Science to Action:
Working Together to Build Resiliency at Lake Tahoe

Nearshore Water Quality and Aquatic Invasive Species

Agenda

2:00pm	**Introduce Panel and Topic**
2:10pm	**Panel Presentations:** Past-Present-Future of Science + Management Partnerships
2:50pm	**Questions for Clarification**
3:00pm	**Small Group Discussion:** Priority topics in Science and Management
3:20pm	**Small Group Reports and Panel Q and A**
3:45pm	**Final observations** and adjourn

Panelists

- **Dr. Steven Sadro**, UC Davis
- **Dr. Sudeep Chandra**, University of Nevada
- **Dr. Melissa Thaw**, Lahontan Regional Water Quality Control Board
- **Holly Holwager**, Nevada Department of Environmental Protection

- **Jesse Patterson** (Facilitator), League to Save Lake Tahoe

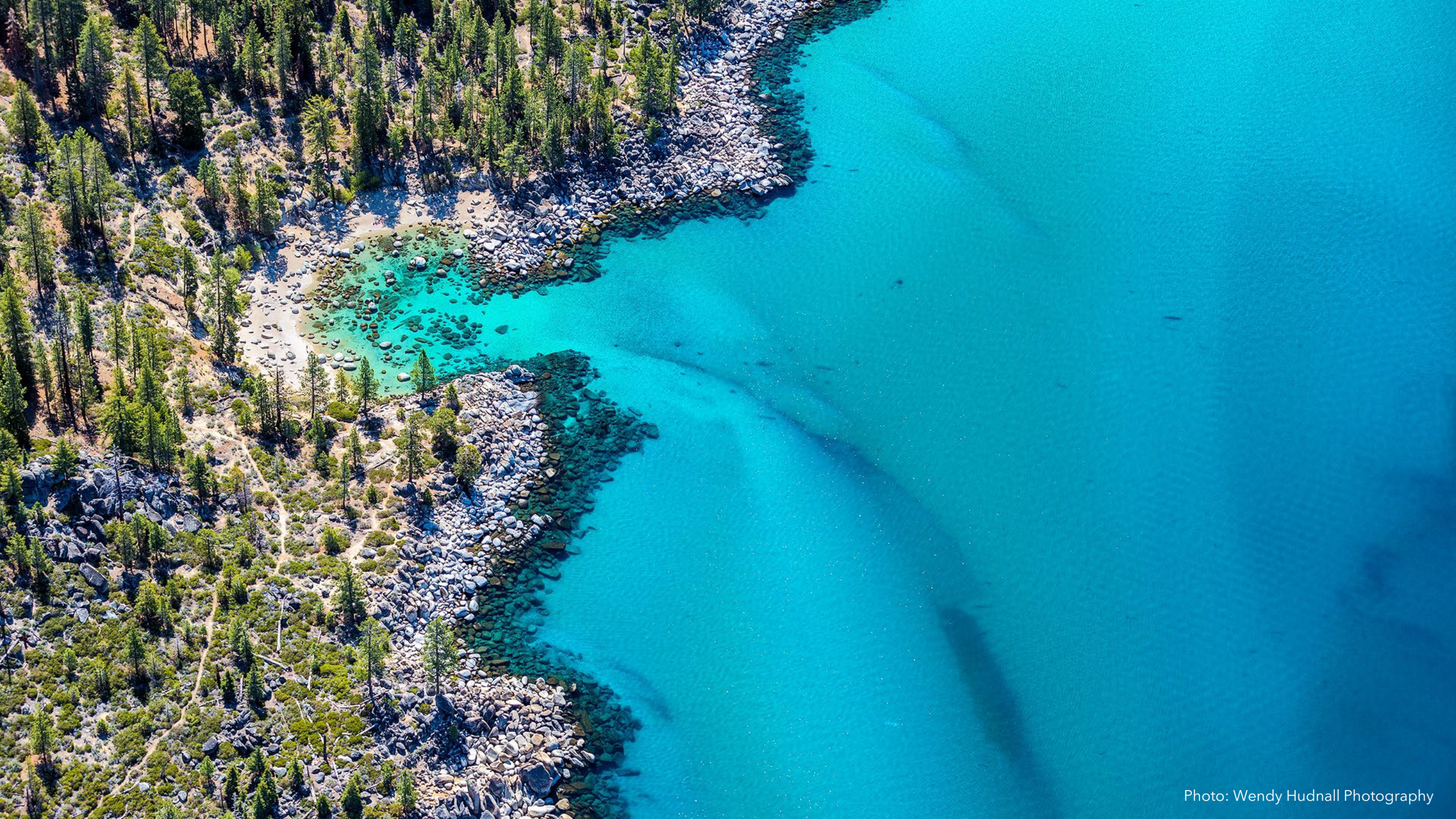


Photo: Wendy Hudnall Photography

Photo: Brandon Berry, UC Davis TERC

Ecosystem dynamics in Tahoe's nearshore waters

Sudeep Chandra: University of Nevada, Reno
Steve Sadro: University of California, Davis

