which annually allocates significant funding to research and fish recovery projects.

### Research needs, long-term solutions

To inform future decision-making, Carlson identified several critical research needs for the Klamath Basin. First, better information is needed about the region's fish and their recovery. Regulators have focused on lake levels and river flows because they are manageable, but these "may not be the most important factors," Carlson says.

Second, better information is needed on the entire Klamath Basin ecosystem so that decisions can be made on a broader basis than what is good for single species. "Water being sent downstream for the salmon was being taken away from bald eagles," Carlson notes.

Third, more research should focus on restoration ecology of entire watersheds: "What happened here is an example of how badly we need that information," Carlson says.

Fourth, Carlson says interagency cooperation and coordination must be improved. In the Klamath Basin, as many as 30 federal, state, tribal and local public agencies have been working "almost at cross-purposes."

According to fish expert Moyle, one of the most important research needs is a standardized annual monitoring program for fish and water quality. "The data is so fragmented right now," he says.

The Klamath Basin situation is so complex and contentious that Moyle also recommends a comprehensive effort along the lines of CALFED, the federal-state interagency consortium that has been working since 1995 to resolve water-use conflicts in the San Francisco Bay-San Joaquin Delta region. In March 2002, President Bush appointed the Klamath River Basin Federal Working Group, which includes the secretaries of Agriculture, Commerce and Interior.

Proposed solutions to the Klamath Basin's water conundrum include a federal buyout of farmland from willing sellers, the promotion of irrigation improvements and less water-intensive crops, federal assistance to diversify the regional economy and the establishment of water banks. Environmental organizations are calling for a comprehensive wetlands and habitat restoration plan on the scale of the current effort to save the Florida Everglades.

Carlson believes that stakeholders in the region are moving toward a more coordinated response. "The crisis was a wakeup call that this is serious and decisions have wide-ranging impacts," he says. "The stakeholders are determined to develop more of a planned response so future water shortages don't come as such a drastic shock."

*— Janet Byron*

# *Salt tolerance of landscape species evaluated*

In recent decades, signs touting the use of reclaimed or recycled water have popped up in many urban settings where landscape plants are watered, such as highways, parks and golf courses. Yet surprisingly, landscape management professionals "don't have much guidance on how safe recycled water is for the plants," says Lin Wu, UC Davis environmental horticulture professor.

The first wastewater treatment plant used solely for recycling water was built in San Francisco in 1932. Today, wastewater is recycled at more than 300 locations throughout California for agricultural and landscape irrigation, groundwater recharge and industrial uses. The California Water Resources Control Board estimates that by 2010, landscape irrigation will be the second largest use of reclaimed water, next to groundwater recharge.

Davis Krauter

**Reclaimed water is increasingly used to water landscaping in golf courses, public highways and parks.**

After most water treatment processes, Wu says, salt (NaCl) is the only remaining constituent that is potentially detrimental to landscape plants. During the mid-1990s, several cities and counties approached the UC Davis environmental horticulture department to request field evaluations of the salt tolerance of landscape plants.

In 1997, Wu, postgraduate researcher Xun Guo and Alameda County horticulture advisor Ali Harivandi initiated a series of studies. They grew common California landscape species in the field, containers and greenhouses; the plants were irrigated with water containing salt levels slightly above those found in most reclaimed waters, applied both by drip and sprinkler irrigation systems. The Elvenia J. Slosson Endowment Fund, Marin Municipal Water District and the city of San Jose supported the research program.

The properties of actual reclaimed water were provided by Marin Municipal Water District and South Bay Water Recycling of San Jose: average "real world" sodium concentrations range from about 160 milligrams per liter (mg/L) to 230 mg/L, and chloride ranges from 170 mg/L to 320 mg/L.

**Species that were less tolerant to salty reclaimed water included liquidambar, *left*, and native California rose, *right*.**

