CLIMATE CHANGE EFFECTS ON SAN DIEGO'S ECOSYSTEMS

Notes from November 7, 2007 Workshop
Sponsored by San Diego Natural History Museum
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Climate change may greatly affect biodiversity and San Diego's ecosystems, as we know them. On November 7, 2007, forty-six scientists, managers, and educators gathered to learn about ongoing local climate change-related work, and to begin to formulate a plan for documenting biological responses to climate change in a meaningful and achievable way. Seven presenters gave overviews of projected climate changes, characteristics of Mediterranean ecosystems, responses of representative animal species to direct and indirect effects of climate changes, and use of herbarium specimens to assess changes. Participants discussed likely landscape-level responses and local adaptations to climate shifts, many of which are related to drought and repeated wildfires. They identified criteria for selecting indicator species; suggested candidate species; described recent field observations; and identified "next steps" for monitoring and education.

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Projected Climate Changes Over the Next Century, Dan Cayan

Notes from presentation by Dan Cayan, Ph.D., Researcher, Scripps Institution of Oceanography, University of California at San Diego and US Geological Survey

- Narrow seasonality of water/precipitation in southern California:
    - Only about 120 days to accumulate 2/3 of the annual precipitation
    - Temperate climates have more opportunities to make up deficits, usually in storm systems
    - Precipitation is heavily influenced by slope and aspect
    - Yearly precipitation in SD ranges from 33% to 280% of average
- Water is "out of balance"
    - Precipitation in SD County is only enough to supply 5-10% of water used
    - Demand for evapotranspiration greatly exceeds water supply
    - Precipitation in Sierra Nevada mountains is more variable than precipitation in Colorado River basin, and Columbia River basin has lower variability
    - Multi-climate-model analyses show that wet areas will get wetter and dry areas will get drier
- Climate models all predict warmer temperatures, ranging from 2-4 ºF from conservative models to 8-10 ºF in higher-impact models
    - Temperature change increases in the western U.S. have tracked those globally, especially in winter and spring
    - Number of days that exceed thresholds of 95 ºF ("heat waves") will increase; that is, there will be more hot days and longer summers
    - Maximum temperatures are likely to increase, resulting in more hot days and longer summer seasons (future downtown San Diego temperatures could be like today's temperatures in La Mesa)
- Other climate model predictions
    - Sea level has been rising globally and along the west coast (about 7 inches over last 100 years)
    - The co-occurrence of "high" high tides with extreme storm-forced sea levels magnifies coastal impacts; high sea level events have occurred during large "El Ninos"
    - Projections for 2100 vary with the amount of warming from historical levels to as much as 90cm
    - California faces significant losses of spring snowpack due to warmer winter storms (less snow and more rain), earlier spring melt and runoff, more flooding, and less stored water
    - "Shoulders" of watersheds at 6000-8000' would generate more immediate runoff
    - Spring has come earlier since the mid-1970s, and snowmelt and plant blooms have advance by 1-3 wks
    - Large wildfire threat is aggravated by warmer springs and summers
    - Humans have altered atmospheric composition and thus are altering the earth's climate; greenhouse gases (GHG) have long lifetimes, so choices made now and in the future will greatly impact climate.

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Characteristics of Mediterranean Ecosystems, John O'Leary

Notes from presentation by John O'Leary, Ph.D., Department of Geography, San Diego State University. [Note that Dr. O'Leary was not asked to talk about responses of Mediterranean ecosystems to climate change, but on the physical factors influencing these ecosystems.]

Mediterranean ecosystems

- Mild, rainy winters and warm dry summers
- Western margins of continents, between 30 and 45 degrees latitude, cool ocean currents offshore, etc.
- Distribution of plants along elevational or latitude gradients
- Generally poorly developed soils with low nutrient levels

Plant adaptations to drought and other physical factors

- Include seasonal drought, low water conductance rates, deep or lateral root systems
- Small, waxy, heavily-cutinized leaves; sunken stomates; some are drought-deciduous
- Some sclerophyllous (hard leaves), some succulent, and water-storing
- Convergent evolution= similar environments select for similar structure and function in phylogenetically unrelated organisms
- Similar habitats around the world
    - Chilean Matorral
    - SW African Fynbos
    - SW Australian Mallee Scrub
    - Mediterranean Basin
    - Alta and Baja California Chaparral and Coastal sage scrub
- Various chaparral types: ceanothus, red shank, scrub oak, chaparral, and montane chaparral
- Attributes of coastal sage scrub
    - Lower statured
    - Shallow root systems
    - Softer leaved/summer drought deciduous

    - Higher water conductance rates than chaparral
    - Higher species richness, herbaceous layer present
    - Tends to occur on finer-textured soils
- Both shrubland types adapted to periodic fire at 20-50 year intervals
- Seedling recruitment methods, after wildfires
    - Disturbance-dependent species
    - Obligate seeders
    - Facultative resprouters
- Disturbance-free species
    - Obligate resprouters

Most local weeds originate from the Mediterranean Basin
- Coevolved with humans and with disturbance regimes for 10,000 years

High threats to all Mediterranean ecosystems
- Habitat fragmentation and development
- Invasive plants from urban-interface and historical grazing
- Type conversion, after too-frequent wildfires, "immaturity risk" of plants
- Confounding effects of nitrogen deposition/pollution

References:

Dallman, P.R. 1998. Plant life in the world's Mediterranean climates. Berkeley, CA: University of California Press, with California Native Plant Society. 258 pp.