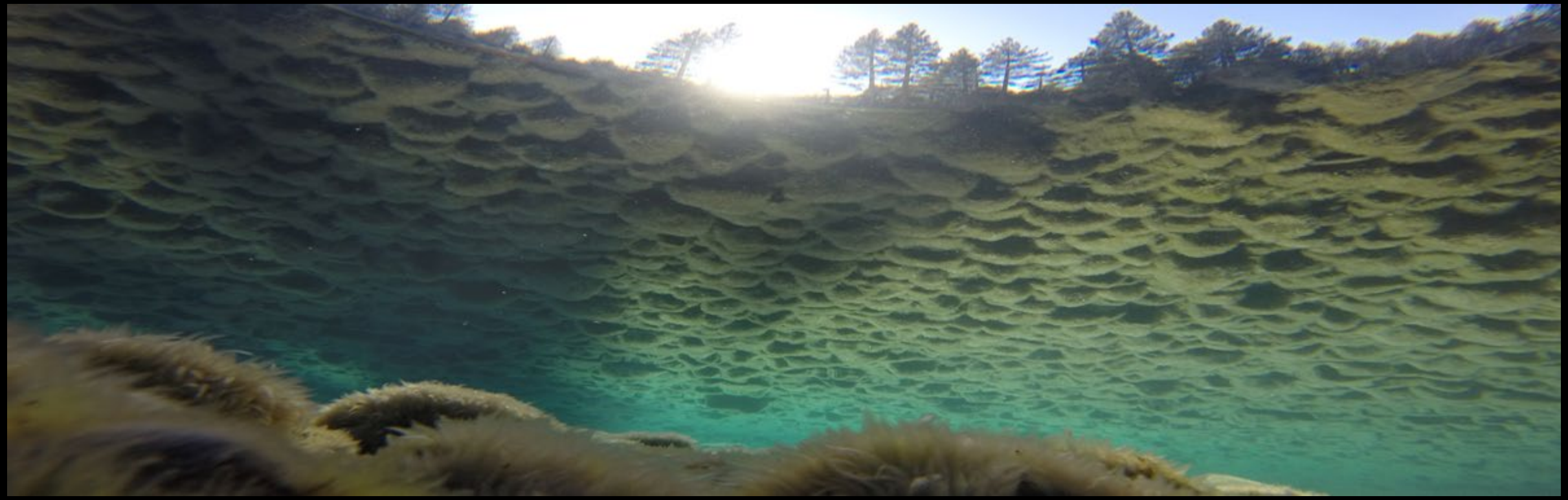


Photo credit: Ramon Naranjo

Presentation outline

Photo credit: Ramon Naranjo

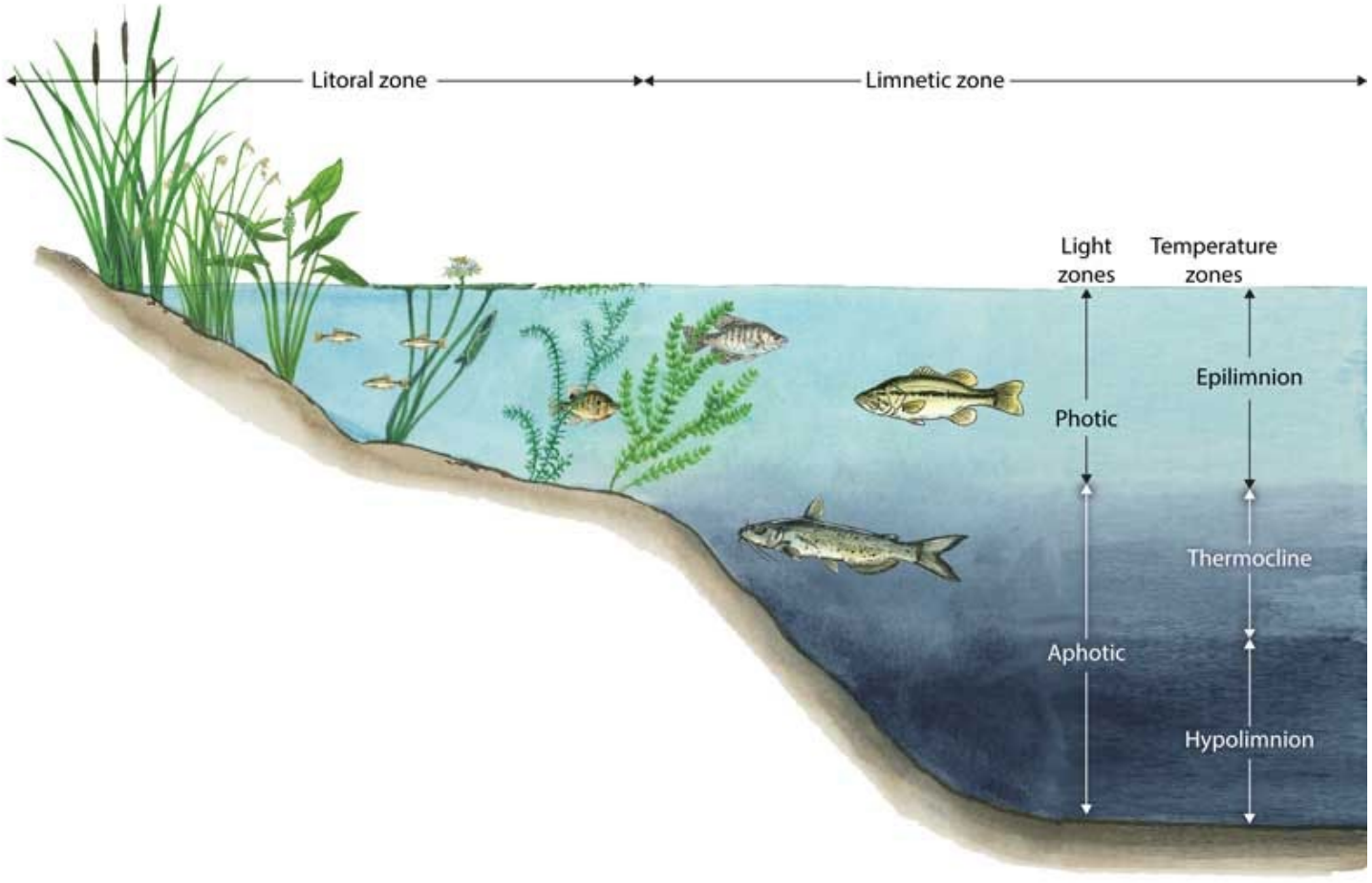
- Defining the nearshore
- Fundamentals of ecosystem function
- Periphyton and biofilms
- A conceptual model of environmental challenges the nearshore faces
- History of nearshore research
- Case studies of science in Tahoe's nearshore
- Looking towards the future

Why is the nearshore so important?

- Interface between terrestrial and aquatic ecosystems (ecotone)
- Hotspot for biogeochemical cycling of nutrients
- Hotspot for carbon transformations
- Critical habitat supporting highest density and greatest biodiversity of organisms
- Highly dynamic in space and time
- Area of the lake most visited by the public and recreationalists (beaches, launching boats, swimming, fishing)

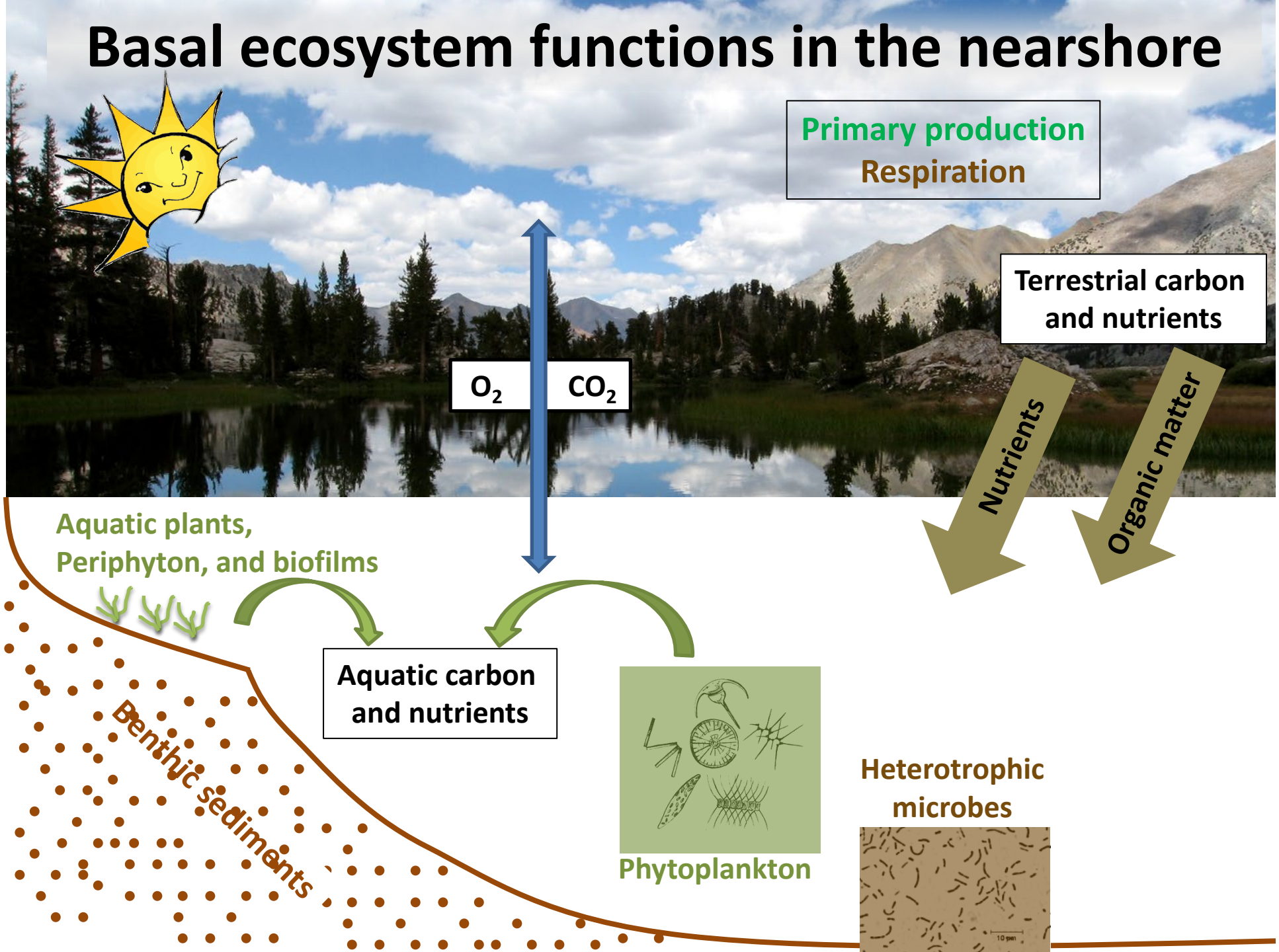
How do we define the nearshore?

Nearshore-littoral zones: defined in many different ways, most often on the basis of light availability, depth, and physical structure



- Light availability determines the distribution of algae and microbial communities (periphyton and biofilms)
- Slope and composition of the bottom affect who can grow and live there
- Hydrodynamics affect temperature, turbidity (light), and nutrient concentrations

Basal ecosystem functions in the nearshore



Periphyton and biofilm

All photosynthesizing algae and microbes attached to the bottom and the community of other organisms that they support

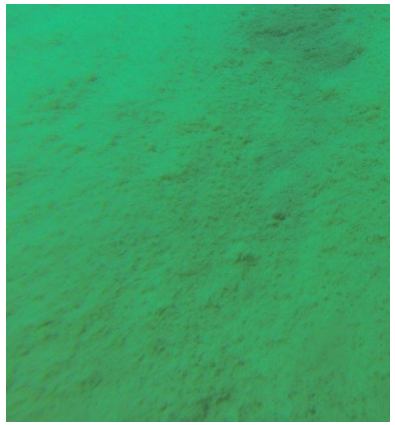
At Tahoe we have focused on understanding the growth of algae called periphyton but in reality we should focus on the combination of algae and bacteria known as biofilm

