CALIFORNIA'S FRESHWATER AMPHIPODS

AND IMPLICATIONS FOR BIOASSESSMENT

Dr. G.O. Graening

Department of Biological Sciences
California State University, Sacramento

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Outline of Presentation

- Summarize the State's Diversity
- Impact of Exotic Species
- Research Goals
- Implications for Bioassessment

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CHECKLIST OF FRESHWATER AMPHIPODA (CRUSTACEA: MALACOSTRACA) OF CALIFORNIA
(in review)

- G.O. Graening
  California State University, Sacramento

  D. Christopher Rogers
  University of Kansas, Lawrence

  John R. Holsinger
  Old Dominion University

  Cheryl Barr
  University of California, Berkeley

  Richard Bottorff
  University of California, Davis

What's In the Manuscript?

- large (exhaustive?) bibliography
- distributions of all taxa
- list of keys (but not a key for CA taxa)
- Conservation status ranks for CNDDB

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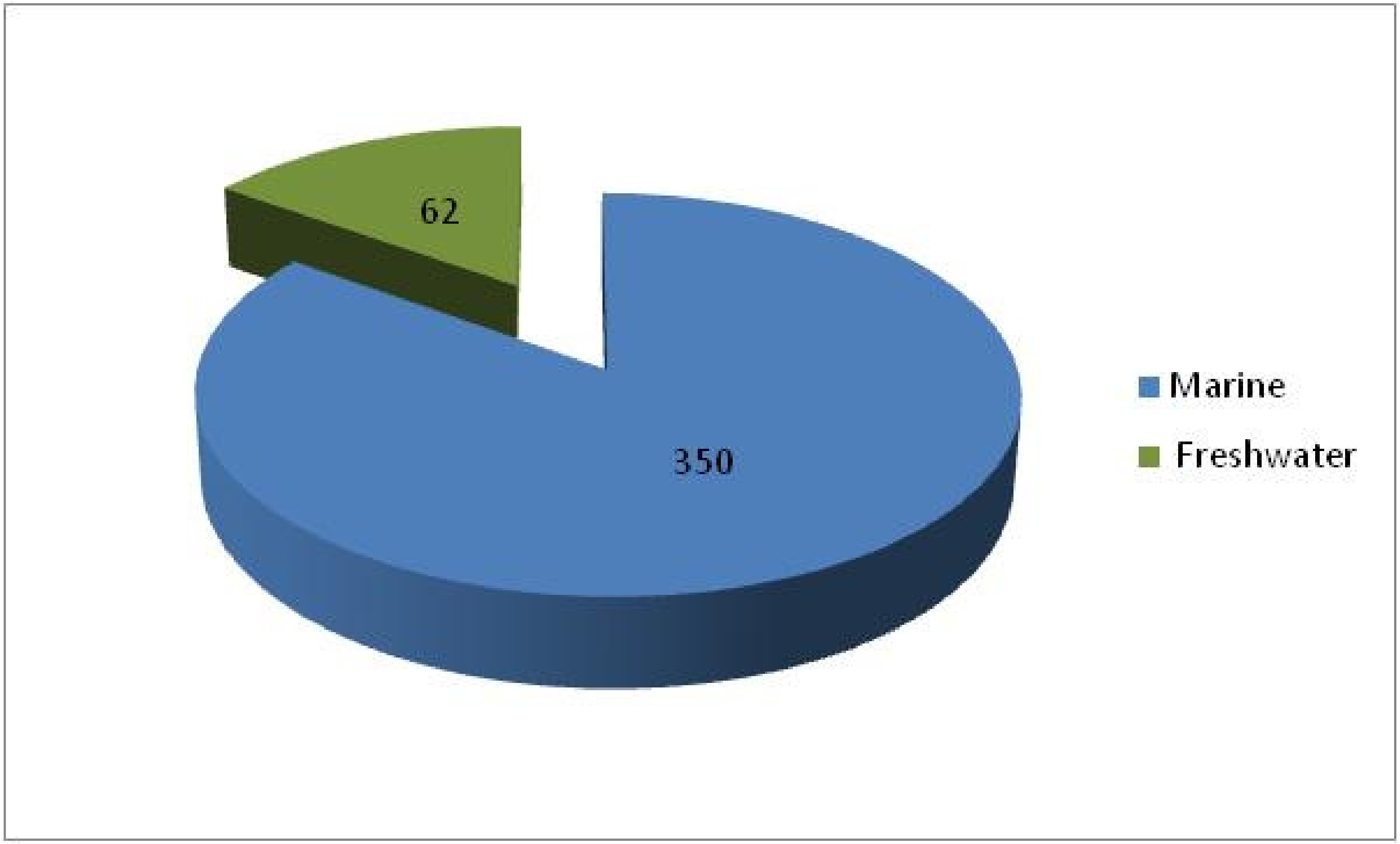
Worldwide (FW) Amphipod Diversity

