herbaceous monocots that are grown more for their foliage than their flowers can be divided into tussocks and strap-leaved plants (Robinson, 2004). Groundcovers and vines may be either woody or herbaceous, but since groundcovers are generally prostrate and vines take the shape of their support structure, these two forms of plants are considered separately as their own forms (Leszczynski, 1999). See Illustration 1.11 (left) for images of these forms.

• Mature height and width: a plant's eventual space needs at maturity, or given at about 15 years of age.

• Foliage texture: general size or division of foliage, described by "coarseness or fineness, roughness or smoothness, heaviness or lightness, and thickness or thinness, which vary somewhat with the season of the year" (Austin, 2002).

• Foliage color: variations include gold, grey, blue, green, and occasionally red to purple.

Top to bottom: Figure 1.12 Fine texture, gold foliage, *Festuca californica.* Figure 1.13 Medium texture, grey foliage, *Salvia apiana.* Figure 1.14 Coarse texture, green foliage, *Umbellularia caifornica.*

Top row: Figure 1.15, *Epilobium canum.* Figure 1.16 *Eschscholzia californica.* Figure 1.17 *Parkinsonia florida.* Figure 1.18 *Rhamnus californica.*
Bottom Row: Figure 1.19 *Ceanothus* 'Concha'. Figure 1.20 *Iris douglasiana.* Figure 1.21 *Ribes malvaceum.* Figure 1.22 *Achillea millefolium.*

• Flower color: different color combinations produce different moods, as discussed above. Color intensity is an important consideration but is more difficult to categorize.

• Flower season: described either as month of peak bloom, range of months with flowers present, or season of bloom. Flower season may depend with altitude, latitude, and other climate considerations, so for the CAPIS project it is described generally as spring, summer, winter, or fall.

• Fruit prominence: edible and decorative fruits such as berries, drupes, pomes, and cones.

• Decorative bark: interesting texture or color qualities. Barks may be peeling, flaking, multi-colored, furrowed, papery, or plated. Only barks with striking visual character are described as “decorative,” usually involving special coloration or unusual texture.

Left to right: Figure 1.23 *Arbutus menziesii.* Figure 1.24 *Calocedrus decurrens.* Figure 1.25 *Platanus racemosa.*

• Special characters: these qualities may solve particular site problems, or provide needed functions. Examples include attractiveness to pollinators (Oudolf, 1999), scent (Robinson, 2004), or presence of spines (Austin, 2002).

• Climate requirements: USDA zone provides info on cold hardiness (USDA). Sunset zone considers more specific regional climatic factors such as average high and low temperatures, precipitation, wind, cold-air settling, etc (Sunset, 2012).

• Native range: Jepson bioregion describes regions based on topography and climate which have a certain flora. Knowing which bioregions a plant grows in naturally helps when planning a garden that will have minimal climatic or microclimatic intervention (Jepson, 2012). See Figure 1.26 for a map of Jepson Bioregions.

• Sun requirements

• Water requirements

• Soil requirements

• Stress tolerance: various environmental stresses can poorly impact plant performance, so knowing species that are tolerant of a given stress can greatly aid in planting success. Such stresses include clay soil, salt spray, drought, periodic flooding, serpentine soils, or air pollution (California Department of Water Resources [CADWR], 1979; Oudolf, 1999).

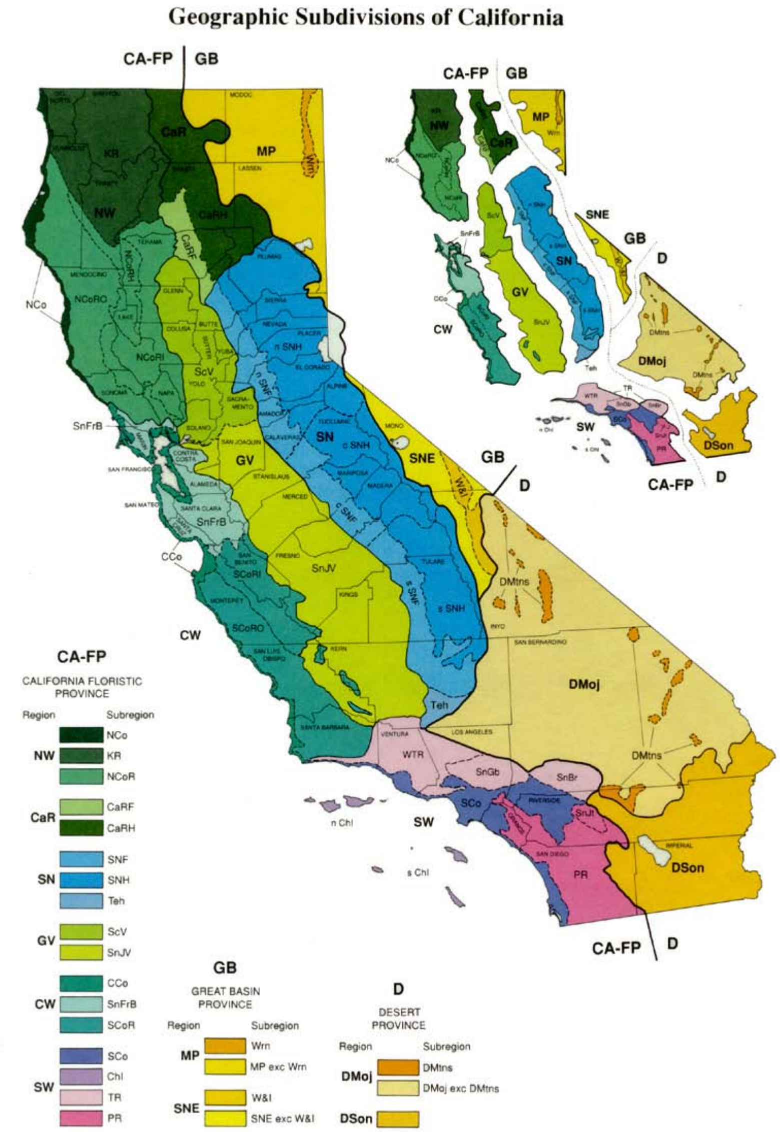


Figure 1.26 Jepson Bioregions in California.

How California natives meet plant selection goals

Aesthetic

Oudolf notes that native or wild plants, rather than those extensively bred and hybridized, lend a different character to the garden, and may allow for a wider variety of combinations. Compared to cultivated plants, wild or native plants have a smaller flower-to-foliage ratio, meaning that there is more neutral green to buffer strong colors. Wild or native plants also lack bred-for-impact bright colors, double blooms, and variegated foliage and therefore blend more smoothly into a varied plant palette (Oudolf 1999, 2005). They create a naturalistic planting theme, and lend themselves to planting designs that strive to emulate natural patterns. (Oudolf 2005). Because California is considered a “hotspot” of biodiversity, the number of California native species allows for a varied planting palette that can suit a number of different planting “moods” by using plants from the many ecological communities found in California’s diverse climate and geology (CNPS, 2012).

Site Ecology

Because native plants are already adapted to climatic conditions, they tend to be very good fits into a given set of site conditions. For instance, California's Mediterranean climate with hot dry summers is unlike much of the rest of the United States, but since California native plants are already adapted to this rainfall pattern, they require little to no summer irrigation. Furthermore, they are adapted to local soils and pests, meaning that less fertilizer and pesticide is required to ensure healthy and vigorous growth. A reduction in pesticide use has the added benefit of increasing attractiveness to beneficial insects such as pollinators, which would otherwise be killed or driven away by the same pesticides that would be required to eliminate pest problems. In addition to these beneficial insects, other wildlife such as birds, small mammals, and reptiles and amphibians have evolved alongside California native plants and can be an attractive asset to the site, with the site serving as a bridge between other local habitat areas (CNPS, 2012). The adaptations that allow plants to survive in the wild make them excellent candidates for a low-water, low-maintenance, wildlife-friendly planting design, but it is important to note that"…urban and many other environments are so unnatural that the best solutions for planting are often dictated not by what is 'native' but what grows best in an artificial setting" (Oudolf, 2005).

Local ecology

Some horticulturalists and others argue that restricting a plant palette to natives may not provide the desired visual impact, and may also fail to provide any benefit to wildlife and pollinators. They argue for a more pragmatic definition to native plants to include those that are naturalized, providing many of the same benefits as natives while greatly expanding the planting list (Oudolf 2005). However, because non-native horticultural species are specifically chosen to be vigorous and easy to grow with little maintenance, they have the potential to become invasive if they escape cultivation into wild settings; in fact, the horticulture trade is "the principal pathway for intentional introductions of invasive plants" (Burt et al. 2007). Due to this and other types of introduction of new species, 24% of the California flora is now non-native (DiTomaso 2011) with the majority of woody invasives having been introduced horticulturally (Truman Young, personal communication, May 18, 2012). Some invasive species, both woody and herbaceous, are considered transformer species – species which "change the character, condition, form or nature of a natural ecosystem over a substantial area" and thus pose significant ecological threat (DiTomaso 2011). Such species include Cape ivy (*Delairea odorata*), Scotch broom (*Cytisus scoparius*), and Purple loosestrife (*Lythrum salicaria*) (DiTomaso 2011), which is "associated with $45 million of damage per year in the US, including control costs and loss of forage" (Burt et al. 2007). It is clear that the choices landscape architects and other professionals make in plant selection can directly impact nearby wildland ecologies. Use of invasive non-native species should be undertaken with great care, particularly in settings where escape or introduction into wild populations is possible, such as parks, agricultural or rural design, or greenway design. Using California natives can preclude introduction of species which will disrupt nearby ecosystems.