Importance of periphyton and biofilm

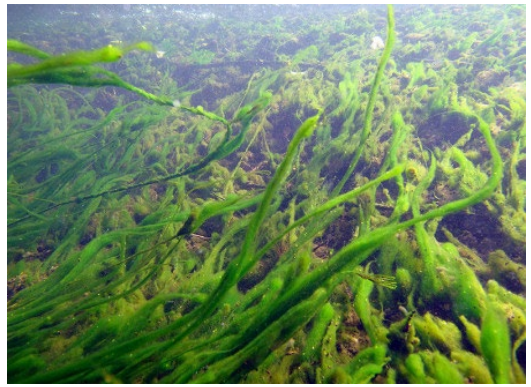
- Support the base of the food web, feeding the invertebrates and fishes
- Drive the majority of carbon and nutrient cycling
- Determine whether lakes are net sinks or sources of CO_2 to the atmosphere
- Provided habitat supporting biodiversity

Species that grow on stones: **epilithon**

Species that grow on fine grained sediment: **epipelon**



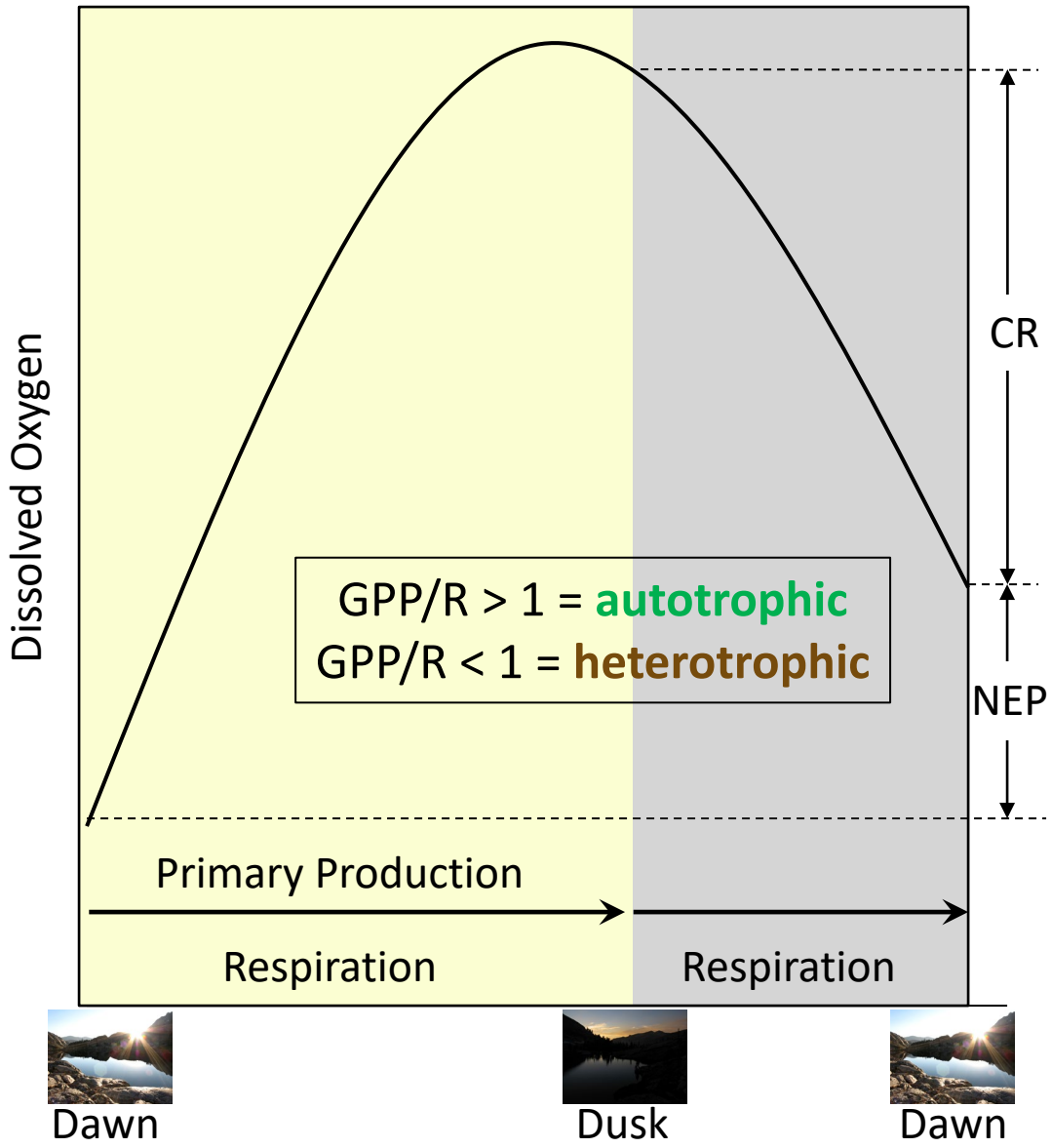
Species that grow on plants: **epiphyton**



Species that grow free floating: **metaphyton**

Photo Credits: Katie Senft, Brant Allen, and Goldsborough et. al 2005

Ecosystem metabolism –fundamentally structures ecosystems



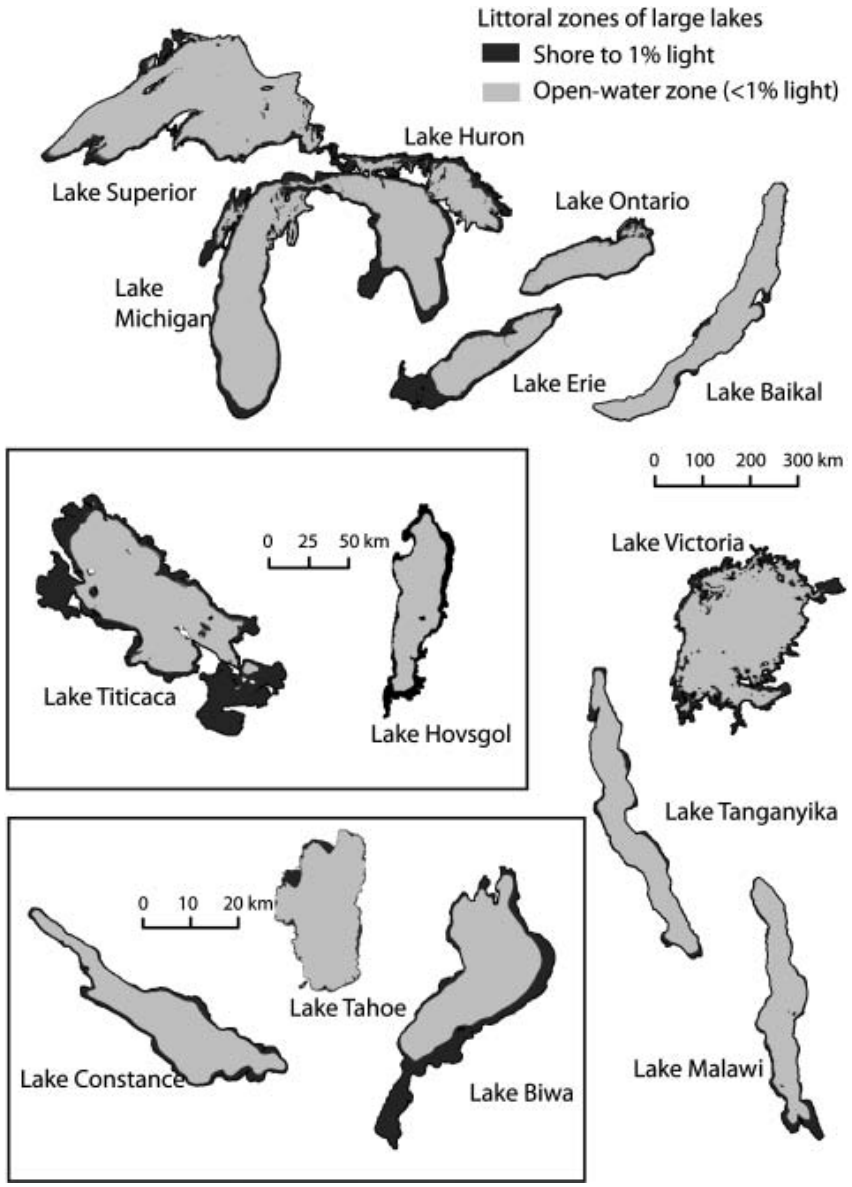
Gross Primary Production (GPP)