- About 1,870 species and subspecies recognized from fresh or inland waters (Vainola et al. 2008)
- North America has 236 FW species in 23 genera
- Marine Diversity 10X greater
  - California has > 350 marine species

Marine Taxa Also Larger

- supergiant amphipod *Alicella gigantea* from the North Pacific gyre - 340 mm (13 in) long



California has 350 marine species and 62 freshwater species
(with annoying overlap = euryhaline)

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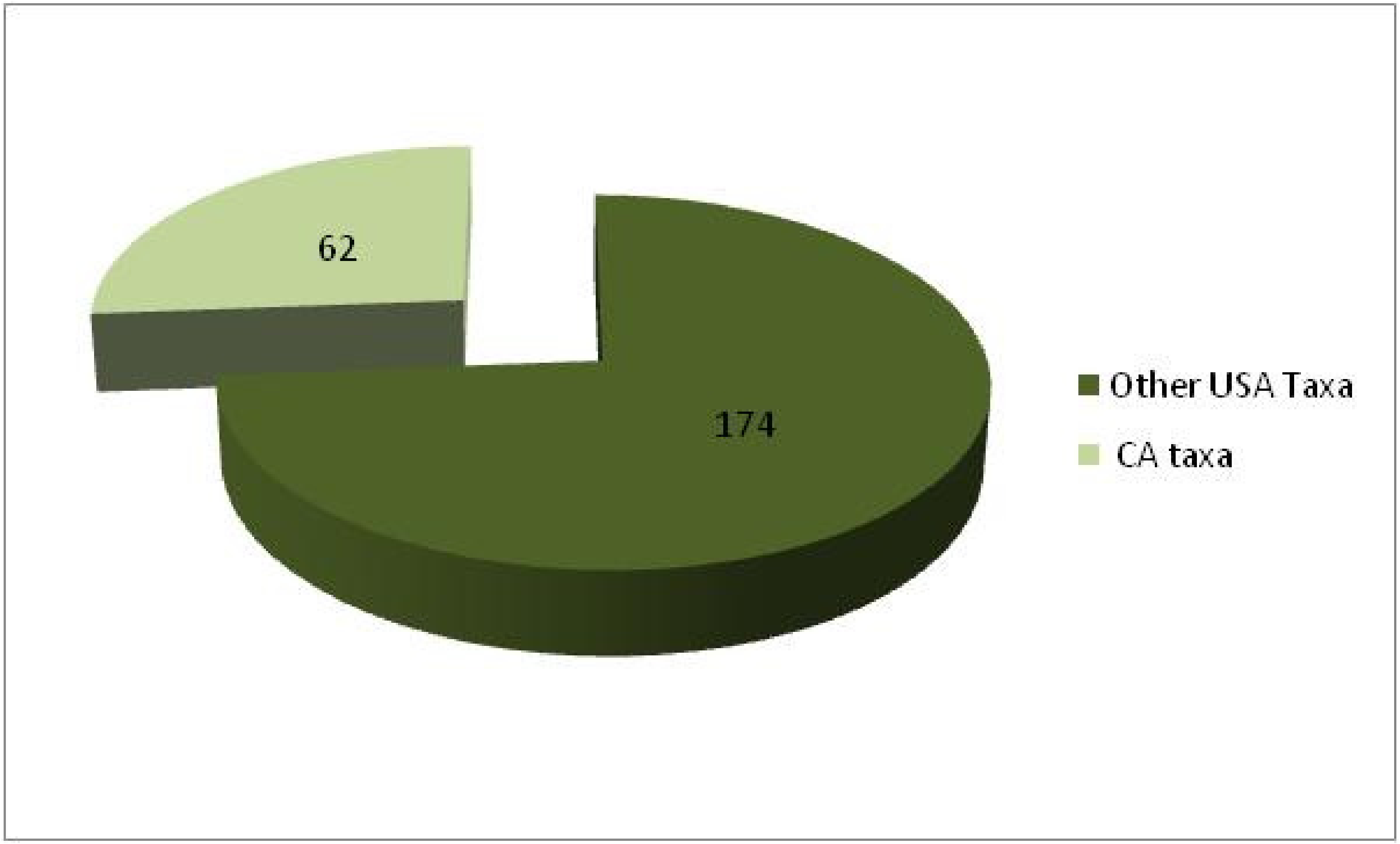
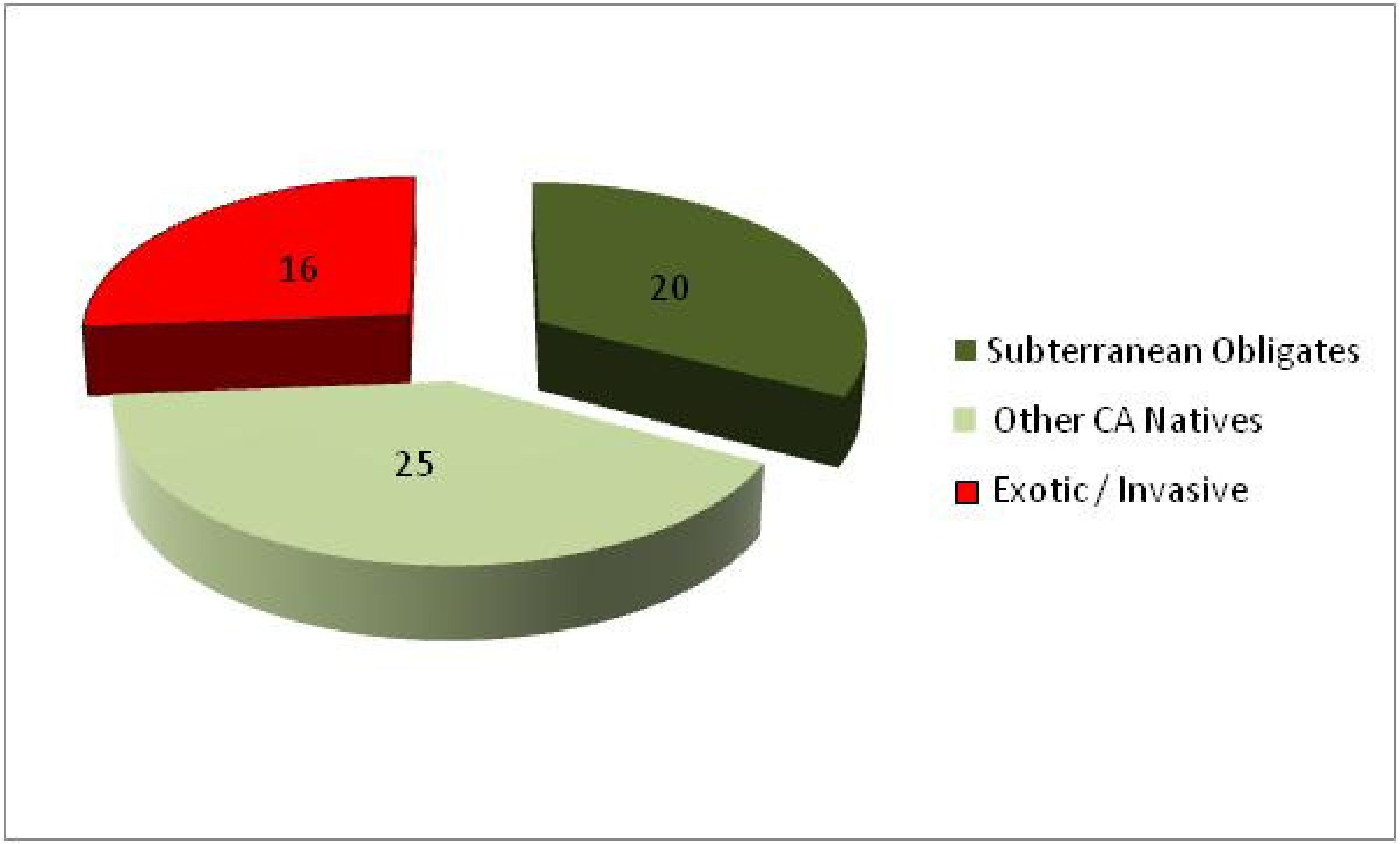


California has about 25% of the richness of North American freshwater amphipod species