Malanson, G.P. and J.F. O'Leary. 1995. The coastal sage scrub-chaparral boundary and response to global climatic change. In: Moreno, J. M. and W. C. Oechel, eds. 1995. Global change and Mediterranean-type ecosystems. New York: Springer Verlag. Chapter 10, p. 203-224. (Available from afege@sdnhm.org)

Using Herbarium Specimens to Assess Climate Change in San Diego County

Presentation by Layla Aerne Hains, Research Project Manager, SD Natural History Museum

Project team
Dr. Mary Ann Hawke, Principal Investigator, Director of the SD County Plant Atlas Project
Dr. Jon Rebman, Curator of Botany
Layla Aerne Hains, Research Project Manager
Consultants Dr. Anne Fege, Botany Research Associate, and Suzann Leininger, GIS specialist

Goals and objectives
- Overall goals are to investigate the responses of plants to climate change over time by compiling and analyzing plant specimen data collected in San Diego County since the 1800s, and collaborate with local scientists and professionals to design a plan for tracking changes in the county's plant life in the future and involve citizen scientists to help fill gaps in data.
- Objectives are to capture and analyze all available records of herbarium specimens collected from San Diego County; involve the community to address scientific issues of local

significance and to increase their knowledge of our natural history and biodiversity; identify needs and draft a sampling plan for assessing future climate change impacts on San Diego's plant life; and collect herbarium specimens in order to help fill identified, high priority gaps

Capture and analyze all available records of herbarium specimens collected from SD County

- 92,252 records collected in SD County
- 48,198 in SD Herbarium
- 9,000 Plant Atlas specimens
- 33,256 from Consortium of California Herbaria
- ~60,000 of total have been georeferenced

Many other studies can inform this work

- Primack et al. (2004) compared flowering time of plants growing at the Arnold Arboretum in Boston, MA with 372 historic records of the same plants. Boston experienced a 1.5°C increase in mean annual temperature since 1885, and this study showed that the plants studied are flowering 8 days earlier over that time frame.
- Lavoie and Lachance (2006) used used herbarium specimens to determined that Coltsfoot (*Tussilago farfara*) is blooming 15-31 days earlier now than in the first part of the 20th century in large urban areas near Montreal and Quebec City. They attributed the earlier blooms with warming trends recorded in the area, especially during the last three decades when the month of April became warmer than in the past.

Where do we begin?

- 2143 species in San Diego County
- 73.4% native to the County
- 26.6% non-native and naturalized

Criteria for indicator species

- Adaptability
- Exotics/Invasives
- Endemics
- Restricted Geographic Distribution
- Rare, Threatened & Endangered
- Ecologically keystone spp.

Why is this type of project important in San Diego?

- International Biodiversity Hotspot: San Diego County is in one of only five Mediterranean climate zones in the world
- Mediterranean Climate: No typical seasons or snowmelt
- Habitat: Coast, foothills, mountains, transition, desert
- Large-scale, repeated wildfires
- 2050 Plan currently led by The San Diego Foundation

Please share with us…

- Possible indicator species

- Criteria for indicator species
- What have you seen in the field?
- Sources for climactic data
- Temperature records
- Precipitation records
- Evidence for urban heat island effect?

References:
Lavoie, C., D. Lachance. 2006. A new herbarium-based method for reconstructing the phenology of plant species across large areas. American Journal of Botany 93(4): 512-516.

Primack, D., C. Impres, R.B. Primack, A.J. Miller-Rushing, and P. Del Tredici. 2004. Herbarium specimens demonstrate earlier flowering times in response to warming in Boston. American. Journal of Botany 91:1260-1264.

Factors affecting desert bighorn sheep, Esther Rubin

Presentation by Esther Rubin, Ph.D.Conservation Biology Institute

- The "typical" habitat of Desert Bighorn Sheep has rugged and steep terrain and high visibility (low horizontal obstruction).
- Physical factors can greatly impact reproduction: lamb recruitment is influenced by forage quality: most lambs are born during spring "green-up", and those born later have lower survival *(Rubin et al. 2000, J. of Mammalogy 81:769-786).* Lamb:ewe ratios are positively correlated with precipitation during the previous winter *(Wehausen et al. 1987, J. Wildlife Management 51:86-98*).
- Disease can also be affected by weather, and there are seasonal patterns of mortality—the least mortality in hot, dry months. There is a positive correlation between monthly mortality and monthly precipitation, and a negative correlation between monthly mortality and monthly high temperature.
- Many physical factors influence predation risk (preliminary results): precipitation and/or temperature, group size, terrain ruggedness, distance to water, subpopulation, proximity to specific vegetation types in the home range.
- Overall the populations are greatly affected by habitat loss, modification, and fragmentation.

References:
Rubin, E.S., W.M. Boyce, M.C. Jorgensen, S.G. Torres, C.L. Hayes, C.S. O'Brien and D.A. Jessup. 1998. Distribution and Abundance of Bighorn Sheep in the Peninsular Ranges, California. Wildlife Society Bulletin 26(3):539-551.

Rubin, E.S., W.M. Boyce, C.J. Stermer and S.G. Torres. 2002. Bighorn sheep habitat use and selection near an urban environment. Biological Conservation 104(2): 251-263.

Factors affecting Quino checkerspot butterfly, Allison Anderson

Presentation by Allison Anderson, Ph.D.