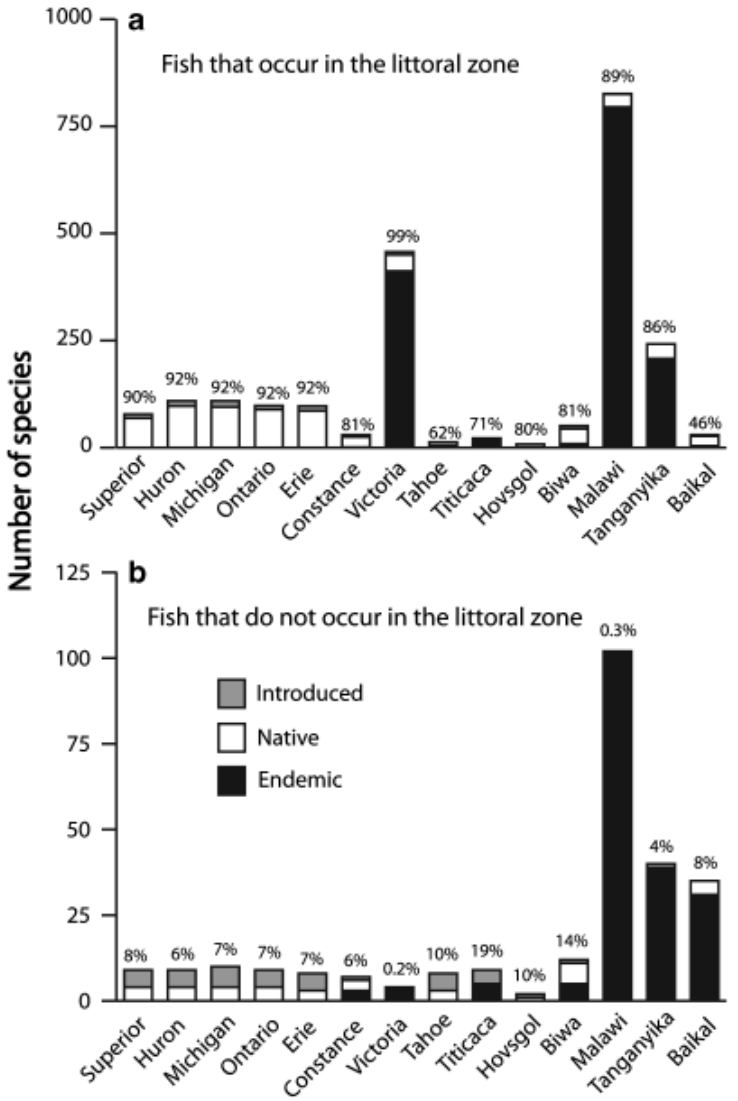
Community Respiration (CR)

Net Ecosystem Production (NEP)

NEP = GPP - R

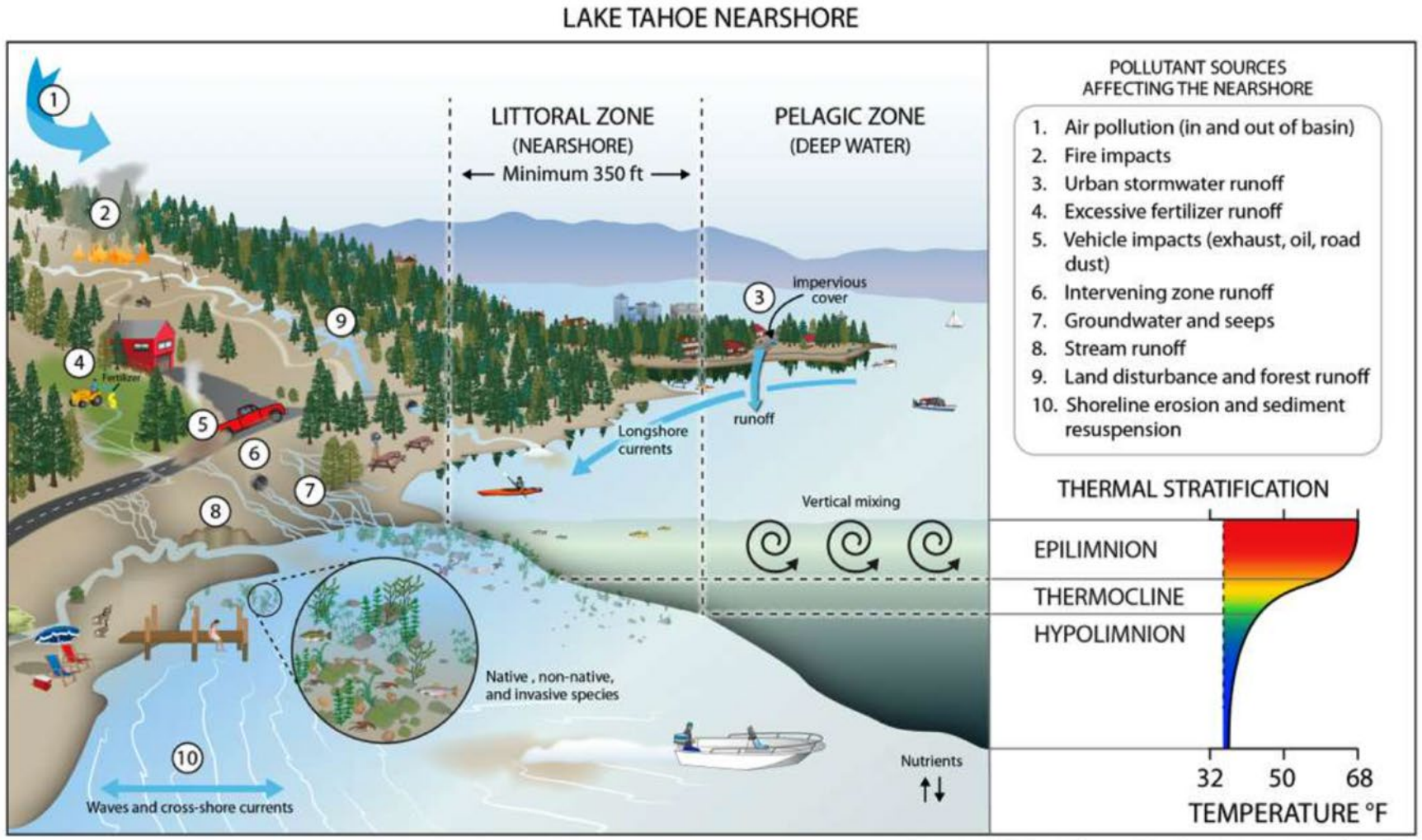
Nearshore is a hotspot of biodiversity in most lakes





- Small proportion of surface area
- Large proportion of biodiversity and energy cycling

Challenges the nearshore faces



Illustration, LJ Wable and A Heyvaert (Desert Research Institute), with additonal clip art contributions courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

Figure 1-2. Illustration of important factors and processes affecting the lake nearshore environment.

- Warming waters
- More storminess and greater organic matter and nutrient loads from the watershed
- Eutrophication
- Non-native species introductions
- Changes in food web structure
- Altered periphyton and biofilm communities and ecosystem function
- Plastics and trash

Presentation outline

Photo credit: Ramon Naranjo

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Significant effort to understand the nearshore was undertaken 10 years ago by scientists and managers to address nearshore issues – we do not have to reinvent the wheel.