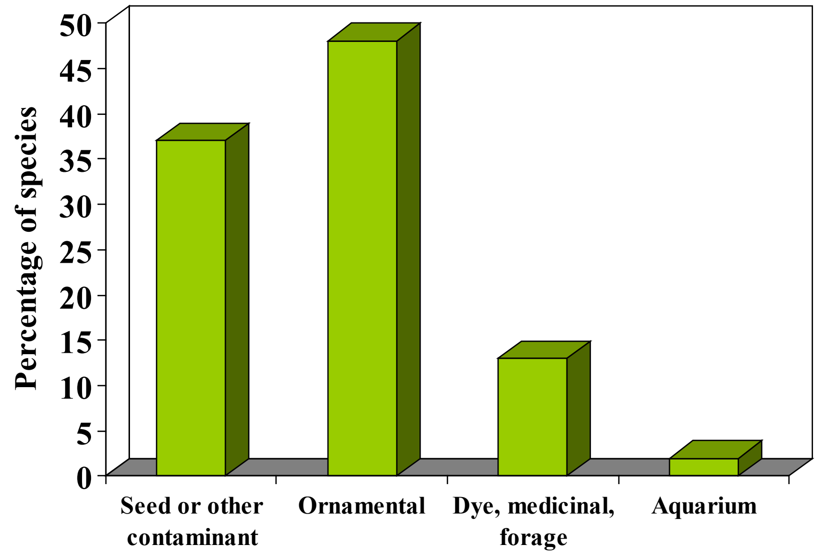


Figure 1.27 Route of introduction for California's invasive plants.


Figure 1.28 Purple loosestrife invading riparian wildlands.

review of existing resources

To solve the dilemma of plant selection, various searchable plant databases already exist for public use. Some of these databases are botanical in nature, providing information primarily about plant morphology and physiology that are of little use to the landscape architect, or otherwise focusing primarily on taxonomic relationships between California native plants (Biodiversity Sciences Technology Group at UC Berkeley [BSCIT], 2011; Calflora, 2009; Regents of the University of California [Regents], n.d.; United States Department of Agriculture [USDA], 2012). Another group is horticultural, listing general characteristics, as well as site requirements and cultural information (Theodore Payne Foundation [TPF], 2011; UC Davis Arboretum [UCD], n.d.; Sunset, 2012). Other databases are provided by wholesale or commercial nurseries, listing their product selection and allowing buyers to find suitable plants by site- or design-specific criteria. (Annie's Annuals, n.d.; Las Pilitas Nursery, 2012; Monrovia, 2012; Moosa Creek Nursery, 2010). Finally, printed plant lists, often in books or periodicals, typically list plants by form or by the region in which they grow, but are not searchable in the same way as the previously mentioned databases (California Department of Water Resouces [CADWR], 1979; California Native Plants Society [CNPS], 2012; Lenz, 1956). An analysis of these existing sources identifies similarities and differences, and also finds gaps in the existing database selection that the proposed project database will strive to fill.

Botanical databases

In general, botanical databases are of limited use to the landscape architect simply because they are intended for use by the scientific community rather than the design

Figure 2.1 Cal-Flora.
Figure 2.2 Jepson Online Interchange.
Figure 2.3 USDA PLANTS Database.

community, and thus have information mostly regarding taxonomy, ecology, and botanical characteristics (BSCIT, 2011; CalFlora, 2009; Regents, n.d.; USDA, 2012). For instance, the Jepson Interchange is searchable by name only, and provides taxonomic and botanical information (such as dichotomous keys and morphological descriptions) but links to other information sources such as the USDA PLANTS database and CalPhotos (Regents, n.d.). The botanical information listed for each plant is intended for use in field identification, and includes dichotomous keys and morphological characters such as floral organ fusion, phyllotaxy and leaf morphology, and other distinguishing characters far more minute than the typical non-botanist cares to decipher (Regents, n.d.).

Some botanical databases are more comprehensive in their advanced search, such as CalFlora, which is searchable by common or botanical name, family, native or nonnative status, distribution information by county, plant habit, or plant community (CalFlora, 2009). Like the Jepson Interchange, it provides botanical and ecological but not cultural or design-oriented information and is thus similarly limited in its use. Because it has limited search terms but a very comprehensive database of plants, a typical search provides a very long plant list. For instance, a search for native shrubs found in Yolo county generates a list of 117 species (CalFlora, 2009), a list too broad for a landscape architect to easily use, especially since not all species listed are found in cultivation.

The USDA PLANTS database is similarly problematic – it is not optimized for use by landscape architects. Plant information can be accessed by a name search, by state plant lists, or through an advanced search. However, the state plant list for California returns all plants that grow naturally in the state, an overwhelming 25,318 records, and while an advanced search may provide a much more satisfactorily brief plant list, there are 123 fields by which to search (USDA, 2012). Many of these fields are not directly useful to landscape architects, including 18 terms for taxonomy, 12 different legal status issues, and terms applying to other botanical fields such as the forestry terms "coppice potential," "planting density per acre," and "naval store product". And while some plants have an extensive listing with many of these fields of information filled, some, such as Arctostaphylos densiflora, have only bare bones taxonomic and ecological information (USDA, 2012).

The main benefit to using these botanical databases is the reliability of the information they contain. The Jepson Manual, for example, is considered the definitive resource for botanists on the

Botanical Databases

Pros
- Reliable information
- Links to images
- Ecological data

Cons
- Information too technical
- No design-related data
- Search by name only
  OR
  Search by ecology only
  OR
  Seach form too long

California flora (CNPS, 2012). The Jepson Manual and Interchange (online listing) are academic in nature, part of the UC Berkeley University and Jepson Herbaria (Regents, n.d.). CalPhotos is another project by UC Berkeley, and is scientific in nature, although for the purposes of this project it is used only as an image source (BSCIT, 2011). Similarly, CalFlora is another non-profit group, sharing the goals of educating the public about native plants and furthering conservation of native plants and their habitats (Calflora, 2009).

Horticultural databases

Horticultural databases differ from botanical databases mainly in the type of information they contain, focusing on site requirements like soil, water, and light needs, as well as general plant characteristics such as mature size, plant form, flower color, attractiveness to pollinators (Sunset, 2012; TPF, 2011; UCD, n.d.). This information meets many of the selection criteria required by landscape architects so these sources are invaluable in plant selection and are often used as a cross-reference along with other listings. However, these resources each pose their own set of restrictions and limitations which make them less than ideal. The California Natives Wiki provides a search by plant name, and is in this sense most useful for learning more about a known plant (TPF, 2011). The site also provides lists by several general criteria – plant type, water needs, and flower color – as well as by potential site problems – such as clay soils, high elevation, or the need to attract pollinators and wildlife (TPF, 2011). These lists, while useful, must be cross-referenced to determine plants that meet multiple criteria. Furthermore, this site does not list several critical criteria such as USDA or Sunset Zone, and is not searchable by all the criteria listed in the plant entries, such as size and

Figure 2.4 Theodore Payne Foundation California Natives Wiki growth habit (TPF, 2011). Despite these limitations, this site is an important resource in identifying plants which meet many of the selection criteria reliably listed here and in few other places.

Figure 2.5 UC Davis Arboretum All-Stars

The Arboretum All-Stars database is another good model, but has quite a distinct set of problems in terms of use by landscape architects. The plant selection in the database is fairly narrow, especially since the database contains only plants grown in the UC Davis Arboretum, and is narrowed further to include only "all-star" plants which are considered optimal for the Central Valley. As such, the database only considers that one region of California, and furthermore lists only 45 native plants out of 100 total species in the database. It is searchable by a combination of plant type, size (small, medium or large), and sun exposure, a somewhat limited search but appropriate for the size of the database overall (UCD, n.d.).

The Sunset Plant Finder is the online searchable version of well-respected Sunset Western Garden Book. It has a comprehensive advanced search including a combination of plant type – a rather broad and jumbled category – along with Sunset Climate Zone, water needs, light needs, height and spread, flower and foliage colors, and other "special" characters that include a variety of horticultural and site-specific problems. However, this guide, like the Western Garden

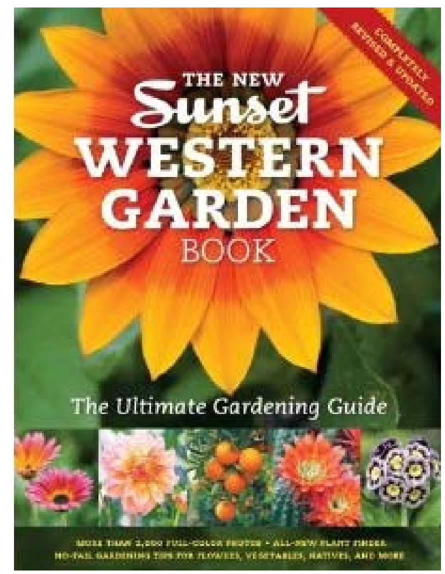


Figure 2.6 *The New Sunset Western Garden Book.*

Book, is written for the entire Western United States, so many plants are inappropriate for use in California and are furthermore non-native to this part of North America. The Plant Finder is geared more towards home gardeners than professionals, so it also has search parameters like “houseplants” and “plants for cut arrangements” and plant descriptions are in narrative rather than list form (Sunset, 2012), sometimes making information difficult to find.