**Salt tolerance of landscape plant species grown under sprinkler irrigation**

**Salt tolerance ratios:**
**Low = < 50% growth**
**Moderate = 50% to 90% growth**
**High = > 90% growth**

| Plant species | 1,500 mg/L salt | 500 mg/L salt |
|---|---|---|
| *Abelia grandiflora* 'Edward Goucher' | Low | Low |
| *Acacia redolens* (redolen acacia) | High | High |
| *Albizia julibrissin* (silk tree) | Low | Moderate |
| *Arbutus unedo* (strawberry tree) | Moderate | High |
| *Buddleia davidii* (butterfly bush) | Low | Low |
| *Buxus japonica* (Japanese boxwood) | High | High |
| *Ceanothus thrysiforus* (ceanothus) | Moderate | High |
| *Cedrus deodara* (deodar cedar) | High | High |
| *Celtis sinensis* (Chinese hackberry) | Low | Low |
| *Clytostoma callistegioides* (trumpet vine) | Low | Low |
| *Cornus mas* (Cornelian cherry) | Low | Low |
| *Cotoneaster microphyllus* 'Rockspray' | Low | Moderate |
| *Escallonia rubra* (escallonia) | Moderate | High |
| *Euryops pectinatus* (golden Marguerite) | Low | Low |
| *Forsythia intermedia* (forsythia) | Moderate | High |
| *Fraxinus angustifolia* (raywood ash) | Low | Moderate |
| *Ginkgo biloba* (ginkgo) | Low | Low |
| *Jasminum polyanthum* (jasmine) | Moderate | High |
| *Juniperus virginiana* 'Skyrocket' (juniper) | High | High |
| *Koelreuteria paniculata* (goldenrain tree) | Low | Moderate |
| *Lantana camara* (lantana) | Moderate | High |
| *Liquidambar styraciflua* (liquidambar) | Low | Low |
| *Mahonia pinnata* (California holly grape) | Low | Moderate |
| *Myrtus communis* (true myrtle) | Moderate | High |
| *Nandina domestica* (heavenly bamboo) | Low | Moderate |
| *Nerium oleander* (oleander) | High | High |
| *Olea europea 'Montra'* (dwarf olive) | High | High |
| *Pinus cembroides* (Mexican piñon pine) | High | High |
| *Pistacia chinesis* (Chinese pistache) | Low | Low |
| *Pittosporum tobria* (tobira pittosporum) | High | High |
| *Plumbago auriculata* (cape plumbago) | High | High |
| *Prunus caroliniana* (Carolina laurel cherry) | Low | High |
| *Quercus agrifolia* (coast live oak) | Moderate | High |
| *Rhaphiolepis indica* (indian hawthorn) | High | High |
| *Rosa* sp. (rose) | Low | Low |
| *Sambucus nigra* (elderberry) | Low | Moderate |
| *Sapium sebiferum* (Chinese tallow tree) | High | High |
| *Washingtonia filifera* (California fan palm) | High | High |

Three salt levels were used in the studies: control (potable water containing about 80 mg/L sodium and 40 mg/L choride), low salt (500 mg/L salt) and high salt (1,500 mg/L). Plants were irrigated every third day with 1 inch of water.

For a nondestructive evaluation of salt stress responses, plant heights and canopy diameters were measured at the beginning and after 6 weeks of salt treatments. Visual symptoms such as chlorosis and leaf burn were recorded. Plant species were placed into three salt-tolerance categories for how well they grew (low, less than 50% growth; moderate, 50% to 90% growth; and high, greater than 90% growth).

All the plants irrigated by drip irrigation systems with either 500 mg/L or 1,500 mg/L salt exhibited normal growth, with most showing no foliar symptoms of salt stress. Apparently, the drip irrigation conducted by the study did not create soil salinity sufficient to induce salt stress in most of the plant species tested.

In California, however, "sprinkler irrigation is used for most landscape settings because it requires less maintenance and is less vulnerable to traffic," Wu says. Under sprinkler irrigation with low-salt water (500 mg/L), 21 (56%) species were salt tolerant, 7 (81%) were moderately tolerant and 10 (26%) were salt sensitive. In irrigation with high-salt water (1,500 mg/L), 12 (32%) species were salt tolerant, 8 (21%) were moderately tolerant and 18 (47%) were salt sensitive (see table).

Some of the best-performing species included Japanese boxwood, oleander, juniper, dwarf olive, Mexican piñon pine and California fan palm. Salt-sensitive species included rose, liquidambar, ginkgo and trumpet vine.

Wu says the studies found good agreement between the salt tolerance measured by actual plant growth and that measured by salt-stress symptoms. "The performance of landscape plants is judged by their appearance," Wu says. "So the tolerance of leaves to salt-laden water is a critical trait for selecting plants to irrigate with reclaimed water."

Demonstration gardens of landscape species irrigated with reclaimed water have been planted in San Jose and by the Marin County Water District. So far, no negative impacts on either the plants or the environment have been reported, Wu says.

The researchers recommend infrequent, heavy irrigation with reclaimed water, rather than frequent, light watering. Sprinkling should be done at night or in the early morning, and not on hot, dry, windy days. "Slowly rotating sprinklers that allow drying between cycles should be avoided as well," Wu says. — *Janet Byron*