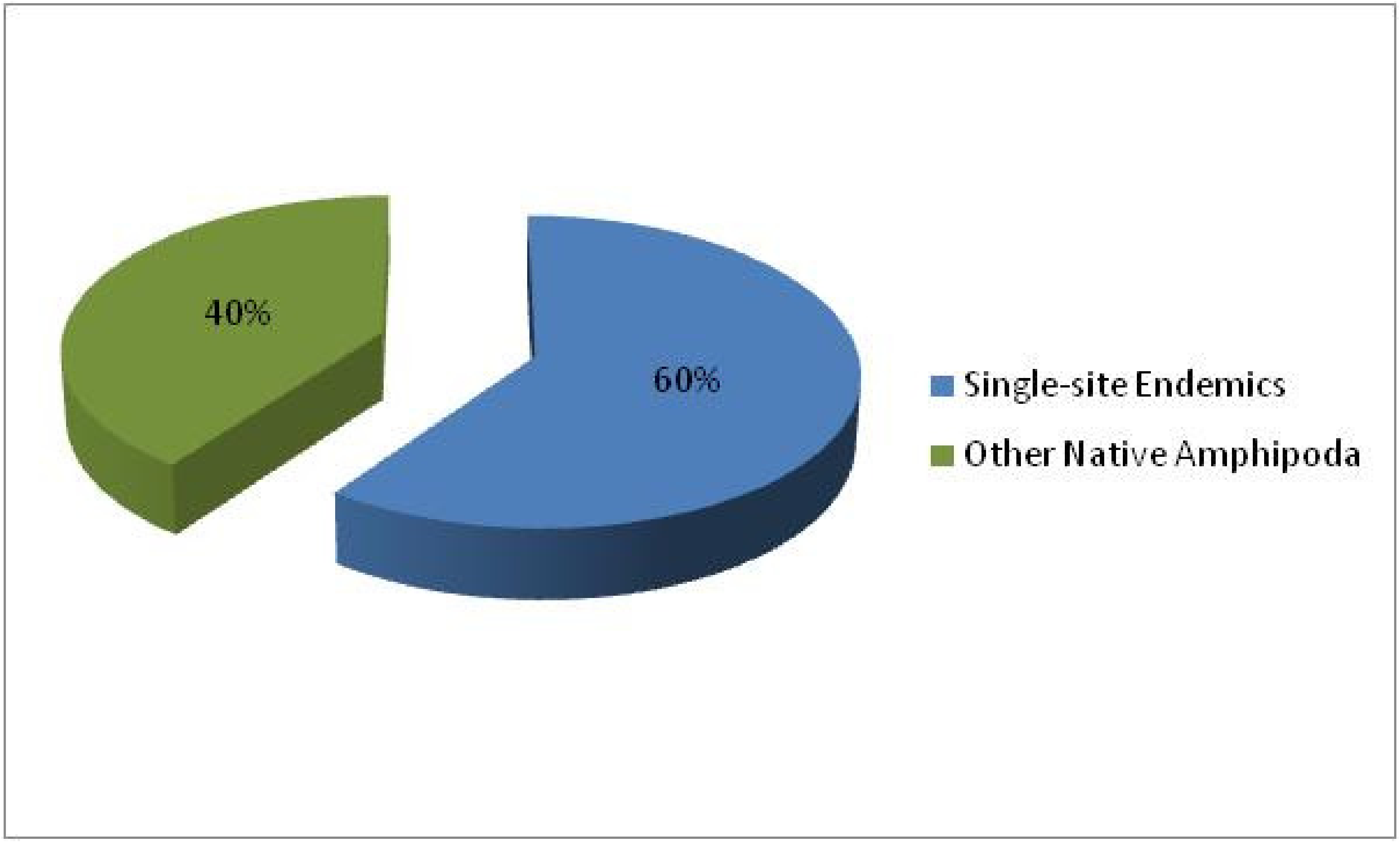
Californian (FW) Diversity

- 46 native taxa
- 16 exotic taxa

- CA is under-inventoried + taxonomic crisis



The majority of Californian taxa are either stenohaline, cold stenotherms (subterranean obligates) or invasive, euryhaline species.



What is also remarkable about California's native amphipod fauna is its narrow endemism: 60% of the taxa are restricted to a single body of water

High Endemism

- 24 species are known only from California
- 19 species are restricted to a single body of water
  - singletons
  - typically 1 spring or 1 cave stream
  - 2 spp. in Lake Tahoe benthos
- 3 species are known from only two sites
  - doubletons

THE CALIFORNIA CHECKLIST

FAMILY AMPITHOIDAE

- 3 species (euryhaline)

Family ANISOGAMMARIDAE

Eogammarus

Family ANISOGAMMARIDAE

- *Anisogammarus pugettensis* (euryhaline)
- *Eogammarus confervicolus* (euryhaline)
- *Ramellogammarus californicus* (stenohaline, singleton)
- *Ramellogammarus columbianus* (hyporheic)
- *Ramellogammarus oregonensis*
- *Ramellogammarus ramellus*

Family AORIDAE

- *Grandidierella japonica* (euryhaline, exotic)
- *Microdeutopus gyrllotalpa* (euryhaline, exotic)

Grandidierella japonica

Family COROPHIIDAE

Corophium

Family COROPHIIDAE

(tube builders, burrowers, etc.)