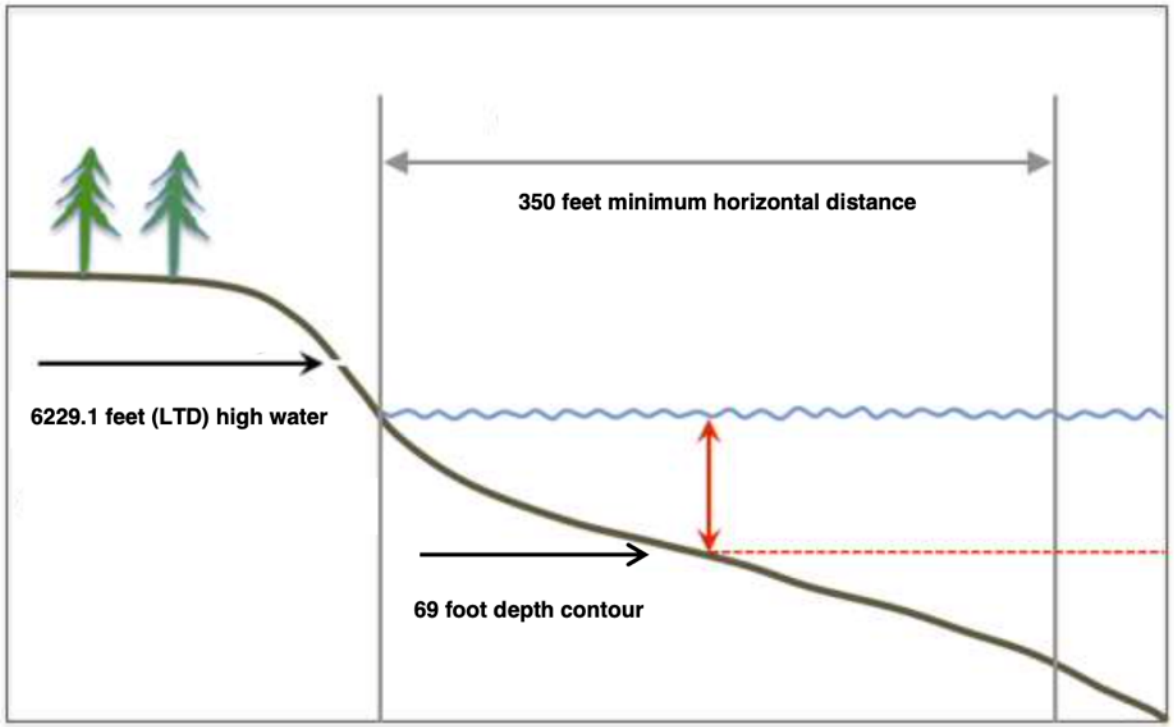
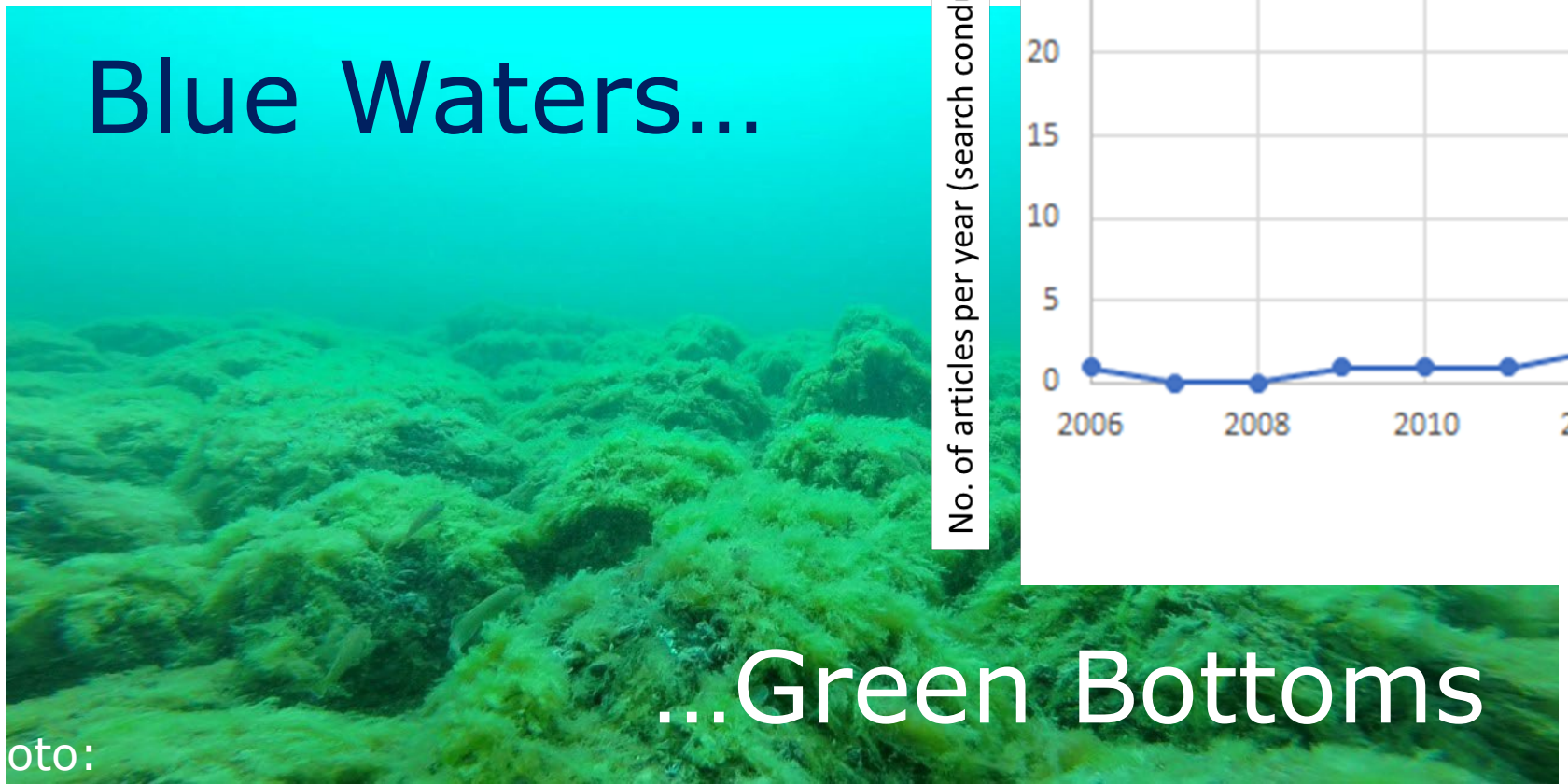


Figure 4-2. Lake nearshore area for monitoring and assessment, defined at the summer thermocline depth (typically 69 feet) or at 350 feet from the shoreline, whichever is greater. The depth and minimum lateral distance are taken from existing lake level rather than the high water level.

Nearshore Evaluation and Monitoring Framework (Heyvaert et al, 2013)

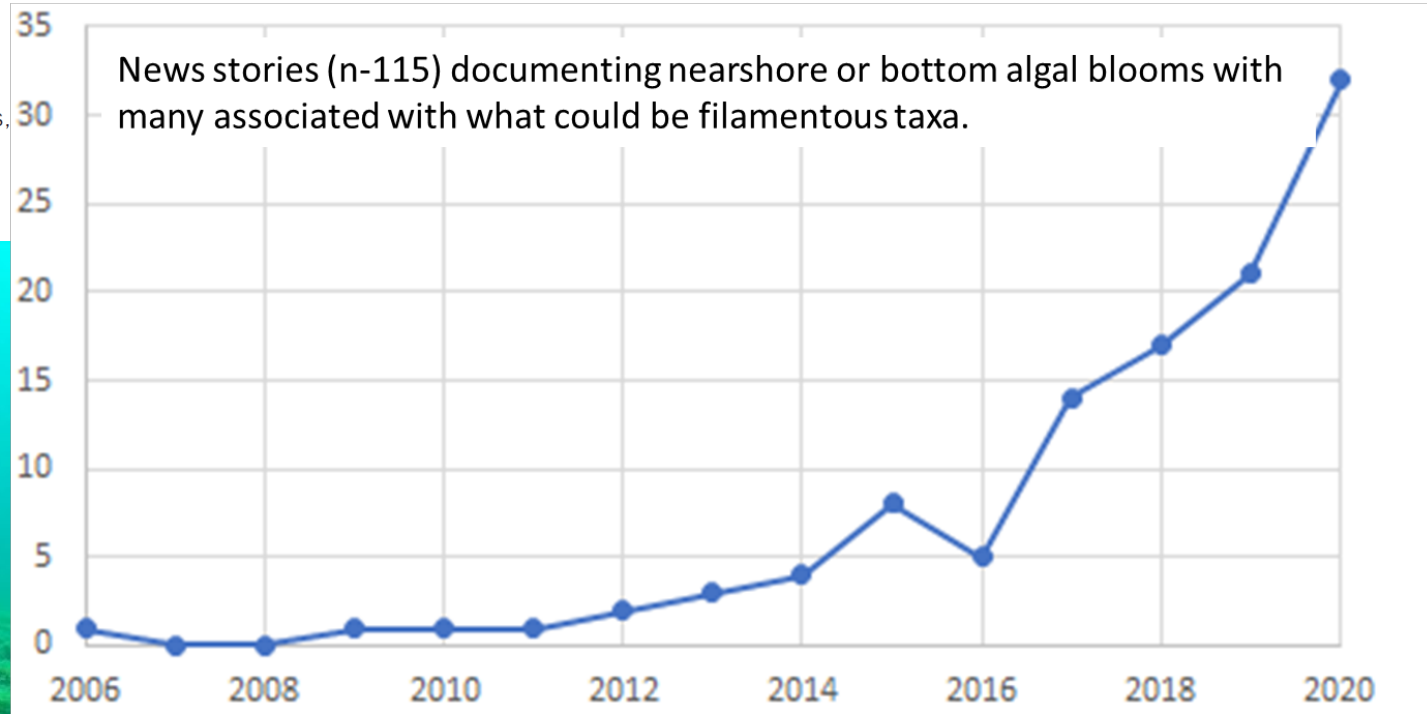
Blue Waters, Green Bottoms: Benthic Filamentous Algal Blooms Are an Emerging Threat to Clear Lakes Worldwide

YVONNE VADEBONCOEUR, MARIANNE V. MOORE, SIMON D. STEWART, SUDEEP CHANDRA, KAREN S... NS,
JILL S. BARON, KEITH BOUMA-GREGSON, SOREN BROTHERS, STEVEN N. FRANCOEUR, LAUREL GENZO...
SCOTT N. HIGGINS, SABINE HILT, LEON R. KATONA, DAVID KELLY, ISABELLA A. OLEKSY, TED OZERSKY...
MARY E. POWER, DEREK ROBERTS, ADRIANNE P. SMITS, OLEG TIMOSHKIN, FLAVIA TROMBONI, M. JAK...
VANDER ZANDEN, EKATERINA A. VOLKOVA, SEAN WATERS, SUSANNA A. WOOD, AND MASUMI YAMAMU...