Horticultural Databases

Pros
- Site-specific criteria
- Design-specific criteria
- Search by special use

Cons
- Not restricted to CA natives
- No comprehensive search

Commercial databases

For this project, commercial databases are defined as those created or sponsored by a nursery as a means of selling and distributing information about their wares. While the information provided is not backed by cited sources (Annie’s Annuals, n.d.; Las Pilitas Nursery, 2012; Monrovia, 2012; Moosa Creek Nursery, 2010), it is important that nurseries provide correct data, particularly cultural information, to ensure the success of their products when transplanted into their new sites. Several of these nursery databases have very comprehensive advanced searches including a wide variety of cultural and design-oriented criteria and are therefore very useful in the plant selection process (Monrovia, 2012; Moosa Creek Nursery, 2010), but since the plant list provided is limited by the stock of the nursery the results list may be

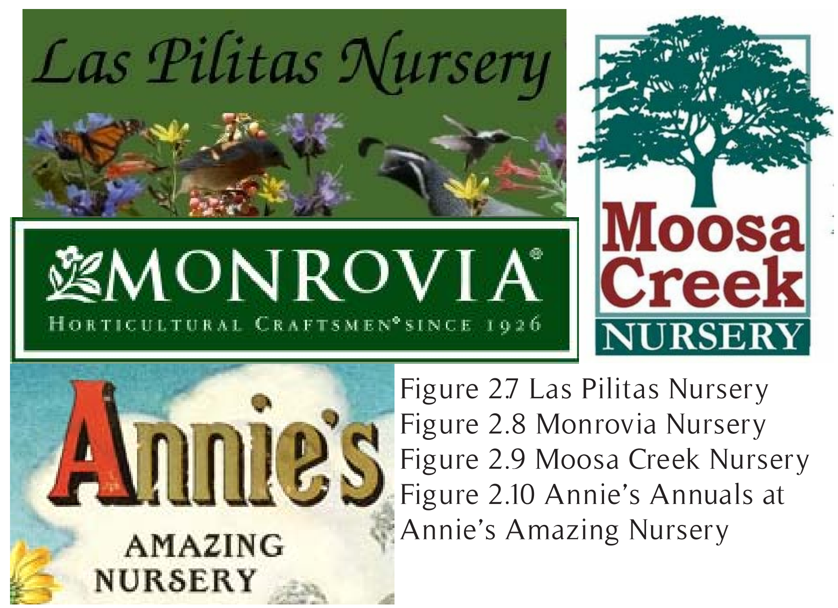


Figure 2.7 Las Pilitas Nursery
Figure 2.8 Monrovia Nursery
Figure 2.9 Moosa Creek Nursery
Figure 2.10 Annie’s Annuals at Annie’s Amazing Nursery

unsatisfactorily short, or may include cultivars not locally accessible to the landscape architect.

While some nurseries such as Moosa Creek Nursery and Las Pilitas Nursery specialize in California native plants, others such as Annie's Annuals and Monrovia sell a wide range of cultivated and hybridized garden plants and have no function to narrow results by California natives (Annie's Annuals, n.d.; Las Pilitas Nursery, 2012; Monrovia, 2012; Moosa Creek Nursery, 2010). Native plant nurseries are fairly widespread and many common natives can be found at conventional nurseries (CNPS, 2012), but since not all of these nurseries provide full search tools, finding locally available native plants may be difficult without the aid of a master database.

Commercial Databases

Pros
- Site-specific criteria
- Design-specific criteria
- Comprehensive search

Cons
- Not restricted to CA natives
- Limited by nursery stock

Print: plant lists and recommendations

Of the information sources available on plant selection, print sources are considered the most trustworthy. They are usually written and edited by an authority on the subject, and are to be held accountable for the quality of the information they contain. This reliability is essential when the success of a design rests at least partly on the health of the plants. However, print lists are not ideal for discovering new plants to suit a specific need, either because they list too many plants and are thus unwieldy to sift through, or because they list a smaller number of plants, but may not include plants for a certain site or design criterion. For instance, entries in Native Plants for California Gardens are organized by plant habit, and with 56 entries for "shrub," refining a list of plants for a certain need may be difficult (Lenz, 1956). Plants for California Landscapes is organized similarly, and presents much the same problem, but this booklet also provides several lists of "Plants for Special Purposes" such as salt-spray or air pollution-tolerant problems, which can greatly help in plant selection for problem sites (CADWR, 1979). Often, these print sources are best used to learn more about a known plant, such as appearance, care needs, ecology, or taxonomic data, rather than to discover new plants. CNPS, a well-respected authority on the conservation and promotion of California plants, comprised of botanists, restoration ecologists, horticulturalists, and plant enthusiasts, provides lists of native plants by region, as defined by the regional CNPS chapters (CNPS, 2012).

Print Lists

Pros
- Organized by plant type
- Reliable information
- Notes on appearance and use

Cons
- Not searchable
- Limited list

Despite the reliability of print resources, their inflexibility in use makes them a time-consuming way of compiling a plant list, requiring cross-referencing with other horticultural guides to find desired information.

methods

Data collection

Plant list

Because CAPIS is intended as a resource for landscape architects and related professionals, it is important that the plants included in the database are actually California natives, and that they are appropriate for use in the built environment. For the purposes of this project, a California native plant is defined as "a plant that grew naturally in California before 1769, when the first foreign settlers began to introduce and naturalize new species into the California flora" (Potter, 2011). This agrees with the Jepson Manual definition of a native plant, which is a plant"… occurring naturally in an area, as neither a direct nor indirect consequence of human activity; indigenous; not alien" (Regents, n.d.). Plants listed in the CAPIS database are verified as natives according to the Jepson Interchange. Naturalized species – species which are not native but have been introduced by human activity and have stable wild populations – are excluded from the CAPIS database at this time, but this is a possible area for expansion (See Discussion, p. 42). Also excluded are species which have been identified by the California Invasive Plant Council (Cal-IPC) or the Bay Area Early Detection Network (BAEDN) as invasive. As discussed above, invasive species are problematic to local ecosystems, and introduction for horticultural or landscape use should be avoided (CalFlora, 2012). Cal-IPC and BAEDN classification status is listed on the CalFlora website, which is used as the primary source for information on invasive status for this project.

In addition to being native, plants must be appropriate for use in the built environment. Primarily, this means that they must be available for purchase at wholesale or commercial nurseries. This is verified by ensuring that the plants are listed in at least one of the commercial databases listed above (See Review of Existing Resources, p. 22), beginning with Las Pilitas Nursery. Another baseline for usefulness in landscape architecture is inclusion in the Sunset Western Garden Book, which is an important horticultural reference for cultivated plants. Plants not listed as Las Pilitas nursery nor at any other nurseries or the Western Garden Book are excluded from the database because it is unlikely that, should a CAPIS user choose to install such a plant, it would easily be found for purchase. Since most nurseries sell young plants in pots, this also excludes those plants which are only sold as seed, such as non-bunching grasses and most ephemeral annuals, or those that are too difficult to propagate on a commercial scale. It also precludes addition of plants which are unacceptable in the built environment because they are difficult to cultivate, or require too much maintenance and are therefore poor sellers and have been eliminated from nursery stock. Landscape architects are faced with these limitations in all planting choices, so it is unlikely that these exclusions will cause an undue problem.

The CAPIS plant list is derived first from the UC Davis Arboretum All-Stars database using the "California Natives" search tool, for a total of 46 species. These species are selected by the UC Davis Arboretum as those which are easy to grow and have "outstanding qualities in the garden," having been tested and proven in the UC Davis Arboretum (UCD, n.d.). The second resource plant list is the book Plants for California Landscapes: A Catalog of Drought Tolerant Plants published in 1979 by the California Department of Water Resources and intended as a "tool for home landscapers, nurseries, government agencies, and landscape professionals who are interested in designing water-conserving, low maintenance landscapes" (CADWR, 1979). This book focuses on plans which are most likely to be commercially available and are therefore ideal for inclusion in the CAPIS database; however, not all plants in this book are native (CADWR, 1979), so native status is verified as discussed above. Additional species are found in print plant lists, such as Native Plants for California Gardens, Complete Garden Guide to the Native Shrubs of California, and Complete Garden Guide to the Native Perennials of California or selected from the CNPS regional plant lists (CNPS, 2012; Keator, 1990; Keator, 1994; Lenz, 1956). All species are verified to be California natives, noninvasive, and acceptable for landscape use. Any questions about plants in the database are addressed by committee member and UC Davis restoration ecology professor Truman Young.