- *Americorophium salmonis* (euryhaline)
- *Americorophium spinicorne* (euryhaline)
- *Americorophium stimpsoni* (euryhaline)
- *Corophium louisianum* (euryhaline, exotic)
- *Sinocorophium alienense* (euryhaline, exotic)

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Family COROPHIIDAE

- *Sinocorophium heteroceratum* (euryhaline, exotic)
- *Monocorophium acherusicum* (euryhaline, exotic)
- *Monocorophium insidiosum* (euryhaline, exotic)
- *Monocorophium uenoi* (euryhaline, exotic)
- *Paracorophium* sp. (euryhaline, exotic)

Family CRANGONYCTIDAE

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- *Crangonyx floridanus* (exotic, stenohaline)
- *Crangonyx pseudogracilis* (exotic, stenohaline)
- *Crangonyx richmondensis* Ellis' Bog Amphipod (stenohaline)
- *Stygobromus*

Stygobromus

Photo by Dr. Jean Krejca

Stygobromids

- cold stenotherms
- extreme k-selection
  - long life span
  - slow metabolism = adapted to oligotrophic waters
- Singletons, Doubletons = Narrow Endemics
- Sensitive to Pollution

- Stygobionts
- Phreatobionts
- Hyporheics

} Hypogean

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Stygobromus

- *Stygobromus cherylae* (phreatobioint, singleton)
- *S. cowani* (phreatobioint, singleton)
- *S. gallawayae* (phreatobioint, singleton)
- *S. gradyi* (stygobioint)
- *S. grahami* (stygobioint)
- *S. harai* (stygobioint)
- *S. hyporheicus* (hyporheic; singleton; historic)
- *S. imperialis* (stygobiont, singleton)
- *S. lacicolus* (benthic; singleton; also Nevada)

Stygobromus

- *S. mackenziei* (stygobiont, singleton)
- *S. myersae* (phreatobioint)
- *S. mysticus* (phreatobioint, singleton)
- *S. rudolphi* (phreatobioint, singleton)
- *S. sheldoni* (phreatobioint, singleton)
- *S. sierrensis* (phreatobioint, singleton)
- *S.* sp. nov. (*hubbsi* group) (hyporheic, singleton)
- *S.* sp. nov. (Sonoma Co.) (phreatobioint, singleton)