- Typical life cycle: caterpillars come out in late December; adults fly for about a month February-April; new caterpillars emerge in April – May; and caterpillars diapause (low metabolic-rate resting stage) during the summer and fall
- Habitat includes plantain (*Plantago* spp.), white snapdragon (*Antirrhinum coulterianum*), owl's clover (*Castilleja exserta*), and bird's beak (*Cordylanthus rigidus).*
- Vegetation availability must coincide with population life cycles.
- Primary threats are habitat destruction by urban, rural, and agricultural development; landscape fragmentation by development; habitat degradation by off-road vehicles and other recreational activities; and habitat degradation by invasion of foreign plant species.
- Current range (2002) is far less than historic range.

Factors affecting montane lizards, Brad Hollingsworth

Presentation by Brad Hollingsworth, Ph.D., San Diego Natural History Museum

Southern sagebrush lizard (*Sceloporus vandenburgianus*). The distribution of the Southern Sagebrush Lizard extends in a series of disjunct, montane sky islands from Los Angeles County, southward to the Sierra San Pedro Martir in Baja California. It is commonly found above 5,000 feet in elevation, depending on latitude. These lizards enjoy open ground, with clear sunlight and dappled low vegetation. Information from http://www.sdnhm.org/fieldguide/herps/scel-van.html .

Western fence lizard (*Sceloporus occidentalis*). It is commonly found from the coast to the highest mountain areas at over 6,000 feet. It isn't found in the desert. This lizard is conspicuous and common in its range. It thrives in a wide variety of habitats, ranging from coastal sage scrub and chaparral on the coast and foothills, to the forests of higher elevations. It's usually found on or near the ground, in rock and wood piles, tree trunks, and the lower branches of shrubs. Information from http://www.sdnhm.org/fieldguide/herps/scel-occ.html.

Populations range from 1500-3000 m in San Gabriel and San Bernardino Mountains; 800-2400 m in San Jacinto Mountains; about 1500 m on Palomar and Laguna Mountains.

There has been recent research on thermoregulation of the southern sagebrush lizard, by Jorge Valdez of Universidad Autonoma de Baja California (UABC), in collaboration with Gorgonio Ruiz-Campos, UABC, and Bobby Espinoza, California State University at Northridge

Factors affecting San Diego's bird populations, Phil Unitt

Presentation by Phil Unitt, San Diego Natural History Museum

- Variable rainfall can dramatically affect reproduction, with much higher nesting attempts per pair and fledglings per pair of birds in higher rainfall years
- Total bird counts varies by year (and rainfall)
- Response of birds after fires (2002 Pines Fire and 2003 Cedar Fire) varied by species; wintering and nesting season sightings provided for Hutton's vireo, California thrasher, wrentit, Bewick's wren, and loggerhead shrike
- Historical data from Christmas bird count provided for Cassin's songbird, tri-colored blackbird, and house wren

- More information at http://www.sdnhm.org/research/birds/index.html

Local Climate Changes, Walter Oechel

Presentation by Dr. Walter Oechel, Ph.D., Professor, Department of Biology, San Diego State University, Wednesday, November 14, 2007 (Climate Change Lecture Series)

Global perspectives

- Global and regional environmental threats are cumulative (increases in CO2, human populations, species extinctions, and others) and are pushing "earth support systems" to their extreme
- Many feedbacks are non-linear and positive (reinforcing), and many rates of change are higher than predicted
- Models of fossil fuel emissions vary
- For decades, there had been increasing CO2 emissions per unit of gross domestic product-GDP (fossil fuel use efficiency)
- Now the CO2 emissions per unit of GDP globally is higher than the earlier most-pessimistic scenarios
- We say, "if only we knew it 30 years ago"—and we did know it then

Is the current situation due to population growth or over-consumption? Actually, both

- The U.S. emissions are 4 times as high per capita, compared with China
- China's population is 4 times that of the U.S.
- Third highest emissions are from Indonesia, due to loss of tropical forests and peatlands

Carbon sources and sinks

- Most CO2 is absorbed by land (26%) and ocean (26%) and remainder is building in the air
- Many biological and climatic factors control CO2 uptake by these sinks
- Chaparral is a significant sink for CO2, especially old-growth, and should be maintained for carbon sequestration, wildlife habitat, watershed and other values

Free Air CO2 Enrichment (FACE) experiments provide information about individual, population, and community impacts of higher CO2 exposures

- Generally, CO2 increased water use efficiency, plant growth, flower and seed set
- Weedy species often respond more than native species
- Species interactions are often altered in these communities

Likely regional changes

- Decreased precipitation and runoff, increased drought
- Increased summer monsoons
- Increased fire weather, fuels, wildfire frequency and intensity
- Increased climate variability
- Decreased biodiversity
- Decreased utility of MSCP and conservation reserves, unless there is significant redesign
- Projections for California made by Ron Neilson and others (see references below)

What can we do?

- Plan conservation areas with climate change in mind
- Allow migration paths
- Stabilize and reduce regional and local population
- Educate (both formal and informal)
- Work with media to objectively present facts (factual, fair, balanced media)
- Adopt, require, demand zero emissions energy (solar, wave, methane clathrates with offsets)
- Require policymakers to act in the public's best interest
- Create a shared vision for the future (2050) to provide a target for policy
- Avoid piece-meal legislation; instead create a coherent vision and plan
- Make deeper policy changes

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Lenihan, J.M., R. Drapek, R.P. Neilson, and D. Bachelet. 2005. The response of vegetation distribution, ecosystem productivity, and fire in California to future climate scenarios simulated by the MC1 dynamic vegetation model. Report from the California Climate Change Center CEC-500-2005-191-SD, 24 pp. Available at http://www.energy.ca.gov/2005publications/CEC-500-2005-191/CEC-500-2005-191-SD.PDF. Accessed on 8/30/07.