Plant Data

In accordance with the previously discussed research on plant selection, a list of important site and design criteria is compiled according to those qualities most important to the landscape architect's plant selection process. This list has been refined with the help of committee member and UC Davis Environmental Design associate professor Steve Greco. The lists of data gathered for each plant in addition to basic taxonomic data (genus, species, common name, family) is as follows:

Site	Design	Links
USDA Zone	Habit	Main Photo
Sunset Zone	Width	2 Thumbnails
Jepson Bioregion	Height	Photo Enlargement
Sun	Form	Photo Authors
Water	Flower Color	Range Map
Soil	Flower Season	CalPhotos
Drought	Foliage Texture	Jepson Interchange
Flood	Foliage Color	California Native Plants Wiki
Clay	Deciduous	
Serpentine	Fall Color	
	Fruit Prominence	
	Growth Rate	
	Decorative Bark	
	Special	

Figure 3.1 CAPIS data fields.

Information for each plant in the plant lists is compiled from a variety of sources. Site and design criteria are compiled from the plant's Jepson Manual treatment (found at the Jepson Interchange), the Sunset Western Garden Book (online listing), the California Native Plants Wiki, and the Las Pilitas Nursery listing. The Jepson Manual treatment is used only for verifying native status and gathering information about native range, including Jepson Bioregion and Range Map (Regents, n.d.). Sunset Zone information is gathered from the Western Garden Book as the definitive source (Sunset, 2012). USDA Zone information is gathered from Las Pilitas Nursery, which has shown to be the most consistent source for USDA hardiness zone data, since the USDA PLANTS database may not list horticultural information for any given plant (Las Pilitas, 2012; USDA, 2012). Other cultural information is gathered collectively from the Western Garden Book online, the California Native Plants Wiki, and Las Pilitas Nursery, with the Sunset listing serving as the definitive source in the case of inconsistency of information between these databases.

Links and references are provided with each database listing to other sources of information, including photos, native range maps, and the above information sources and databases – the Jepson Interchange, the Sunset plant listing, and the California Native Plants Wiki page. Three photos are provided for each plant: one main photo, to be displayed at 360x270 pixels, and two thumbnail photos, to be displayed at 194x130 pixels. These photos aim to display the most important or visually striking characteristics of each plant – such as flowers, fruit, and foliage – along with it's general form and appearance. Photos are sourced primarily from CalPhotos, but in the case that no acceptable photo is available, images are used from the California Native Plants Wiki. All images are linked to their source page and credited with year and author name as is required by their host sites. CalPhotos permits use of thumbnail-sized images (194x130 pixels or smaller) without requesting author permission (BSCIT, 2011), but all large images are used with written consent from their authors, either stated on the photo page or gained by emailing the author. Plant availability information – where a user can purchase plants or seeds from nurseries – is provided by the California Native Plant Link Exchange. This database provides, on the entry page for each plant, a list of nurseries by area that sell the plant of interest, along with information on what form the plant is sold in – seeds, potted, or other (Malpas, 2011).

Building the Database

Software and coding: MySQL with SQL

The CAPIS system is a relational database – a system in which one or more tables of related data may be linked by unique identifiers that define the relationship between one table and those it is related to. The CAPIS system consists of only one table which stores basic information for each plant, called `plant_info`. This table identifies each unique database entry by it's scientific name – genus and species. This unique identifier can be used to build new tables that are linked to plant_info in a one-to-one relationship – each entry in the new table would have the same unique identifier, or primary key, as exactly one entry in `plant_info`. Relational database systems also allow for tables to be linked in many-to-one relationships; for instance, a separate table could match each genus to the plant family it belongs to – one family contains many genera, but each genus is only a member of one family. Information about the linkages between these tables is stored in the database as metadata, or data about the data

(Sheldon and Moes, 2005). Although the CAPIS project currently only consists of one table, the relational database system was chosen for the project for several reasons: first, because MySQL, the software used to manage the CAPIS system (discussed below), is easily integrated with web applications to create dynamic websites. Queries in MySQL can be complex, specifying many parameters for data return, an necessary function to allow users to select only plants that meet multiple selection criteria. Relational database systems also allow for greater flexibility in database design and limit redundant information, thus optimizing data storage (Sheldon and Moes, 2005). Tables can be joined, altered, separated, and relinked, and queries can be carried out over multiple tables in the database (Sheldon and Moes, 2005).

MySQL is a relational database management system (RDBMS) that is free for download and is easily integrated with web applications such as the CAPIS system. An RDBMS such as MySQL is a system which allows users to access and manipulate data and to store metadata, interacting with and managing their databases and the tables within them (Sheldon and Moes, 2005). Interactions with the database are carried out through the MySQL user interface (see Figure 3.3) using SQL or Structure Query Language, a database-specific coding language used to carry out commands like table creation, table linking and joining, data input and manipulation, and database queries (Sheldon and Moes, 2005). The MySQL program is used in this project to create the CAPIS database, create tables, add and manipulate data in tables, and manage connections between tables. MySQL databases can be uploaded to web hosting services and used to create dynamic websites (Ullman, 2012) such as CAPIS, allowing other users to retrieve information from the database through their web browser.

Data modeling

The data model for the CAPIS system is overall very simple, as discussed above, consisting of one table. This basic data model is possible because there is very little redundant information that could potentially be eliminated

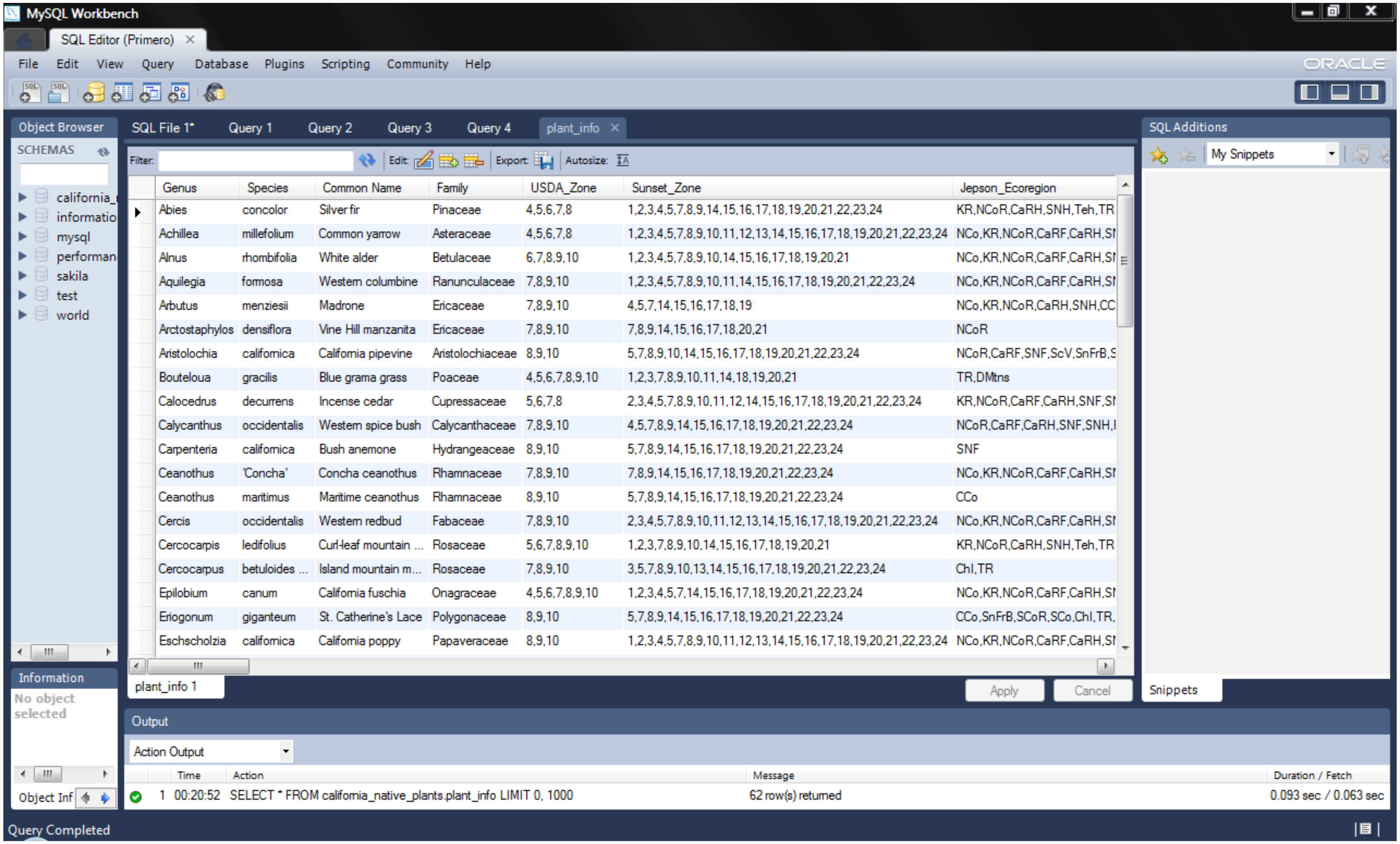


Figure 3.2 MySQL user interface for data entry and editing.

by creating additional tables; furthermore, the CAPIS database is very small compared to many MySQL data systems and therefore any data redundancy is of little concern. Advice on database structure is received from UC Davis Arboretum staff research associate Brian Morgan. The `plant_info` table contains all basic information about the each plant, as well as links to images and other information sources. In this tables, data is stored in the following way:

string Any combination of alphanumeric characters
Genus, Species, Common Name, Family, all other horticultural info, Photo and Link URLs

integer Any positive or negative number
Height, Width

enum One value from a list of possible values
Water Requirements, Habit, Form, Foliage Texture, Maintenance Needs

set Zero to many values from a list of possible values
Zone, Bioregion, Sun Requirements, Flower Color, Special Characteristics

Figure 3.3 CAPIS data types and descriptions.