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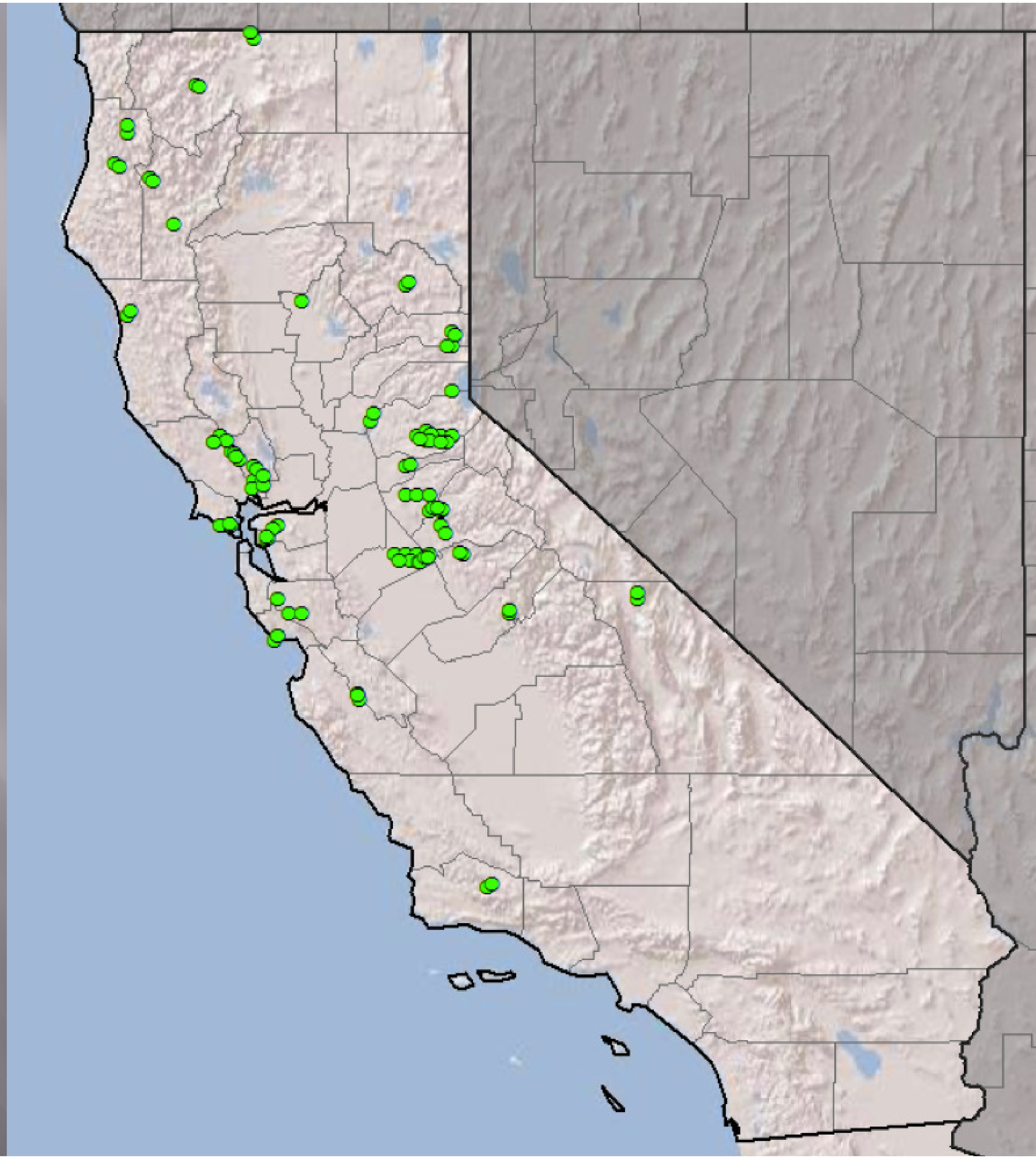
Stygobromus

- *S. tahoensis* (benthic; singleton; also Nevada)
- *S. trinus* (stygobiont, singleton)
- *S. wengerorum* (stygobiont, doubleton)
- *S.* sp. nov. aff. *imperialis* (phreatobioint, singleton)
- *S.* sp. nov. aff. *mackenziei* (hyporheic, singleton)
- *S.* sp. nov. cf. *mackenziei* (hyporheic)
- *S.* sp. nov. aff. *sierrensis* (phreatobioint, singleton)



Family GAMMARIDAE

Family GAMMARIDAE

- *Gammarus daiberi* Bousfield 1969 (exotic)
- *Gammarus lacustris sensu lato* (native?)
- *Gammarus mucronatus* (exotic)

Family HYALELLIDAE

Family HYALELLIDAE

- *Hyalella azteca sensu lato*
- *Hyalella muerta* Death Valley Amphipod (doubleton)
- *Hyalella sandra* (doubleton)
- *Hyalella* sp. nov
- 33 provisional species (haplotypes) present in the Great Basin ecoregion of California and Nevada (Witt et al. 2006).

Hyalella azteca sensu lato

- Cosmopolitan in California
- Native + introductions
- Polyphyletic = *Hyalella* sp.
- Tolerant of high temperatures & salinities

Other Families

- HYALIDAE
- ISAEIDAE
- MELITIDAE
- PONTOGENEIIDAE

Taxonomic keys

- Very few comprehensive keys
- None for the California fauna
  - except for Rogers (2005)
- Part of the Taxonomic Crisis

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Impacts of Invasives

- Alteration of aquatic food webs
- Transmission of parasites
- Ship and harbor fouling
- Cause the disappearance of native taxa
  - competition
  - displacement
  - direct predation

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Impacts of Invasives

- Transportation is the major species dispersion vector
  - Globalization of international trade
- 7,000 marine and coastal species travel across the world's oceans every day
- 84% of the world's marine regions reported invasive species in 2008
  - primarily shipping
- Ship's Ballast Water

Source: Ba et al., 2010

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Open Niches, Ideal Conditions

- Carlton (1979) identifies the factors needed for a successful estuarine introduction
- = habitat alteration and synanthropy
- Sediment Pollution (from Hydraulic Mining) Created New Niche for tube-builders/burrowers