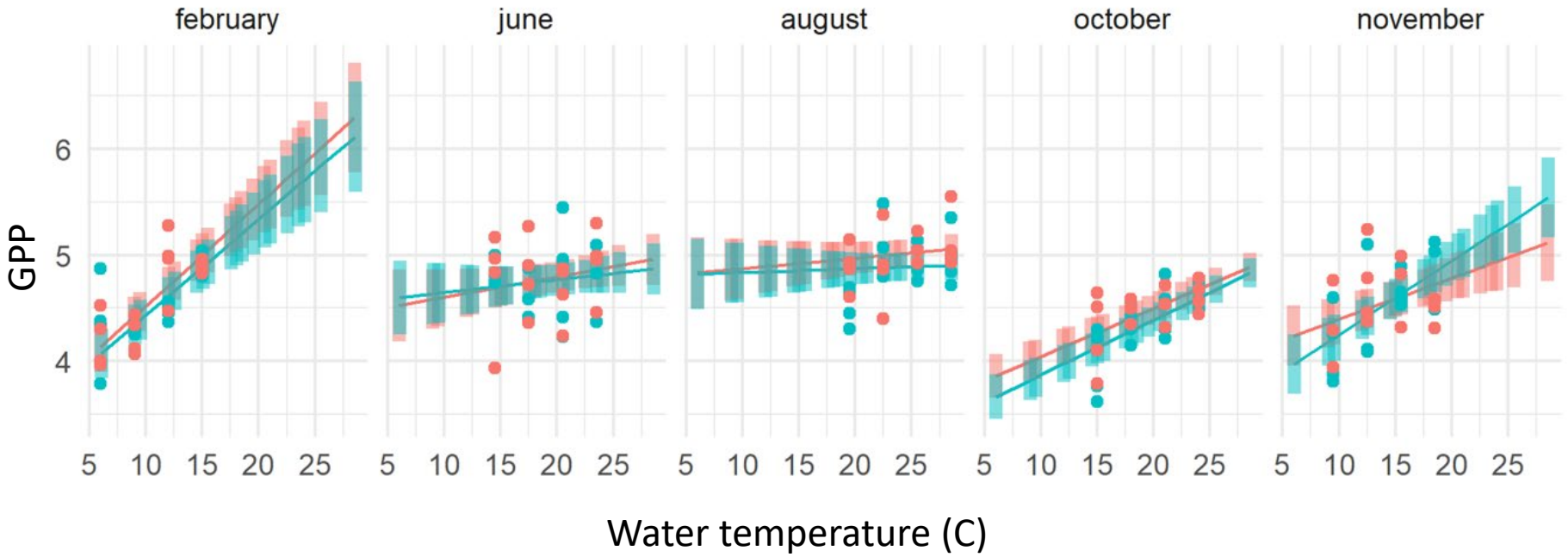
oto:

We are not alone! The bottom waters of some lakes are greening worldwide – what can we do about it?



Warming waters stimulate increased algal and bacterial growth nearshore

- 4-7 % increase in NEP per 1 °C of warming
- Effect is largest in the warmest months (autumn/winter)
- Laboratory evidence suggests that warming alone over the last 30 years would cause significant increase in periphyton biomass



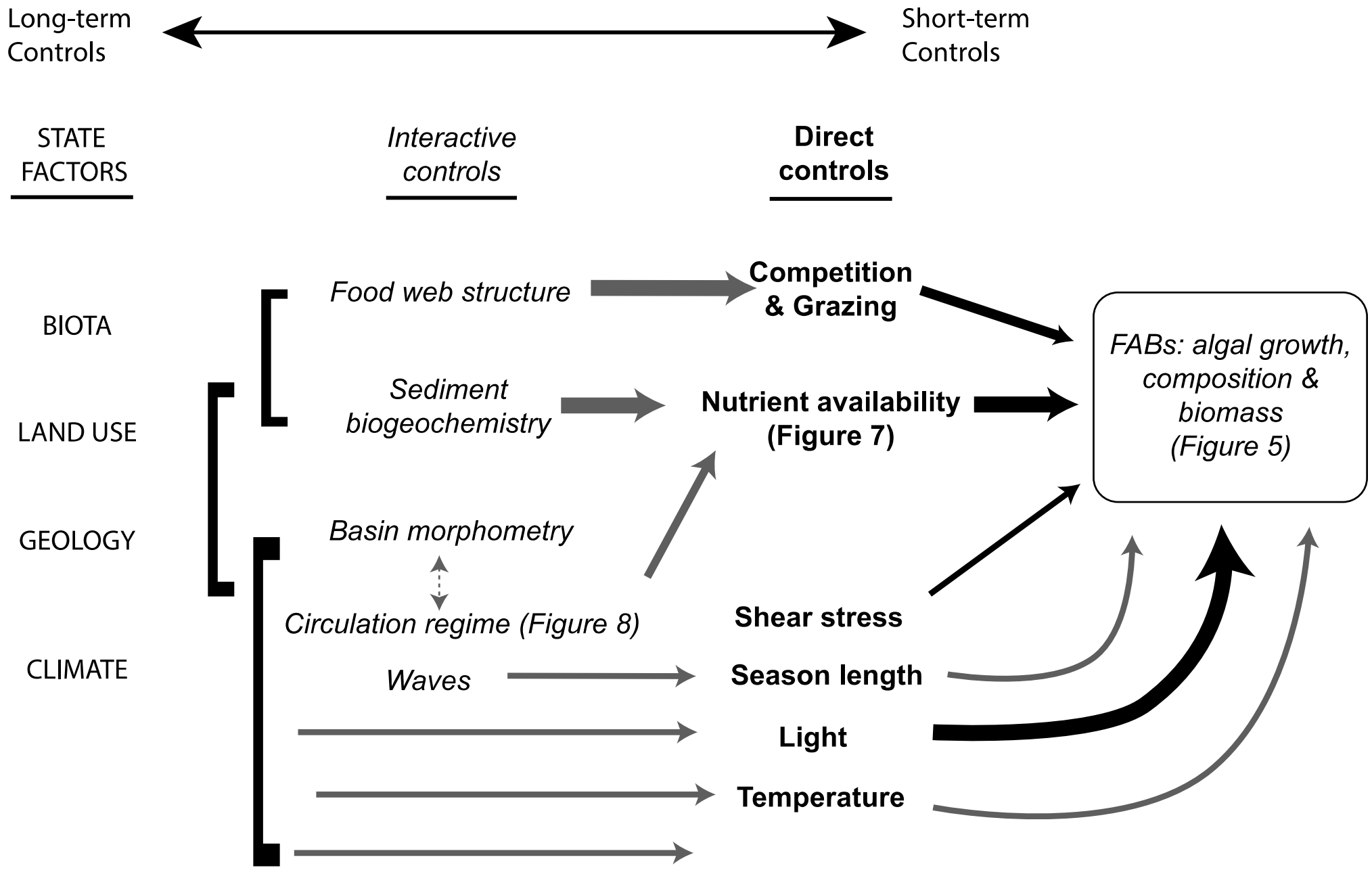

Long-term Controls
Short-term Controls
STATE FACTORS
Interactive controls
Direct controls
BIOTA
LAND USE
GEOLOGY
CLIMATE
Food web structure
Competition & Grazing
Sediment biogeochemistry
Nutrient availability (Figure 7)
Basin morphometry
Circulation regime (Figure 8)
Shear stress
Waves
Season length
Light
Temperature
FABs: algal growth, composition & biomass (Figure 5)

Figure 2. (a) On the southeast shore of Lake Tahoe in Marla Bay, a benthic FAB composed of Zygnema has occurred sporadically in summer since 2008 when this photo was taken. Photograph: Elena Wave. (b) On the west shore of Lake Tahoe, a FAB develops because of seasonal variation in groundwater inputs of nitrogen and phosphorus that are driven by hydroclimate. Attached algal biomass, as chlorophyll a, is correlated with groundwater nutrient concentrations. This algal biomass is low in November, but a robust biofilm develops and persists through the winter. In spring, the algae are senescing. By June, filamentous algae are bleached and chlorophyll is again low. Photographs: Naranjo and colleagues (2019).