The String data type is an all-purpose data type, allowing for each field to contain a unique piece of information about each plant, such as its common name (Sheldon and Moes, 2005). The Integer data type is only for numeric values, ideal for data such as height and width (Sheldon and Moes, 2005). Enum and Set data types are used when a field will contain one or more of a predefined set of values (Sheldon and Moes, 2005) – for instance, values for flower color can only be `red`, `orange`, `yellow`, `green`, `blue`, `purple`, `pink`, or `white` and values for Foliage Texture can only be `fine`, `medium`, and `coarse`. Enum is used when a plant can only have one characteristic from the list – its foliage is either `fine`, `medium`, or `coarse`, never a combination of those. The Set data type can store any number of values from the list, for instance, a plant may have `pink` and/or `white` flowers, so both values should be stored in the database.

Using Web Standards

The CAPIS site is `www.california-plant.com`, a website built specifically for the project. The site is built using current web standards, a set of recommendations from the World Wide Web Consortium (W3C) intended to improve website compatibility between web browsers, including older and newer versions as well as future versions still to be released (Zeldman, 2010). This reduces redundant code that is sometimes needed to ensure that a site renders properly in different browsers, and furthermore makes code easier to read, understand, edit, and troubleshoot (Zeldman, 2010). General information about web standards is found in Jeffery Zeldman's book Designing with Web Standards, and coding syntax is found in Brian P. Hogan's HTML5 and CSS3 or online at the W3C site www.w3schools.com. Assistance, advice, and troubleshooting help is provided by committee member and UC Davis web design professor Glenda Drew.

Coding Languages

An important part of adherence to web standards is using up-to-date coding languages to serve their appropriate functions. The languages used in building the CAPIS website are HTML5, CSS3, and PHP5. HTML, or hypertext markup language, is used to "mark up" website content to designate page structure, in other words, to describe the meaning of each element on the page (Zeldman, 2010). For instance, the page header, containing the website title and navigation bar, is designated by the `<header>` tag followed by the content of the header such as text and links and closed by the tag `</header>`, indicating that the next part of the website is no longer part of the page header.

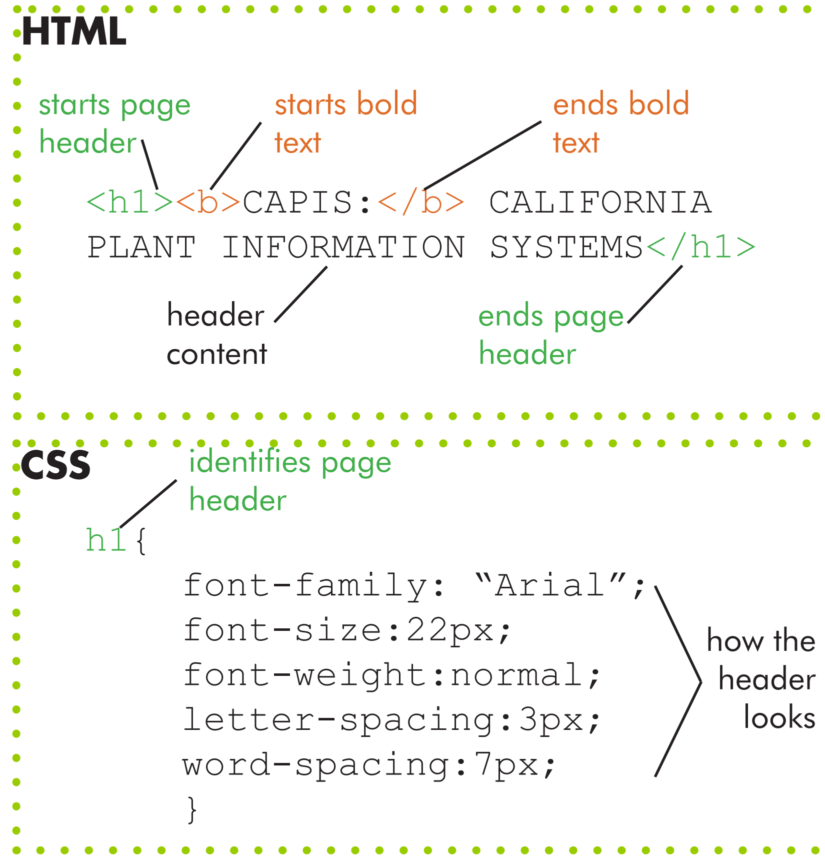
Coding Languages

HTML
- Define website content
- Identify similar elements
- Build page structure

CSS
- Change element appearance
- Build page layout
- Refers to HTML identification tags

PHP
- Connect and query database
- Translate between SQL and HTML
- Create dynamic content

Similarly, the Design Criteria section of the Plant Search page is designated by the `<section id="design_criteria">` tag, followed by the section's content and the `</section>` ending tag. These pieces of code identify each element on the page by its use, rather than specifying how it should be displayed on the page. CSS, or cascading style sheets, is the correct language to use when specifying how each of the elements defined in the site's HTML should be displayed, including information about font face, font size, text alignment, background color, image size, and positioning on the page (Zeldman, 2010). Whereas the HTML for each page is written as its own file, all pages reference the same CSS file, ensuring that all `<header>` elements on the site are displayed the same way.



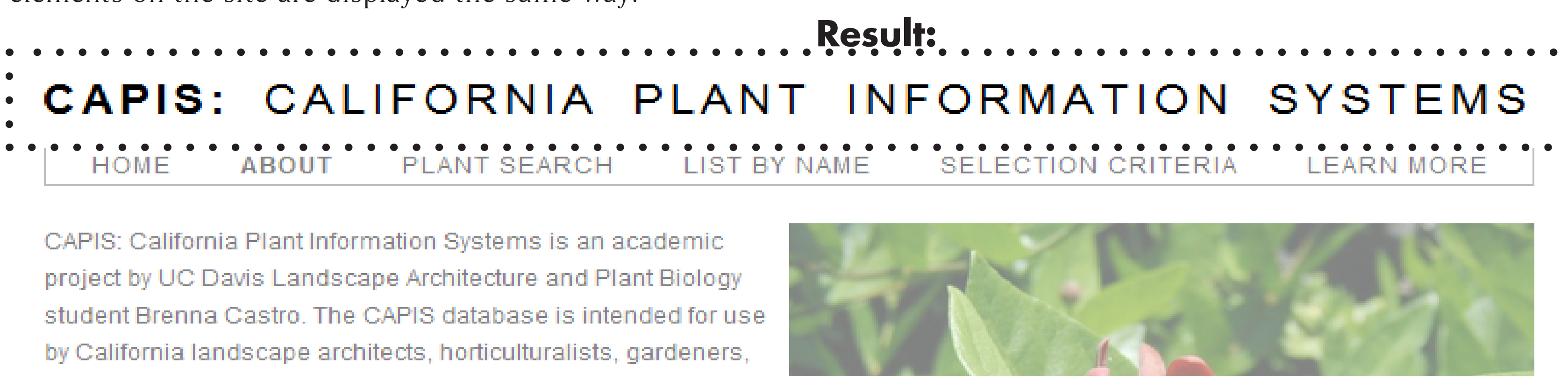


Figure 34 HTML and CSS code samples, showing the output as it appears on the CAPIS website.

The CAPIS system uses a dynamic website - a website with content that responds to user parameters, which the user specifies using HTML forms to perform searches or other interactive activities (Ullman, 2012). While some pages are static – they always look the same and carry the same information – other pages are dynamic – the information on them changes according to what information the site user has requested. For instance, when a user fills out the Plant Search page with their selection criteria and hits "Submit," the content of the Query Results page changes according to which criteria was selected on the plant search form. The form takes user input, selected from dropdown menus, checkboxes, and text inputs, and converts it into an SQL query used to gather information from the database. Then, the query results are displayed on the Query Results page and when the user clicks on the plant of interest, information for that plant is filled into the Plant Page template. The language PHP is used to connect to the database, translate form inputs into a query, and translate the query results back into HTML to be displayed by the web browser (Ullman, 2012). PHP is designed to integrate databases into websites, so it can be added to HTML pages simply by using the `<?php` opening tag, indicating that the following code is PHP not HTML, then the `?>` tag, indicating the end of the PHP code (Ullman, 2012). The integration of the MySQL database into the website allows for some pages to be designed as templates – the Plant