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Roberts., S.W., W.C. Oechel, P.J. Bryant, S.J. Hastings, J. Major and V. Nosov. 1998. A field fumigation system for elevated carbon dioxide exposure in chaparral shrubs. Functional Ecology 12(4):708-419.

How would climate change impact plants/animals in each habitat type?

(Small group exercise, with one habitat type assigned to each table)

Physical Factors	Habitat type and likely response
Mean temperature increase	Foothills: California sage will move up in elevation; existing areas will type convert. Mountains: Butterflies moving up in elevation. Desert: increase evapotranspiration, would have negative effect on riparian and

	aquatic habitats
Extreme max temperature	Foothills: By itself, may not affect species, but will amplify other effects.
Extreme min temperature	Foothills: Kill young gnatcatchers, cause frost damage on vegetation Mountains: More beetle reproduction (warmer winters)
Drought	Foothills: Lower overall productivity of ecosystems, changes in blooming phenology Mountains: Loss of trout habitat, increase in water temperature, no reproduction
Summer rainstorms	Foothills: Increased exotic species, insects not commonly present, more lightning strikes Increase flash floods, physically wash out oases, and damage palms
Increased wildfire frequency	Mountains: loss of conifers, changes in species composition Desert: increase mustard and other exotics, negatively impact native shrubs and cacti

What's the worst case/scenario in 50 years? Impacts and adaptations?

(Small group exercise, with one habitat type assigned to each table)

Physical factors	Worst-case scenario (50 years)	Landscape-scale impacts	Adaptations
Temp-erature	Coastal: more continental air influence Foothills: dust storms Mountains: increase up to 10^{o}F Desert: trends toward hyper-aridity, loss of riparian zones and species dependent upon water supply in the drainages 2-month extension of dry season	Coastal: narrower band of coastal vegetation types, CSS reduced Foothills: substantial dieback of perennials; shorter growth period for annuals Mountains: bark beetles, increased fire Desert: vegetation-animal assemblages become more like drier deserts in Salton sink, northern Sonora, lower Baja; humans likely to have greater effects on remaining habitat Dieoff, ecosystem drift	Mountains: more research to better understand ecosystems, establish baselines, invest in education, maybe replant conifers Extirpation of species Dwarfing of plants, reduced habitat values Preserve design to accommodate habitat shifting
Precip-itation	Coastal: fog zone and period reduced; less regulated/moderated runoff Foothills: less precipitation and fog, greater annual	Coastal: fires reduce moisture-retaining vegetation; pollutants/toxins on land held longer because of briefer rain events	Mountains: no management, get used to ceanothus forest? Desert: climate change adaptation corridors mandated by USFWS-CDFG Drought tolerant plants favored

	variability Mountains: less precipitation Desert: see above box; some adaptable species find refuge in remaining niches (e.g. washes) Only 5" rainfall/year	Foothills: stress on shrubs, erosion processes and slope failures Mountains: perhaps loss of meadow habitats Desert: see above box Fewer annuals	
Weather events	Foothills: more extreme and less reliable precipitation Mountains: extreme events Extremely irregular events	Foothills: possible increase in periodic rain events, due to dissipation of hurricanes Mountains: degraded soil nutrients Erosion and siltation of streams	Mountains: conifers to oaks to chaparral Select for different species
All	Coastal: less regulated and moderated runoff, Pollution/toxins held for longer periods because rain events briefer and more intense, then contribute greater influx of pollution to ocean	Coastal sage scrub reduced due to reduced fog zone and period, increased fires Narrower band of coastal vegetation types convert to chaparral or weeds	
All	Desert: trend towards hyper-aridity, loss of riparian zones and species dependent on water supplies in drainages, some adaptable species will find refuge in remaining niches/washes	Desert: vegetation/ animal assemblages will become more like drier deserts in Salton sink, northern Sonora, lower Baja. Human development likely to have greater effect on remaining habitat.	Desert: preserve design to accommodate shifting of habitat types. Climate change adaptation corridors mandated.

What have you seen in the field?

Coastal sage scrub

- Good recovery of severely mechanically disturbed CSS along Sweetwater River over more than 10 years, i.e., recovery to pre-disturbance structure and composition with little to no additional invasion by exotic plants. However, this was an acute, not repeated disturbance. Variable recolonization of this area by previously documented birds; that is, a lag effect.

- Chamise plant moisture levels lower than long-term norm earlier in season, and lower levels at end of summer drought

Other plants

- Several thousand flowering thread-leaved brodiaea (*Brodiaea filifolia*) in 2005 in a Carlsbad preserve, then only 78 plants in 2006 and only 5 flowering plants in 2007. Drier conditions produce much less flowering. Will prolonged and much drier/warmer conditions actually kill the thread-leaved brodiaea over time? By 2050?
- *Monardella linoides* ssp. *linoides* have recovered poorly and suffered big declines since the Cedar Fire, largely due to the increased cover of non-native grass and associated litter, and possibly the long-term drought
- Very little green-up or bloom in desert shrubs and cactus, due to the drought
- Repeat counts of *Dudleya* (2005 to 2007) were decreased, due to lower rainfall
- Flower blooms on native spring/summer flowering plants, i.e., monkey flower
- Far fewer full strands of fennel, and much less *Erodium*
- Extremely dry shrub conditions in summer
- Frost killing *Malosma laurina* in 2007 winter
- Trail use and off-highway vehicle activity spread weeds into previously all-native vegetation

Birds

- Northward shift of tropical seabird nesting species; for example, gull-billed terns, elegant terns, black skimmers nesting in southern California since the 1980s.
- Disappearance of certain elevationally wide-ranging bird species (such as black-chinned sparrow and lazuli bunting) from coastal sage scrub and other lowland habitats in years during and following droughts.
- Opportunistic variation in nesting initiation by some birds (such as Rufous-crowned sparrow) in response to early/late or heavy/sparse rainfall.
- Upward shift in elevational range of cactus wren on desert slopes.
- Decrease in winter abundance of white-winged scoter and Bonapartes' Gulls, perhaps not migrating this far south.
- Increase in winter abundance of Cassin's kingbird and barn swallow.
- Reduction in raptors and cactus wrens, on Marine Corps Air Station El Toro, from the mid-1990s to present.