Lake Tahoe - increases in nearshore algal growth due to groundwater inputs and changes to biological assemblages from invasive species.

Journal of Hydrology 568 (2019) 877–890

Linkages between hydrology and seasonal variations of nutrients and periphyton in a large oligotrophic subalpine lake

Ramon C. Naranjo[a], Richard G. Niswonger[b], David Smith[a], Donald Rosenberry[c], Sudeep Chandra[d]

However, existing, 37 years of monitoring does not indicate that algal biomass has increased over time in the very edge of the lake.

PRIMARY RESEARCH PAPER

Variability in periphyton community and biomass over 37 years in Lake Tahoe (CA-NV)

Karen S. Atkins · Scott H. Hackley · Brant C. Allen · Shohei Watanabe · John E. Reuter · S. Geoffrey Schladow

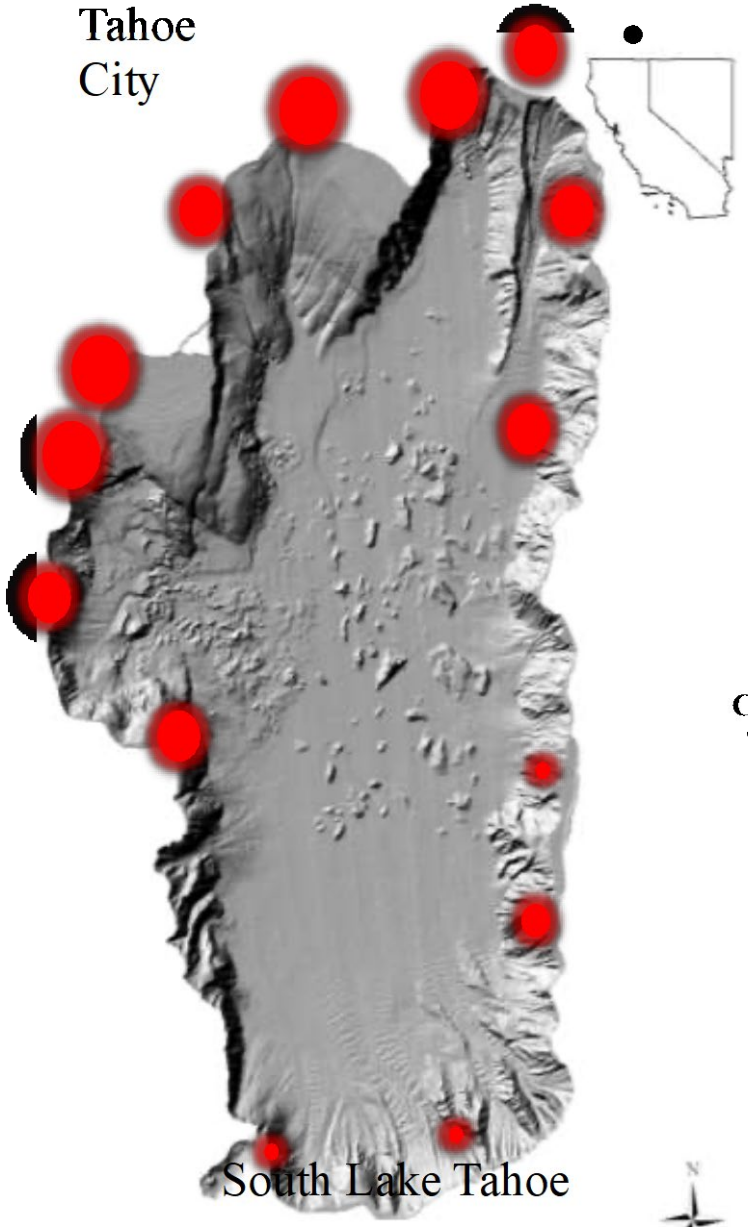
Since the 1980s, all invasive species have established in the nearshore

2 plants (milfoil and curly leaf pondweed), 5 warmwater fish (e.g., bass, bluegill, goldfish, crappie), 2 invertebrates (clams and snails)

Coldwater crayfish have differential controls on algae, sometimes reducing them and other times increasing algal mass. In neighboring Crater Lake they have reduced invertebrate snails which eat algae resulting in algal blooms.

Climate change facilitation of warmwater fishes, Asian clams, and probably crayfish like in Crater Lake.

Signal crayfish can live up to 10 years in age, affecting nearshore biofilms

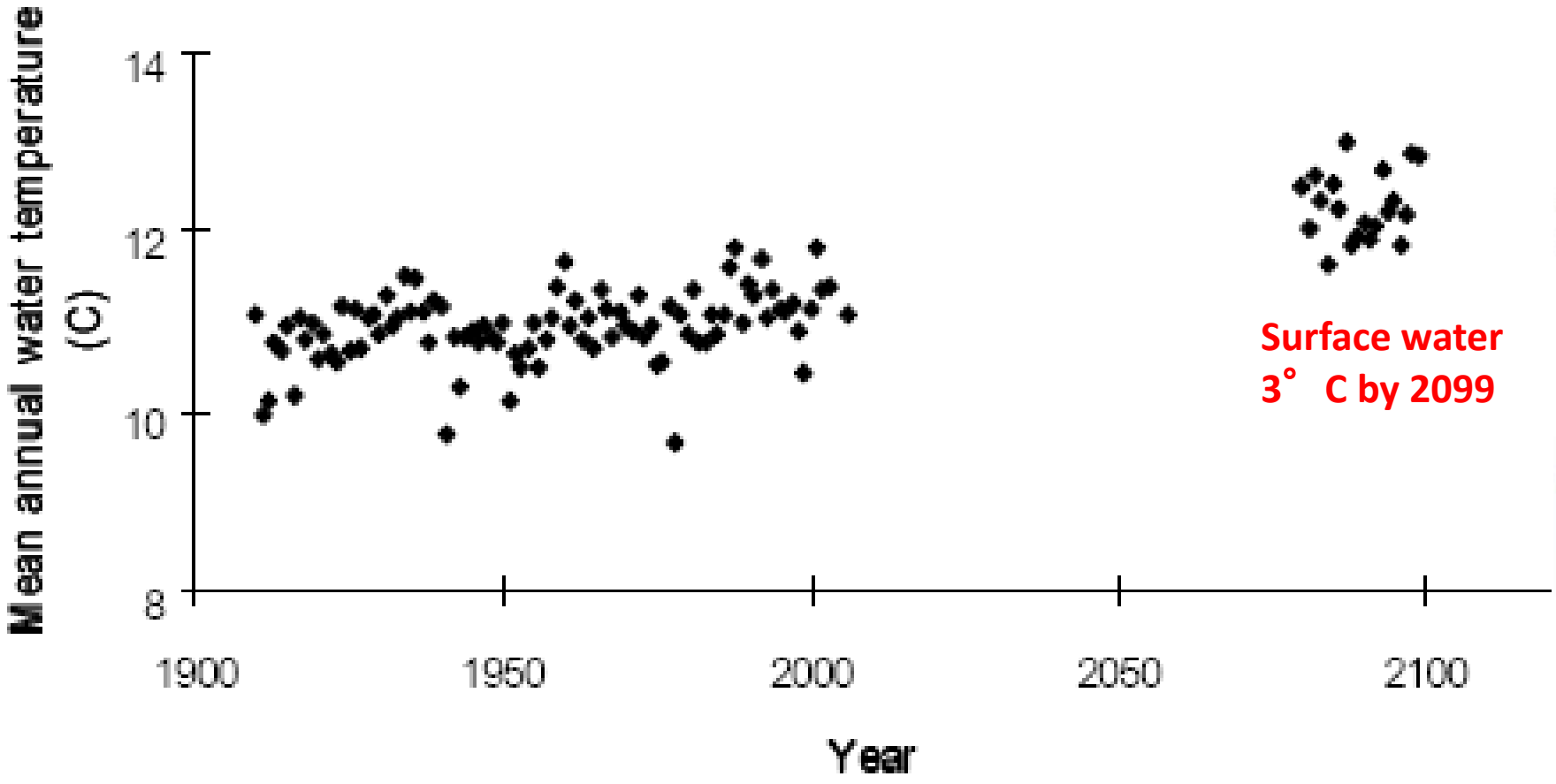


Crayfish lead to an increase in algal biomass in Fall with a enchanced species dominance of *Epithemia* species and cyanobacteria.

In the summer, there is a reduction in algal biomass and the dominance of the community changes to diatoms, fragilarioid chains such as *Staurosirella* species.