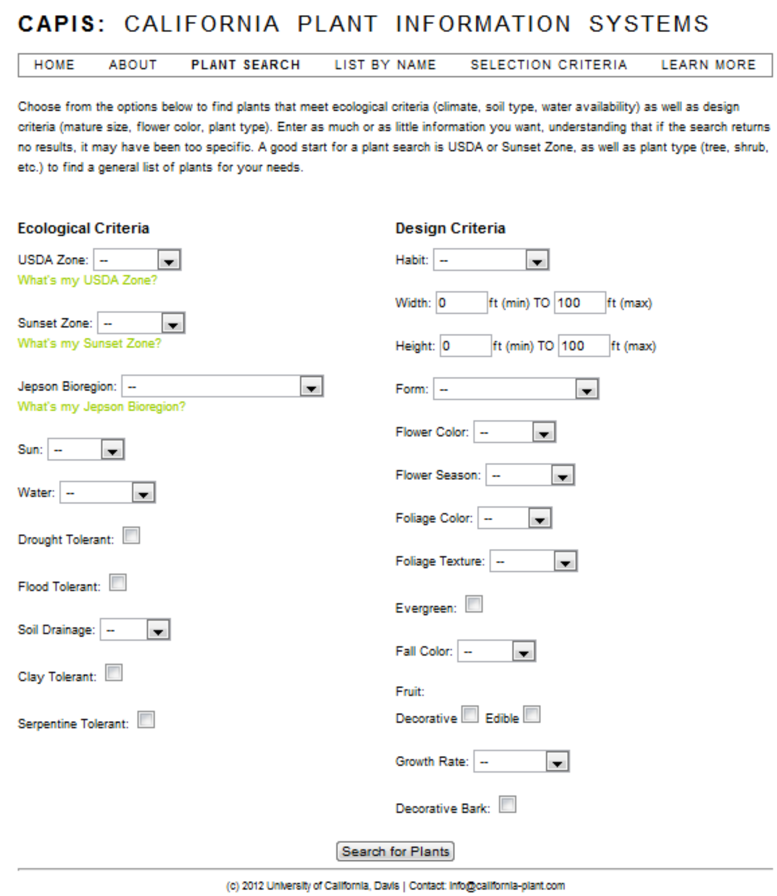


Figure 3.5 The CAPIS Plant Search page.

Page HTML template designates where images should go, what kind of text should be on the page, and the overall page structure, while PHP variables, much like the variable x in algebra, designate where information from database query results should be placed.

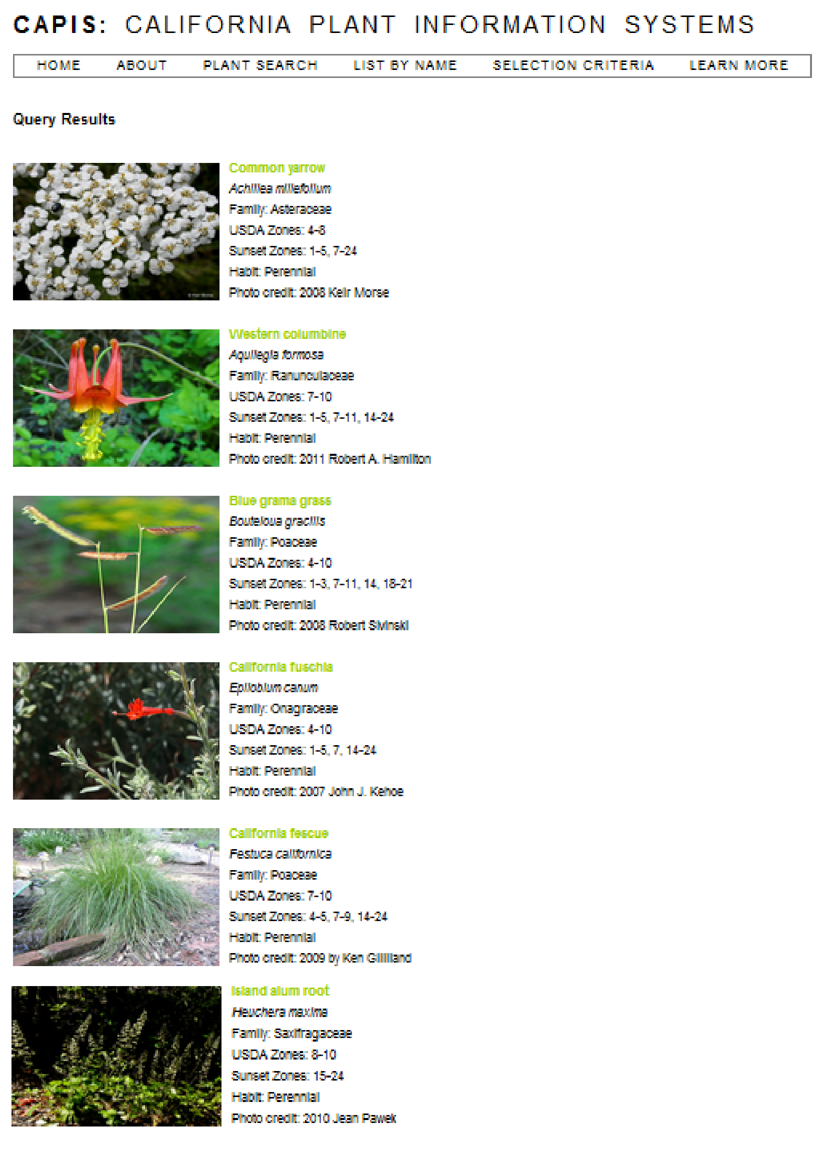


Figure 3.6 The Query Results Search page, showing sample results from a query for plants with a perennial herbaceous habit.

Parts of the Information System

The CAPIS website consists of just eight pages – four static pages that provide users with basic information, and four dynamic pages which allow users to interact with the database. Some of the dynamic pages are discussed above, including the Plant Search page (Figure 3.5), the Query Results page (Figure 3.6), and the Plant Page template (Figure 37). The Plant Search page allows users to choose as many or as few criteria as possible, customizing the search to suit thier needs. Another way users can access the database is by the List by Name page (Figure 3.8), which allows users to access the Plant Page for by clicking on a plant's name. The List by Name page displays the scientific and common names of the plants in the database organized alphabetically, but the user can choose List

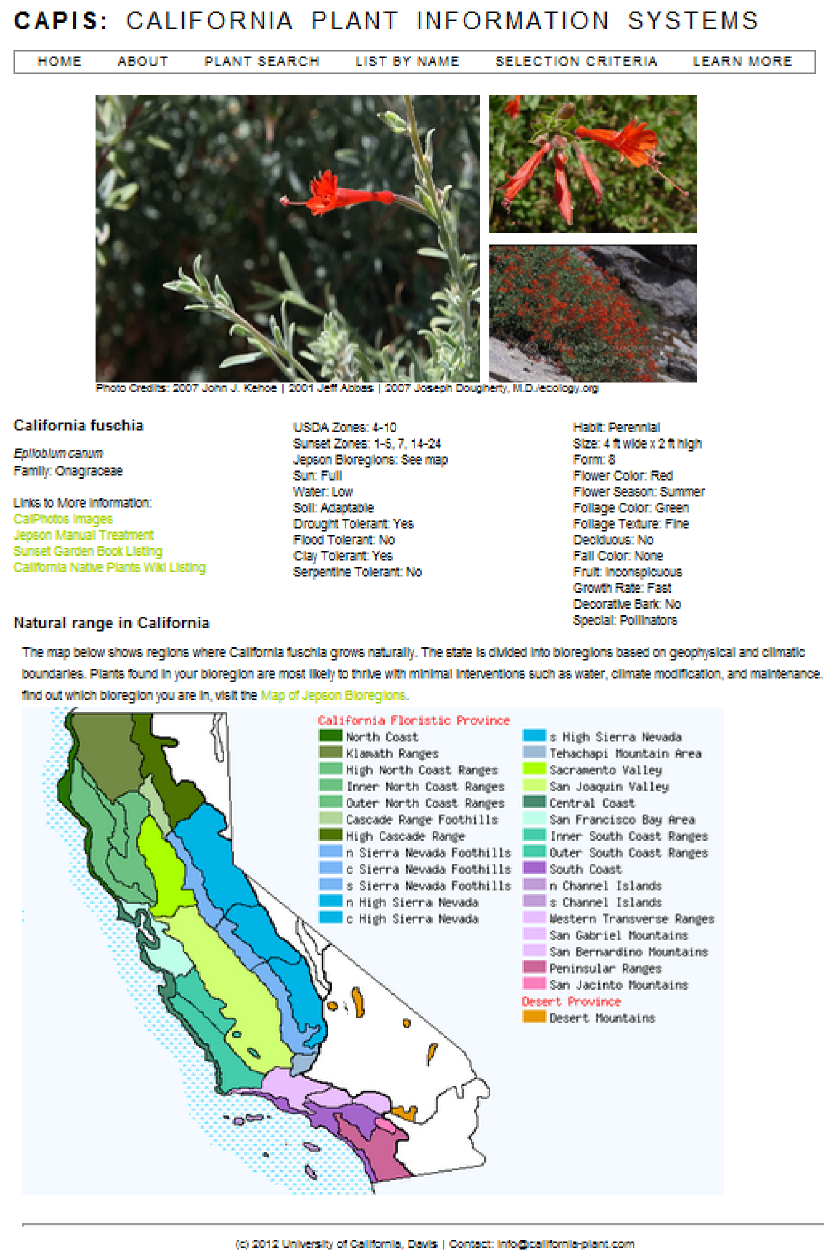


Figure 37 The Plant Page for California Fuchsia.