Insects

- Altitudinal adjustment of the Laguna Mountain skipper and other butterflies.
- Tropical lepidopteras are now becoming established.
- Shorter adult Quino checkerspot season
- Shorter flowering seasons affect potential pollinators.

Other animals

- Increased survival (range expansion) of subtropical *Racinus communis* (except 2007 winter)
- At Quail Botanical Gardens, witness to the disappearance (since 1995) of two relic colonies of harvester ants; western toads; California quail; acorn woodpeckers; grey fox; bobcat; roadrunner; and spadefoot toad

- One bobcat and one roadrunner moved to Quail Botanical Gardens, from neighboring developments
- Increase and upward movement (in elevational range) of house wren and Lincoln's squirrel
- Increased interaction between mountain lions and humans

Riparian areas
- No flows in streams that normally flow for at least a few weeks or months in the spring, such as Cottonwood Creek during the current drought.
- Large-scale "die off" of riparian dominant trees (willow, cottonwood) in Cottonwood Creek watershed when fire is followed by drought.
- Thinning of riparian forests (less cover) by old trees dying, seedlings dying due to drought, and sun-loving weeds invade.
- Reduced stream flows have reduced activity and reproduction of arroyo toads.

Mountains
- In the mountains, tree dieback due to drought; shift from conifers to oaks; and loss of sugar pine and perhaps other conifers on Palomar Mountain
- More invasive plants; reduced stream flows, which do not expose gravels for spawning; and more crowded stream pools
- Bark beetle kills and drought effect in mountains

Recovery after wildfire
- Coastal cactus being burned and coming back well, improves cactus wren nesting habitat
- With each burn, percent of invasive weeds increases, while natives decrease in coastal sage scrub
- Slow recovery of natives after fires follow drought
- Dying back of shrub seedlings in areas burned in 2002 and 2003
- Type-conversion of vegetation due to too-frequent fires at Daley Ranch (east of Jamul) and MCAS Miramar Slow or no recovery of coastal sage scrub. Recorded location on western and southern slopes of San Vicente Reservoir and Mission Trails Regional Park. In these areas before the Cedar Fire, CSS was occupied by California gnatcatcher; after the fires (combined with droughts), CSS is not recovering, possibly due to type conversion to non-native grasses. Gnatcatcher have not recovered (not occupying site).

Plants and animals are "telling us what's going on"

What criteria could be used to select indicator species in San Diego?

Objectives of predictions
- What is currently being monitored for MSCP
- Select indicators that relate to people and their basic needs (clean air, water)

Trends
- Some trends are longer than we can envision
- Climate change observations are exceeding some predictions of changes

Monitoring considerations

- Plant associations may not be sustained, and composition changes may be more informative than patterns of individual species
- Some "thresholds" have been and will be crossed, for example, pines have not returned after the 2003 wildfires in Cuyamaca Rancho State Park, and neither has the pygmy nuthatch that depends on them
- Costs of monitoring; short lists are cheaper and not everything can be measured
- Monitor at various levels and scales—species, populations, and landscape
- Controls are important, but there is a risk with climate change, "watch them get wiped out"
- Spatial distributions, not just changes in presence/absence of species
- Look for species with plastic phenology, in terms of blooming or egg-laying with respect to extremes in short-term rainfall variance
- Look at seed set as well as phenology, as that may inform reproductive success
- Look at plants that bloom based on photoperiod and not weather conditions (perhaps *Arctostaphylos, Ceanothus, Salvia*)
- See if ephemeral species and plant health correspond to climate data; that is, does a 10-inch rainfall year have the same affect on health if the precipitation comes predominantly in December or March?
- Review the physiological tolerance of species to predicted climate conditions (which species are likely to survive? which are more adaptive?)
- Indicator transects will be more valuable than a focus on selected species; that is, a series of sites covering a diversity of elevations and habitats
- Monitoring may need to be modified to capture factors/data that provide information about climate change
- Consider inviting trained "citizen scientists" to collect and report data

Select some adaptable species

- Likely to respond slower to climate changes
- Many have extensive ranges and exist elsewhere
- Compare these to rare and endemic species
- Some newly-introduced species may be adapted to "new" climates, even if they were not suited to historical climates

Physical climate changes

- Physical climate changes are now being extensively measured, but not ecosystems and species
- Microclimate is important, not just elevation and latitude
- Climate change impacts include extreme wildfire events and interactions between temperature, precipitation and weather.
- Uncertainty about climate trends, interactions, and extreme events. Relate species observations to all of these
- Depeletion of soil nutrients from wildfires and erosion

Concerns

- Overheard comment about "setting aside land for 50 years then it will be up for grabs," with regard to about Multiple Species Conservation Programs
- Are we going to do something, or just document the decline/demise of species and habitats?
- Nitrogen deposition is increasing in southern California, and influences plant responses to other stress factors

Build on historical observations and collections

- Refer to Camille Parmesan's analysis of museum collections and trends, then measurement of current insect populations
- Look at trends observed at key collection points, irrespective of species
- Some trends are happening faster than predictions
- Ultimately may be limited by species with adequate numbers of records
- Look at collections with long labels; if they have a long list of associated species, this could be more valuable than the plant record itself, and this serves as a mini-flora for a point in time and space

Special places

- Include rare, threatened, and endangered species
- Riparian habitats in the desert are very susceptible to precipitation, and would be important to monitor, or individual species that depend on this habitat
- Don't forget about desert and "transition" places (between mountains and desert)

What species would you choose as indicators in San Diego?