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Ship's Ballast Water

Current recommended solution:

- Open ocean exchange of ballast water
- Elimination of organisms using chemicals

Source: Ba et al., 2010

Research Goals

- Create checklist
- Find / create keys
- Solicit additional records and specimens
- Explore zoogeographic patterns
- Update Natural Heritage Ranks (CNDDB)

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Soliciting additional records and specimens

- Send to:

G.O. Graening
Department of Biological Sciences
California State University, Sacramento
6000 J Street, Sacramento, CA 95819
graening@csus.edu
916.452.5442

- Collaborating Taxonomist: Dr. John Holsinger

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Explore Zoogeographic Patterns

- Marine invasions of freshwaters
- Bousfield and Morino (1992) hypothesize that the limits of Pleistocene (Wisconsin) glaciation explain the distribution of some amphipods (e.g. *Rammellogammarus*).
- Gammaridea demonstrate a preference for cold water (Barnard and Gray 1969)
- Faultlines as dispersal corridors

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update Natural Heritage Ranks (CNDDB)

Taxon	Current Rank	Suggested Rank	Niche, endemicity, etc.
Americorophium salmonis	GNR, SNR		euryhaline
Americorophium spinicorne	GNR, SNR	S4	euryhaline
Americorophium stimpsoni	GNR, SNR	S3	euryhaline; rare, according to Chapman (2007)
Ampithoe lacertosa	GNR, SNR		euryhaline
Ampithoe simulans	GNR, SNR		euryhaline
Ampithoe valida	GNR, SNR		euryhaline
Anisogammarus pugettensis	GNR, SNR		euryhaline
Apohyale pugettensis	GNR, SNR		euryhaline
Cheirimedeia macrocarpa	GNR, SNR	SNA	euryhaline, exotic
Corophium louisianum	GNR, SNR	SNA	euryhaline, exotic
Crangonyx floridanus	G5, SNA		stenohaline, exotic
Crangonyx pseudogracilis	G5, SNR	SNA	stenohaline, exotic
Crangonyx richmondensis	G5, SNR	S1	stenohaline
Elasmopus antennatus	GNR, SNR	SNA	euryhaline, exotic
Eogammarus confervicolus	GNR, SNR		euryhaline
Eohaustorius estuarius	GNR, SNR		euryhaline
Gammarus daiberi	GNR, SNR	SNA	euryhaline, exotic
Gammarus lacustris sensu lato	GNR, SNR	G5Q, S1	stenohaline; may be polyphyletic
Gammarus mucronatus	GNR, SNR	SNA	stenohaline, exotic
Grandidierella japonica	GNR, SNR	SNA	euryhaline, exotic
Hyalella azteca sensu lato	G5, SNR	G5Q, S5	stenohaline? polyphyletic
Hyalella muerta	G1, S1		phreatobioint, doubleton
Hyalella sandra	G1, S1		phreatobioint, doubleton
Hyalella sp. nov.		GU, SU	phreatobioint, 33 provisional species

Bioindicators

- Presence / absence of rare (indicator) taxa
- Stygobromids – highly endemic & susceptible to pollution
- Proposed are regional lists of indicator species that are not part of SWAMP score
  - non-numeric criteria?