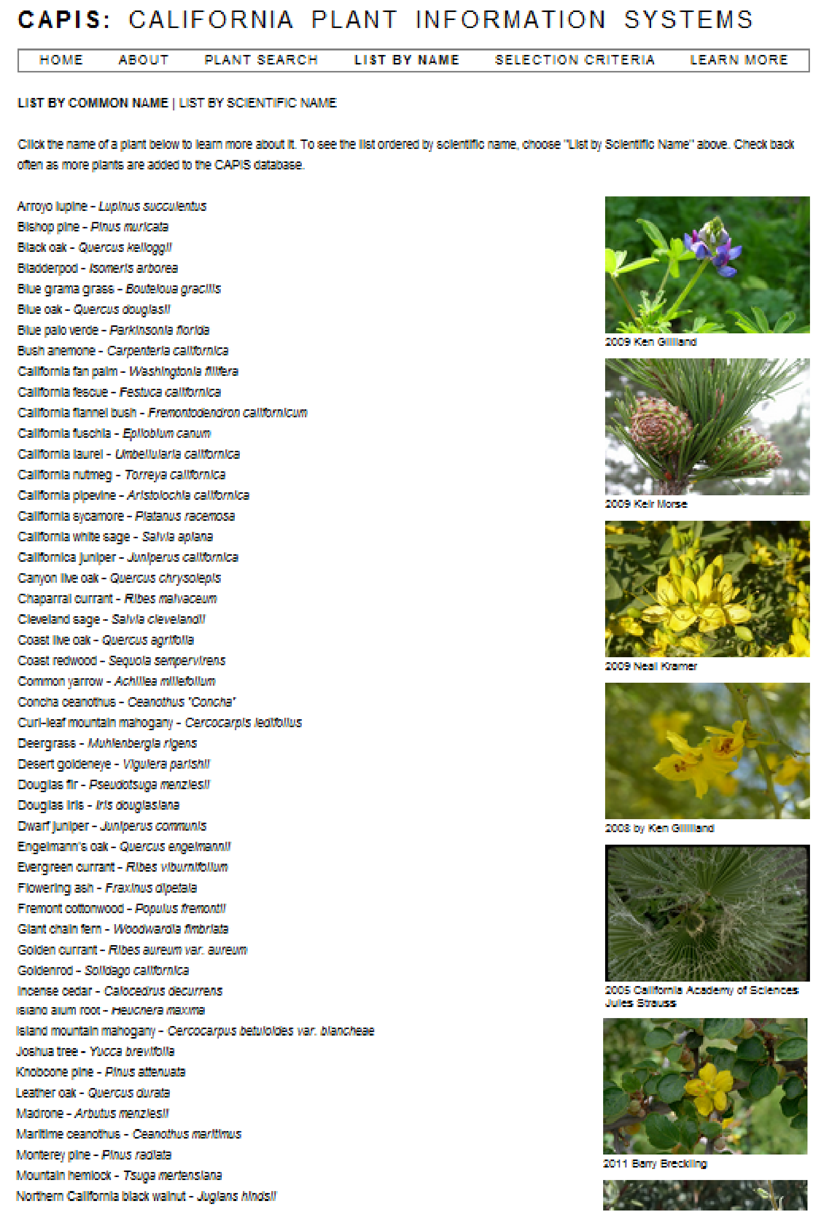


Figure 3.8 The List by Name page, sorted by common name. Users can also choose to sort by scientific name, resulting in a list reordere alphabetically by genus.

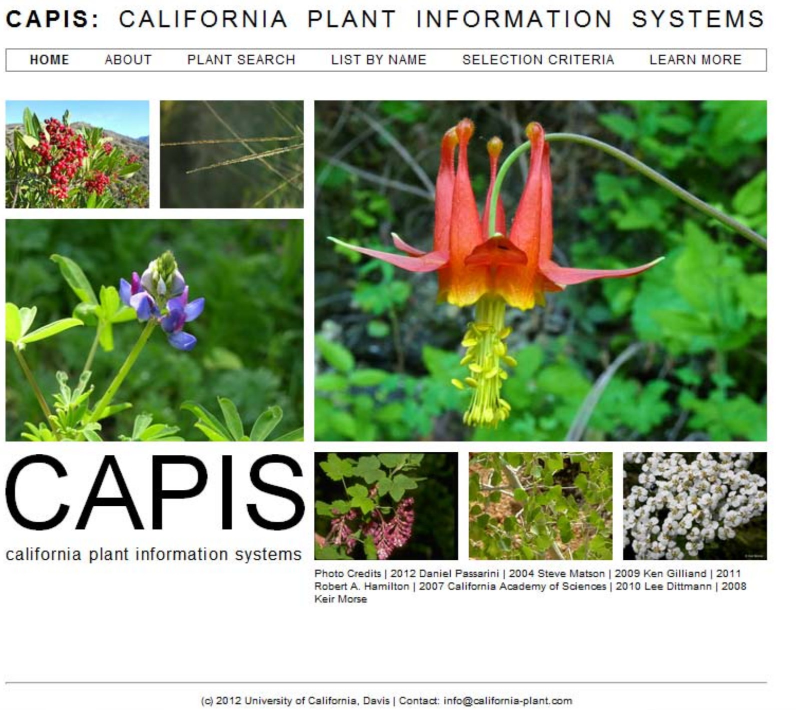


Figure 3.9 The CAPIS home page.

by Common Name or List by Scientific Name to see the plants listed in a different format. This page is generated dynamically by querying the database for the names of all plants and sorting the results in different ways.

Static pages on the CAPIS site provide information that allow users to interact better with the dynamic information system, and include the Home page, the About page, the Selection Criteria page, and the Learn More page. The About page describes the CAPIS project, explains the uses of the website, and provides a link to the project report. The Selection Criteria page describes the criteria used in the Plant Search tool, providing images and descriptions to explain what is meant, for example, by "foliage texture," "sun requirements," or "plant form." It also provides links to help users determine their USDA and Sunset Zones, their Jepson Bioregion, and soil types in their area. This page is intended to help users choose the right criteria for their needs so that they can find the right list of plants for their project. The final part of the information system is the Learn More page, which provides links to additional information about native plants, including links to other databases (organized by database type), image sites, care and maintenance guides, and information about plant availability. This integration of information sources is what defines CAPIS as an information system rather than just a plant search tool – it brings all the information that is already available into one place, helping users discover new resources and access other sites quickly.

discussion

Meeting Project Goals

During the process of this project, a number of important gaps in current database selection were identified according to the landscape architect's plant selection process, as noted above in "Understanding Plant Selection" (See p. 5) and "Review of Existing Resources" (See p. 17). There is, in general, a separation of aesthetics and ecology in most plant selection tools, with databases and plant searches focusing either on ecology and botany or on horticulture and garden performance. Many databases fail to integrate multiple search criteria or, on the other extreme, provide many criteria not particularly relevant to landscape architects, overwhelming users with an overabundance of search options. The CAPIS database addresses these issues by providing a comprehensive but streamlined plant search page, allowing users to select as many or few criteria as they choose, and further sorting these options into site criteria and design criteria to improve usability. Search criteria for a wide range of possible sites and projects are included, allowing users to search by flood tolerance, native range, and serpentine tolerance among other selections, accommodating the many specialized projects that landscape architects undertake.

Since the focus of the CAPIS website is on database access and ease of use, the website design is simple and functional, with content focused on helping visitors to use the database as efficiently as possible. There is minimal extraneous information and superfluous styling, keeping the site running quickly and maintaining its focus on the plants in the database. This simple design keeps the website flexible, allowing for future expansion and changes with minimal effort. All coding is written to meet web standards for compatibility and tested on multiple browsers and operating systems, ensuring that CAPIS is accessible to as many users as possible. Additional website content meets the project goal of creating a network of information about California native plants and their use in the landscape. The Learn More page, with its list of links sorted by use, directs visitors to other important resources and helps to establish credibility for the CAPIS project, since it does not stand alone but is integrated with well-respected California plant sites.

Meeting Personal Goals

Working on CAPIS as a senior project helped me to meet many of my personal goals for my last term at UC Davis. I was able to learn more about the California flora, building on what I have studied in my plant biology and horticulture classes and improving my own plant selection abilities. Even the simple task of building a database and entering plant data familiarized me with a huge number of California plants and alerted me to several non-natives, such as Santa Barbara daisy (*Erigeron karvinskianus*), that are not, in fact, native to the California flora. This additional knowledge about California plants will help me in my career as I build my own plant palettes, helping me to make informed and responsible decisions. My research into the plant selection process changed the way I think about plants in the landscape, helping me to see their many varied characteristics more clearly and understand how these qualities may be combined. I learned how different plants are part of a living system in a new built ecology which is connected to the greater environment.

The technical aspects of this project – creating and managing a database and building a dynamic website – allowed me to expand on existing skills and learn new ones. Studying and implementing web standards allowed me to bring my web design skills up to date with the current web climate, including new coding guidelines as well as the latest versions of HTML and CSS. One of the most significant challenges in this project was learning two new coding languages, PHP and SQL. A brief introduction to database management in learning ArcGIS served as a basis for learning much more in-depth information about building queries, linking tables, and ensuring data integrity. This new suite of skills, naturally well-suited to use together, can help me when I embark on future projects. Most importantly, learning these skills helped me to understand my own learning process, helping me identify when I have reached my own personal limitations, when to seek help from others, and what informational resources are available to me online and through personal connections.