Bird species that are sensitive to fire

- Hutton's vireo, plain titmouse (oak woodland)
- Mountain chickadee and pygmy nuthatch (coniferous forest)
- Scott's oriole, black-throated sparrow (desert transition)
- California thrasher, wrentit (chaparral)
- California gnatcatcher, cactus wren (coastal sage scrub)

Other birds

- Belding's sparrow, clapper rail (susceptible to rising sea levels)
- Cassin's kingbird, house wren (facultative migrants)
- Well-monitored listed species that migrate, to track changes to arrival times, start of nesting, and changes in location, for example, California's least tern, least bell's vireo, Southwestern willow flycatcher

Plant species

- *Malosma laurina* (frost damage, resprouter)
- *Ceanothus greggii* var. *perplexans* (obligate seeder after wildfires)
- *Arundo donax* (riparian invasive)
- C3 vs. C4 grasses (climate change is likely to favor one over the other)
- *Cupressus forbesii* (host plant for Thorne's hairstreak butterfly, obligate seeder)

- *Brodiaea filifolia* (listed status, geophyte, blooms related to rainfall)
- *Larrea tridentata* common desert shrub
- *Cylindropuntia californica* var. *californica* succulent, important for cactus wren
- *Antirrhinum coulterianum* common after fire, Quino checkerspot host plant
- *Encelia farinosa* expanding toward the coast.
- Chamise (*Adenostoma fasciculatum*) to monitor live fuel moisture and plant-soil water relationships in chaparral
- *Ceanothus* and pollination strategies (common shrub that is also a narrow endemic, and has important relationships with beetles)
- Common endemic species limited to a narrow range (*Adolphia, Comarostaphylis*) to track recruitment and mortality, and common enough to include in landscape-scale analyses
- *Nolina parryi* and *Pinus monophylla* have limited distribution and also would be useful in landscape-level analysis
- In the mountains, various conifer species/communities may be shifting in distribution; for example yellow pines on Palomar Mountain declining and black oak expanding
- *Viguiera laciniata* and *Eriogonum fasciculatum*, as these species are responsive and variable in their blooming phenology to inter-annual variations in rainfall amount and timing, and presumably would show measurable shifts over longer-term trends
- Warm season annual grasses, as shifts in precipitation as likely to benefit these species; their competitive effects are well-studied; and fire regime effects are well-documented
- Measure compositional shifts in plant communities, especially movement (recruitment) from "adjacent" community types

Animal species
- Keystone species, such as snakes.
- Invasive species, such as European grasses
- Pathogenic species, such as freshwater mosquitos
- Sensitive species, such as *Dudleya brevifolia* (CA endangered)

Desert species
- Mesquite, influenced by precipitation and ground-water overdraft.
- Pupfish
- Palm oasis, perhaps monitoring elevational distribution of palms as well as abundance.
- Golden eagles, because precipitation influences vegetation, then jackrabbits and other prey.

Insects
- Native pollinators and plant-insect interactions
- Look at trapped insects, i.e., on catch-fly
- Quino checkerspot butterflies, host plants, and the relationships between phenology and elevation after diapause

Next steps

Research and monitoring

- Look at the effects on air, water, and other human needs
- Look at changes to locations, not just species
- Monitoring plan lacking in Multi-species Conservation Plans
- Prepare a "gap analysis" for monitoring efforts
- Look at threats of invasive species
- Look at species that had abundant collections (or population levels) in the past, and are now less common, i.e., Quino
- Take advantage of long-term monitoring and protected research areas at SDSU and UCSD reserves, San Clemente Island
- Controlled experiments (extension of FACE with CO2 enhancement)
- The "devil is in the interactive effects"

Professional education
- Assemble our "corporate knowledge"
- Provide training for monitoring
- Most universities are educating few "whole-organization" biologists
- Apply current knowledge and extend/explore management options
- "We" are the experts, and we need to continue learning

Public education
- When will we invest in children's nature education and adult science literacy?
- How much science gets to policymakers?
- Share research and monitoring information for public awareness and education of eleected officials

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List of Participants

Layla Aerne Hains Allison Anderson Bruce April Prue Arbib

Carl Bell	Bruce Goff	Patrick McConnell	Heather Schmalbach
Reva Block	Patrick Gower	Jim Means	Pete Sorensen
Jeremy Buegge	Allen Greenwood	John O'Leary	Markus Spiegelberg
Dan Cayan	Mary Ann Hawke	Chris Otahal	Jim Stone
Brian Collins	Joan Herskowitz	Nancy Owens	Doug Stow
Andrea Cook	Brad Hollingsworth	Renner	Phil Unitt
Erica Cunningham	Isabelle Kay	Jim Peugh	Jessica Vinje
Julian Duval	Michael Klein	Ken Quigley	Annette Winner
Daniel Eliseuson	Suzann Leininger	Chris Redfern	Ed Woch
Anne Fege	Jeff Lincer	Jim Rocks	
Mary Freeman	John Lovio	Ester Rubin	
Sarah Ganiere		Christina Schaefer	