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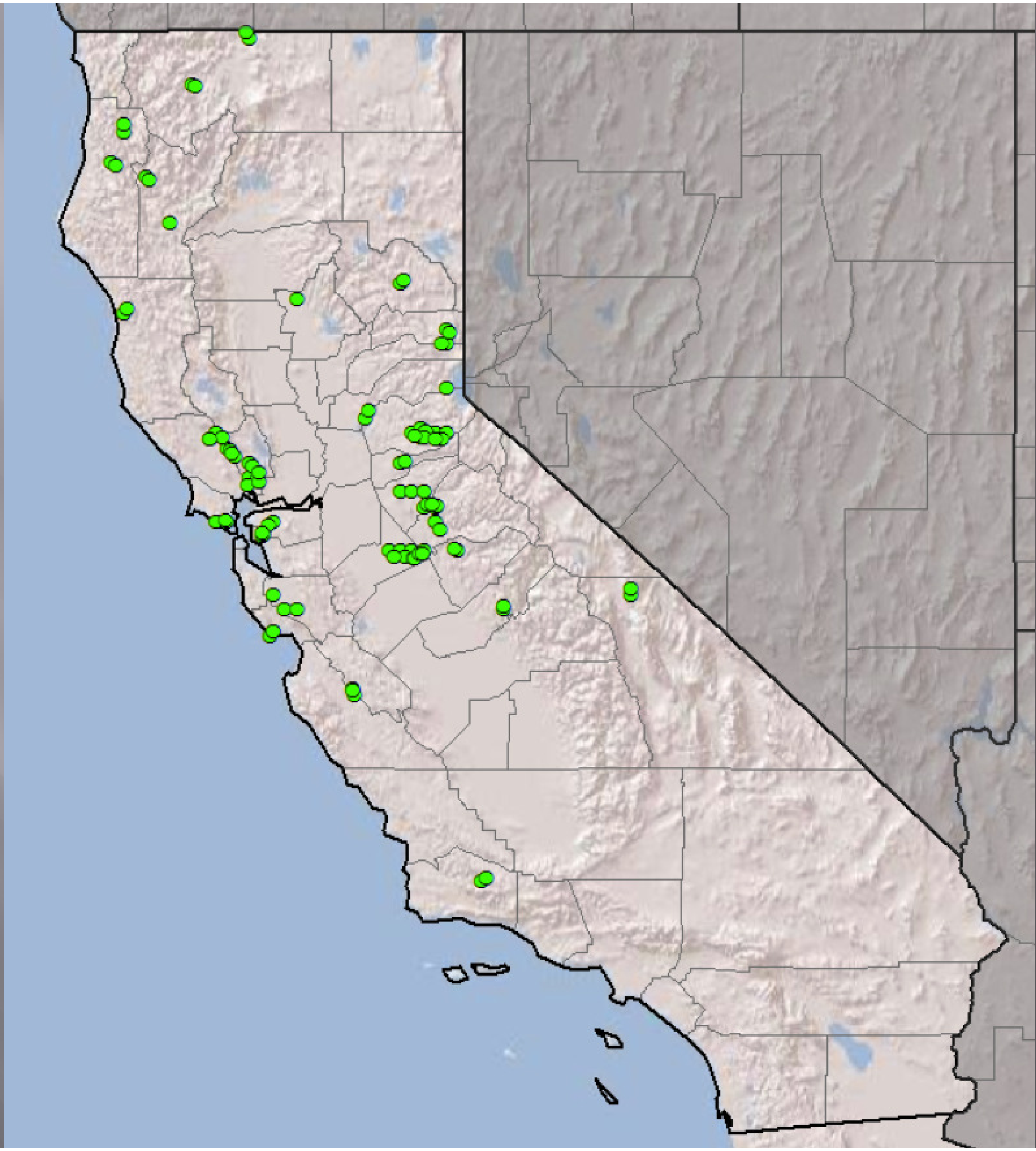

Bioindicators

- Differences in physiology and life history between epigean taxa and hypogean taxa result in differing responses to acute and chronic pollutant exposure
- Differences between amphipods and isopods

Epigean vs. Hypogean

- Example
- In general, epigean crustaceans have very little tolerance to conditions of severe hypoxia or anoxia (Zebe, 1991). Hypogean crustaceans, are generally more tolerant of anoxia (Hervant et al., 1995, 1996, 1997a).

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Epigean / Hypogean Ratio

- Epigean / Hypogean Fauna Ratio (Ronneberger 1975)
- Example: sewage introduced into an aquifer extirpated the hypogean organisms, while epigean fauna remained
- Thus the epigean/hypogean ratio shifted (Malard et al. 1994)

Amphipod / Isopod Ratio

- Even between stygobiotic species, pollution tolerances differ
- Amphipods are more susceptible to pollution than isopods (Whitehurst 1991; Simon and Buikema, Jr. 1997).

Amphipod / Isopod Ratio

- Amphipod / Isopod Ratio (Simon and Buikema 1997)
- The different pollution tolerances of amphipods and isopods could be useful in biomonitoring.
- In general, isopods are tolerant of pollution (Aston and Milner, 1980; Pennak, 1989; Malard *et al*., 1996; Simon and Buikema Jr., 1997).
- In Hidden River Cave, Kentucky, troglobiotic amphipods (*Crangonyx*) are found only in regions not stressed by pollution (Poulson, 1990).

Amphipod / Isopod Ratio

- Ratios of widespread species of isopods and amphipods (such as *Asellus* and *Gammarus*) are used to compare regional water-quality conditions (Naylor et al. 1990; Maltby 1991, 1995; Whitehurst 1991; Mullis et al. 1996; Thorp and Covich 2001)
- However, many California freshwaters are lacking in isopods

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