In completing this project I was able to take full advantage of the resources UC Davis has to offer, including research material at a world-class library, connections to experts in my field of interest, and access to expertise necessary in completing my project. The process of defining a project, identifying goals and sources in conjunction with expert advice, and following through with the support of a committee of experts gave me essential experience in working with experts in a professional setting. The CAPIS project helped me grow as a student and an emerging professional, broadening my repertoire of skills and knowledge and exposing me to a new type of work environment in which my success or failure sits entirely on my own efforts. Successfully completing a project under these pressures gave me confidence to push forward in all my personal, academic, and professional endeavors.

Further Development

Much of the CAPIS project is still in prototype phase, with future opportunities for change, development, and follow-through. Below is a list of information that could be added to enhance the project even further:

- Expand plant list to include naturalized species: many naturalized species are appropriate for use in California and achieve the same plant selection goals as natives in that they are well-suited to thrive with minimal intervention, so they could be a useful addition to the database. An additional search parameter – whether to include natives only, naturalized species only, or both – would maintain the integrity of the native plant lists, while increasing flexibility and options for users who would like to use naturalized species as well.
- Name synonymy: the CAPIS database uses botanical names from the Jepson Manual Second Edition, and some plants have been moved between genera and families, or which have been recently identified as a species rather than subspecies (Regents, n.d.). However, other databases may use out-of-date plant names, or CAPIS users may be most familiar with a plant by a different scientific name. Furthermore, common names are notoriously imprecise, with most plants bearing multiple common names and some common names applying to multiple plants. Integrating synonyms for both scientific and common names would allow users to locate their plant of interest more easily.
- Include plant descriptions on the Plant Page: descriptions can include notes about plant character, appropriate usage, exceptions and unusual character, and other additional information that doesn't fit neatly into

other database fields. However, since this information is easily found on the Sunset plant page, which is linked to each entry, this feature is of low priority.

- Maintenance needs: plants that require little to no maintenance are of special interest to landscape architects hoping to create a design for public space that will fit within city maintenance budgets, and to homeowners with little time for yard care. Maintenance level is difficult to categorize depending on leaf and fruit drop, pruning needs, fertilization needs, pest problems, and growth rate, all of which are factors that depend heavily on the site in which the plant is used. For instance, a plant that is low maintenance in the sandy soils it is native to, having adapted with a slow growth rate to accommodate low soil fertility and quick water drainage, can grow out of control in clay soils which retain water and nutrients much more efficiently. Determining whether a plant is universally “low maintenance” is difficult, and a reliable source for maintenance information is not easily found (Stewart Winchester, personal communication, 16 May 2012). However, an additional step to this project could be to identify plants that generally require little maintenance, especially pruning and fruit or leaf drop.
- Additional specialty search criteria: widening the range of selection criteria can allow users to find plants for more specific needs. Examples include salt tolerance, root habit, flowering month, and plant life span. Adding such search criteria, however, can make the search form unwieldy to use or can overly narrow query result lists if not enough plants meet the criteria, so care must be taking in adding this feature to continue to streamline and optimize the database in terms of user interface and functionality.
- Invasive potential: species that are known to be invasive are excluded from the database, but some species, including natives, can be invasive if planted outside their native range, or are on the verge of becoming invasive. Access to this information can help database users avoid using plants that may be invasive in their project.

Project Significance

CAPIS fills the gap left by so many other databases and plant selection tools, being geared towards use by landscape architects and related professionals, first and foremost meeting the needs of this community. The plant selection process is ubiquitous, an essential part of every built project, and CAPIS is a tool that makes this process easier, promoting informed and responsible plant choice. It is a prototype for an essential resource in a growing field, the use of California native plants in the landscape. It is successful in its ease of use and access, compiling information from many respected sources and integrating flexibility depending on user needs.

While CAPIS is intended for use by landscape architects, it is available to the whole public, including students, horticulturalists, home gardeners, landscapers, and anyone who specifies plants in the built environment. By helping these users access information about California plants, CAPIS promotes use of natives in the landscape. California native plants help to build our local ecologies, contribute to the aesthetic vernacular of our region, and interact positively with the greater ecology, helping us to build more beautiful and functional California landscapes.

references

Annie's Annuals. (n.d.). Retrieved from http://www.anniesannuals.com/

Austin, Richard L. (2002). Elements of Planting Design. New York: John Wiley & Sons, Inc.,

Biodiversity Sciences Technology Group at UC Berkeley. (2011). CalPhotos. Retrieved from http://calphotos.berkeley.edu/

Burt, J.W., A.A. Muir, J. Piovia-Scott, K.E. Veblen, A.L. Chang, J.D. Grossman, and H.W. Weiskel. (2007). "Preventing horticultural introductions of invasive plants: potential efficacy of voluntary initiatives." Biological Invasions 9: 909-923.

California Department of Water Resources. (1979). Plants for California Landscapes: A catalog of drought tolerant plants (Bulletin 209). Sacramento, CA.

Las Pilitas Nursery. (2012). Retrieved from http://www.laspilitas.com/plants/plants.htm

California Native Plants Society. (2012). Retrieved from http://www.cnps.org/

CalFlora. (2009). Retrieved from http://www.calflora.org/

DiTomaso, Joe. (May 2011). "Invasive Species." California Floristics. UC Davis.

Hogan, Brian P. (2010). HTML5 and CSS3: Develop with tomorrow's standards today. USA: The Pragmatic Programmer.

Regents of the University of California. (n.d.). Jepson Interchange. Retrieved from http://ucjeps.berkeley.edu/ interchange/

Keator, Glenn. (1990). Complete Garden Guide to the Native Perennials of California. San Francisco, CA: Chronicle Books.

Keator, Glenn. (1994). Complete Garden Guide to the Native Shrubs of California. San Francisco, CA: Chronicle Books.

Lenz, Lee W. (1956). Native Plants for California Gardens. Pasadena, CA: Abbey Garden Press.

Leszczynski, Nancy A. (1999). Planting the Landscape. New York: John Wiley & Sons, Inc.

Maplas, John. (2011). California Native Plant Link Exchange. Retrieved from www.cnplx.info/

Monrovia Plant Catalog. (n.d.). Retrieved from http://www.monrovia.com/plant-catalog/

"Native plants of California database search." (n.d.). Moosa Creek Nursery. Retrieved from http://www.moosacreeknursery.com/native-plant-database-search/

Oudolf, Piet. (1999). Designing with Plants. Portland: Timber Press.

Oudolf, Piet. (2005). Gardens in Time and Space. Portland: Timber Press.

Potter, Daniel (April 2011). "Introduction and Morphology." California Floristics. UC Davis.

Robinson, Nick. (2004). The Planting Design Handbook. Burlington, VT: Ashgate.

Sheldon, Robert and Moes, Geoff. (2005). Beginning MySQL. Indianapolis, IN: Wiley.

Sunset. (2012). "Western Garden Ideas." Sunset. Retrieved from http://www.sunset.com/garden/

Theodore Payne Foundation. (2011). "California Native Plant Library." California Natives Wiki. Retrieved from http://theodorepayne.org/mediawiki/index.php?title=California_Native_Plant_Library

UC Davis Arboretum. (n.d.). "All-Stars Plant Search." UC Davis Arboretum: Arboretum All-Stars. Retrieved from http://arboretum.ucdavis.edu/plant_search.aspx

Ullman, Larry. (2012). PHP and MySQL for Dynamic Web Sites. Berkeley, CA: Peachpit Press.

United States Department of Agriculture. (2012). The PLANTS Database. <plants.usdsa.gov/>

Zeldman, Jeffrey. (2010). Designing with Web Standards. Berkeley, CA: Pearson Education.

appendix A: glossary

- California Native Plant: a plant that grew naturally in California before 1769, when the first foreign settlers began to introduce and naturalize new species into the California flora (Potter, 2011).

- Database: a collection of related data, organized and classified in a structured format called metadata (Sheldon and Moes, 2005).

- Dynamic website: a website that generates content in response to user inputs, which the user specifies using HTML forms to perform searches or other interactive activities (Ullman, 2012).

- Form (HTML): an online user interface that uses text fields, drop-down menus, radio buttons, checkboxes, etc. to collect user data. Examples include advanced search tools or username-password inputs (Hogan, 2010).

- MySQL: a relational database management system (RDBMS) allowing users to access and manipulate data and to store metadata (Sheldon and Moes, 2005).

- PHP: a scripting language used to relay commands between a web application and a MySQL database, allowing users to interact with the database (Ullman, 2012).

- Relational database: a database composed of multiple tables of related data, linked by unique identifiers that define the relationship between one table and those it is related to (Sheldon and Moes, 2005).

- Semantic markup: code that designates page structure, describing the meaning of each element on the page (Zeldman, 2010).

- Style sheet: a CSS document that defines presentational markup - how page elements are displayed in the browser. It references their HTML identifiers and specifies appearance properties such as fonts, colors, sizes, and positions (Zeldman, 2010).

- SQL: Structured Query Language, a computer language used to manage and interact with data in a relational database (Sheldon and Moes, 2005).

appendix B:
plant list