Agenda

8:30	Registration	Coffee available, nametags, pay $10.00 to reimburse costs of beverages, snacks and lunch
9:00	Welcome and introductions	
9:15	Projected Climate Changes Over the Next Century	Dan Cayan, Ph.D.,Researcher, Scripps Institution of Oceanography, University of California at San Diego and US Geological Survey
9:45	Characteristics of Mediterranean Ecosystems	John O'Leary, Ph.D., Department of Geography, San Diego State University
10:15	Preliminary Trends from Herbarium Specimens	Layla Aerne Hains, San Diego Natural History Museum
10:30	Break	Coffee, bagels
10:45	Mechanisms for local climate change impacts	Small group (table) discussions Local ecosystem structure and function Likely impacts and mechanisms of climate change on local habitats and plant/animal groups
11:30	"What have you seen in the field?"	Observations of changes in the distribution or reproduction of local species
11:45	Lunch	Sandwich fixings ($5.00 each), sodas
12:30	Mitigation and adaptation to local climate changes	Small group (table) discussions What's the worst case/scenario (50 years)? How would we model that? How would we adapt to that?
1:00	Local Field Stories: Factors Affecting San Diego's Species (panel)	Esther Rubin, Ph.D., Conservation Biology Institute Allison Anderson, Ph.D., US Fish and Wildlife Service Brad Hollingsworth, Ph.D., San Diego Natural History Museum Phil Unitt, San Diego Natural History Museum
1:45	Break	Sodas, coffee

2:00	"What indicator species would you choose?"	Identification of possible plant/animal indicator species
2:15	Next steps	Small group (table) discussions
2:45	Closing comments	
3:00	Adjourn	

Workshop feedback and evaluation

Question 1: List your three greatest " learnings" and insights today.

- Got good research ideas, diversity of impacts to various species
    - Awareness of potential impacts of climate change
    - Issue of phenological mismatches
    - Broadened my horizons outside of my discipline, saw how other species impacted by "sky-island" issues (lizards)
    - Ability to network with others, learn about specific research going on in the field
- Climate model predictions for southern California
    - Casual predictions seem difficult and questionable, maybe we should stop discharging greenhouse gasses
    - General climate change information
    - Information on Mediterranean ecosystems, possible increase in summer rainfall
    - Learning several specific elements of projected climate change in SD County (e.g., rate of increased temp, increase scenarios, increased variability of annual precipitation, etc.)
    - We are heading to cataclysmic events but can it turn around??
- Some questions we just don't have an answer to yet, our local species are greatly affected by many events
    - There is a lot we don't know, we haven't got a handle on what to do about climate change yet (2)
- Projected impacts on specific taxa—rare, threatened or endangered—or otherwise
    - Effects of fire on birds was interesting
- We need to develop some "key" species for us to use as future indicators of where we are going in S.D. County's biodiversity
    - Purpose for using indicator species clarified
    - Utility of using herbarium data to help detect/tract impacts of climate change on phenology and distribution of plant species!
- I found every presentation and discussion a great learning activity

Question 2: List three subjects you would like to learn more about (in workshops, monitoring, projects, research).

- What are keystone species in SD County?
    - Indicator species/vegetation community identification
    - More projected impacts on various important taxa
    - Gaps in our knowledge of adaptability of native plants and animals
    - How do we determine what the key species will be and follow what is going on with those species?

    - Is it possible to extrapolate the key species info to a greater number of species?
- Collective trends and ecosystem changes (observed)
    - Where are the data (at varying levels)? (i.e.,, what do we have to work with)
    - Research on "current" on predictors of climate change
    - More on species experiencing population change locally
    - Use of traditional geographic analysis in determining likely ecosystem change under particular climate change scenarios
    - Would like to see some habitat shift model results
    - Climate change and vegetation change modeling for the southwest
    - Everything about the biology of southern California
    - More about climate change models and applying them, local climate change data
    - Learning about studies done on native species and information on climate issues
- Changes in our approach to conservation and long term ecosystems management
    - Adaptive management for climate change
    - More consideration of the impacts of type conversion on the future integrity of San Diego County plant and animal communities
    - What was learned from the post 2003 fires—what were the recommendations?
    - Changes in human impacts—water shortage/drought
    - Reduced urban runoff from imported water
- Insect plant interactions and relationships; i.e.,, nectar resources, pollination, even though the herbarium is historically useful there still lacks the ecological effects—look at ecology, effects of invasive insects and competition for resources
- Expand the topics presented by Dan Cayan
- Maybe have Eric Larson speak on impacts on SD agriculture
- Add ocean to the discussion, ocean plants/animals effect on on-shore critters
    - More in the introduction about ocean processes /currents
- How do we get the general public to pay attention NOW?!

Question 3: What suggestions would you make, for assessing San Diego's climate change impacts and adaptations by 2050?

- Focus on large issues (like plant reactions to climate change, then animal populations follow)
    - Be careful not to be solely focused on individual indicator species (vs. ecological processes/interactions)
    - How the climate change will directly impact the human population locally
- Cohesive research—pool together knowledge
    - Need for further thorough study?
    - Decide what we want to know and what are we looking to do with the data
    - Research on "current" on predictors of climate change
    - Studies based on historic collections vs. current occupancy
    - More studies of rare species- change in distribution- food chain - phenological mismatches, look for correlation with global trends
    - Big questions, accurate mapping of all vegetation communities in Mediterranean-type climate areas of county coupled with examination of earlier vegetation maps and future mapping
- Adequacy of our current natural communities and preserve system, with likely climate change scenarios to determine impacts

    - Adaptations- emphasize corridor restoration to allow habitat to shift
    - County managed projects to coordinate brush control with vegetation preservation
    - Assessing conflict between need for habitat corridors and how those canyons will spread fire
- Less development in the wildlands, to hopefully eliminate development there
    - Talk about limiting development (especially coast)
    - Link SDNHM/science conclusions to San Diego 2050 development plans
- Cooperation between jurisdictions, agencies, academia and field personnel
    - Make sure that the relevant agencies are making this issue a priority for attention and funding
- More workshops to bring together people in the field to talk to one another, and then convey those reports once again to the public.
    - People (public) have to keep hearing this over and over before they finally pay attention!

Question 4: What did you like about today's workshop? What should be continued or added for the next one?

- Group discussions good in particular
    - Especially whole group discussion at 2pm
    - Small groups—gets the job done more effectively
    - The small group breakouts were very interesting
    - Liked focus groups
    - How are we going to apply these results?
- Many very interesting topics discussed and today's workshop provide a useful point of departure
    - Professional exchange and input
    - Professional interaction/synergism (x2)
    - Interacting with the other professionals involved in climate change
    - Interactions with other scientists excellent, speakers excellent
    - All of the speakers were very knowledgeable
    - The overall idea was excellent and timely; we certainly need more awareness of climate change and its effects on our particular environment
- Excellent diverse expertise as speakers and participants (x2)
    - Mixing professional speakers- climate, hydrology, biologists, managers, scientists
    - It was good to see a variety of specialists (birds, plants, government, non-government).
- Lunch and cookies were awesome!
- I liked all of it (x2)

Question 5: What didn't work in today's workshop? What should we do differently next time?

- Don't dwell on the obvious; preaching to the choir.
- In an expert forum such as this, educational games are not necessary and not productive.
    - Facilitators for breakout groups were not adequately briefed/trained on the process and were as lost as the rest of the table of participants.

    - The facilitators, for the most part, were lost as to now to make their respective groups productive.
    - Activity was a good idea. I'd prefer to have fewer speakers and more time to get into productive discussions. It was rushed.
    - Round table discussion dove into gossip
    - The ecozone focus was too limiting
    - Need for technical specialists in each group
    - Asking people questions that are too general "worst case local climate scenario etc."
    - Nothing really became of the breakout group activities due to the lack of time
    - Perhaps the breakout sessions could occur at a subsequent workshop
    - There should have been lots more prep for the exercises, with the blank circle worksheets ready for folks at the tables to fill in, and instructions made clearer.

- Today's goals were overly/unrealistically ambitious. there simply wasn't enough time to adequately address today's topics or really make meaningful sense of them.
    - Next time, cover less material and focus more on fewer topics.
    - Recommend you get these notes out to attendees asking them to add additional comment for record.
    - Give participants more time to respond thoughtfully
- Would have liked to have learned more about the data structure, population statistics, etc. of the Plant Atlas
    - Would like to make suggestions on how to use the Plant Atlas for monitoring
- The presenters were not asked to provide outlines or abstracts of their talks
    - It was difficult to take notes in the semi-darkness while power point presentations were going on, and an outline or abstract, with references would have helped
    - Some of the best info is gleaned from follow-up after the program is over, and there was no way for us to do that without references appropriate to each presenter's topic
    - Presenters had trouble keeping to the time limits, which were indeed very tight; some of them got too involved with their own data and didn't "cut to the chase" when they should have
    - It wasn't clear what kind of audience that presenters were addressing; some presented information that was more basic than a 101-level class, often mixed in with some mind-numbing stuff
- Providing bureaucrats a short list of "indicator" species may be a little dangerous. It may allow conservation, investment, and management decisions based on a few species and may not support other species that are at risk. It may take a fairly large group of indicator species to intelligently make decisions. Maybe the conclusion should be that we need to put lots of money into monitoring, research and decision making.
- Everything seemed to flow very well; except no one went back to post notes on all of the topics posted on they wall. They only posted notes on "What have you seen in the field"
- The week-day, all-day schedule may not be conducive to good attendance of a wide variety of folks; there were way many more chairs than participants, so I assume you were hoping for better attendance
- Can't think of anything right now

Question 6: Other comments about this workshop, the Museum's climate change herbarium project, and San Diego's climate change impacts.

- I was impressed by the collective knowledge, interest and collaboration
    - Very interesting, helpful, made good contacts
- This was a great opportunity to for a base of indicators and participants to continue on for several months, next year and into the future
    - Hopefully coming back together to discuss the changes they are seeing and what is going on throughout SD County
    - Needs an official vehicle for expert participation; this is an extremely complex project that feed on information from many different sources, fields, knowledge etc.
    - Overall, the workshop was a useful start, but perhaps future ones should provide more time to more fully examine the key issues related to the workshop's theme.
- Museum should be commended for initiating this program
    - Good work
    - Thanks for holding this workshop
- How much will this project overlap with Bird atlas/ Can we do a similar thing with birds and look at actual interactions?
- How will these plant changes affect the rest of the environment?
- Combine host plant-insect studies of range shift and other climate impacts
- I'm concerned that the plant data (for individual plant species) might be too limited to answer the questions posed. There is a need to take an ecological approach to understanding, predicting and dealing with changes (vs. individual species)

Meeting report prepared by Anne S. Fege, Ph.D., Layla Aerne Hains, M.S., and Mary Ann Hawke, Ph.D., San Diego Natural History Museum, November 30, 2007