Brant Allen, UC Davis TERC

The warming of the nearshore is predicted to increase the growth, spawning potential, and distribution of warmwater fish species



Surface water 3° C by 2099

Black bass

Black crappie

Bluegil

Brown bullhead

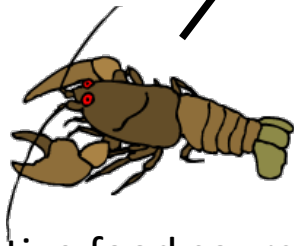
Goldfish

(Ngai, Shuter, and Chandra 2013, *Climate Change*)

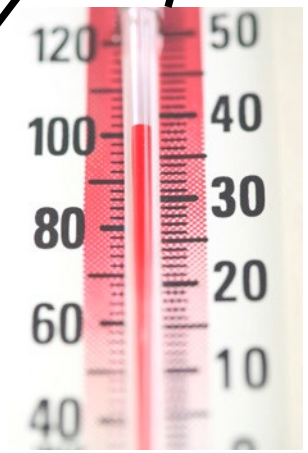
Temperature increases & the expansion of invasive plants is leading to the expansion of largemouth bass around the lake edges

Previous introduced spp. + climate driven temperature change faciltiate invasion by warmwater fish

habitat



nonnative food source



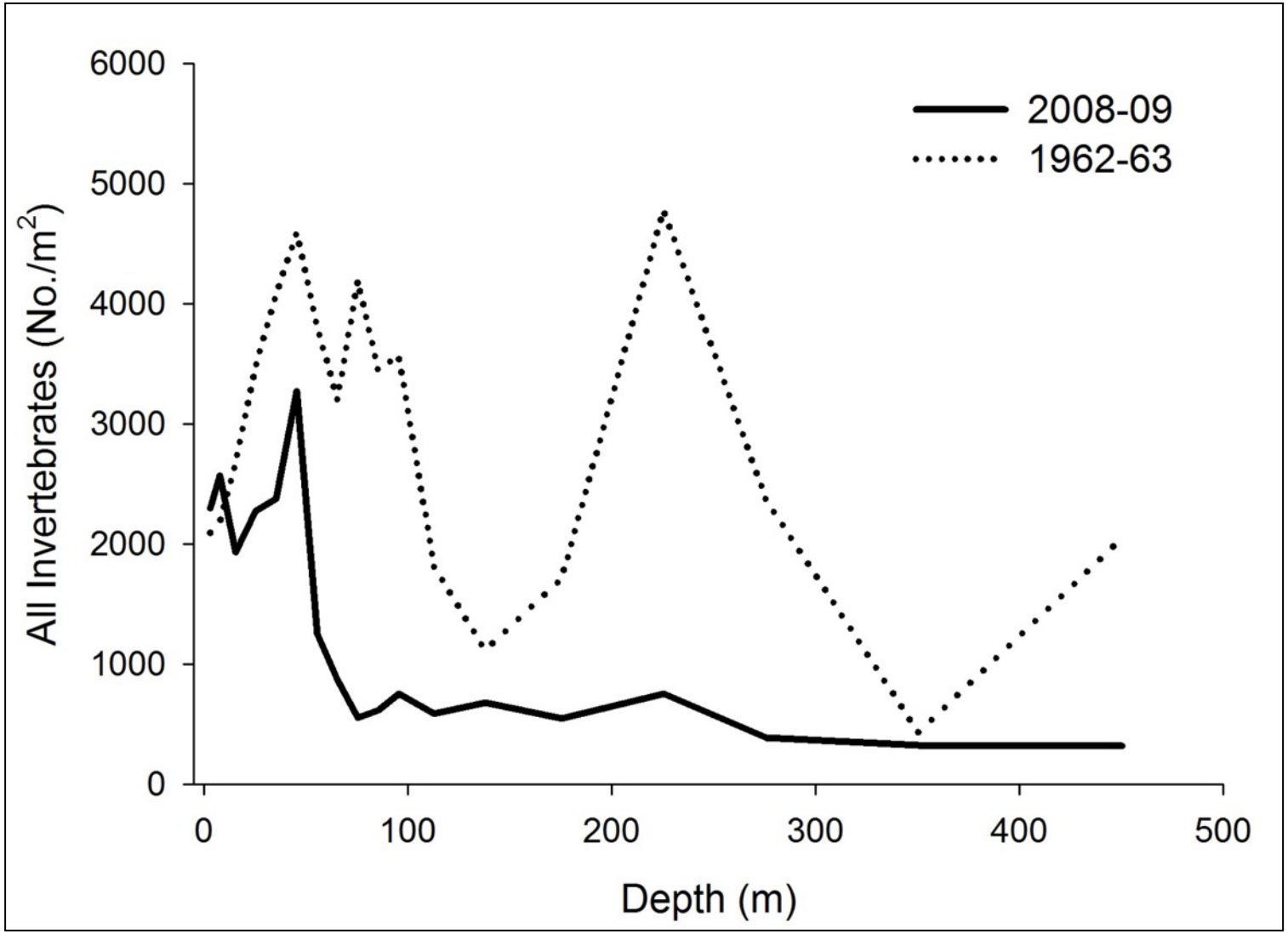
climate warming

Warmwater fish will
1) Increase nearshore N+P & reduce nearshore water quality
2) Reduce native fish species that have already declines 10 fold since the 1960's

N + P = ***clarity***

Thiede 1997, Vander Zanden et al. 2004, Kamerath et al. 2007

10 native, endemic “sensitive” species have declined up to 99% from the historical condition. What does this mean for functioning of the bottom of the lake? Is this change enhancing the stresses on the lake?



ZOOLOGGER 2 September 2016

Stonefly lays eggs or has live births depending on the season

Zoologger is our weekly column highlighting extraordinary animals – and occasionally other organisms – from around the world

Aquatic Ecosystems Analysis Laboratory | Department of Biology | University of Nevada, Reno

Caires et al. 2013.
Freshwater Science

Plastics – yes they are unsightly but how will they impact the lake's ecosystem?

Article | Published: 12 July 2023

Plastic debris in lakes and reservoirs

Veronica Nava, Sudeep Chandra, Julian Aherne, María B. Alfonso, Ana M. Antão-Geraldes, Katrin Attermeyer, Roberto Bao, Mireia Bartrons, Stella A. Berger, Marcin Biernaczyk, Raphael Bissen, Justin D. Brookes, David Brown, Miguel Cañedo-Argüelles, Moisés Canle, Camilla Capelli, Rafael Carballeira, José Luis Cereijo, Sakonvan Chawchai, Søren T. Christensen, Kirsten S. Christoffersen, Elvira de Eyto, Jorge Delgado, Tyler N. Dornan, ... Barbara Leoni + Show authors

Nature **619**, 317–322 (2023) | Cite this article

Where do we go from here? --Priority questions

- How does C and N cycling across hard and soft substrates vary around the lake with respect to different groundwater/surface water inputs?
- What are the implications of the loss of biodiversity on whole lake function including food web structure and nutrient and energy (carbon) cycling?
- What are the implications of climate change on nearshore land-water connections and nearshore processes?
- NZ mudsnails have been documented up to 800,000 snails per square meter in the literature? If this occurred at Tahoe, how would this affect the function of the lake's nearshore?
- What is the fate of plastics, do they contribute to growing biofilms and pathogens, How will they influence the ecology of the nearshore?
- How do nearshore processes influence offshore lake clarity?

TAHOE'S NEARSHORE

A Collaborative Effort to Protect Nearshore Water Quality

Nearshore Agency Roles

- Protect water quality through policy, regulation and/or interlocal agreements
- Fund and implement projects or programs that benefit the nearshore
- Collaborate with, and fund, research partners to gain a better understanding of lake processes
- Internal and public outreach

Protections in place that protect the nearshore

- Aquatic Invasive Species Program
- Lake Tahoe TMDL:
- > 600,000 lbs Fine Sediment Particles
- > 4,400 lbs N
- > 1,300 lbs P
- Sewage export[1](STPUD alone):
- > 37,400 lbs of P
- > 330,600 lbs of N

1. STPUD staff communication

Nearshore Agency Working Group

ALGAE

AQUATIC INVASIVE SPECIES

COMMUNITY STRUCTURE

NEARSHORE CLARITY

PUBLIC HEALTH

TRASH

Example of most recent collaboration: Caldor Fire and new Zealand mudsnails

- Tahoe RCD & TRPA Rapid Response Results
- Emergency funding

Aquatic Invasive Species Program

- AIS coordinating committee
- Nearshore Aquatic Weed Working Group (NAWWG)
  - Over 40 partners from federal, state, local agencies, marinas and nonprofits

AIS Currently Present in Lake Tahoe:

- Eurasian watermilfoil
- Curlyleaf pondweed
- Asian clam
- Largemouth bass
- Smallmouth bass
- Bluegill sunfish
- Black crappie
- Bullhead catfish
- Bullfrog
- New Zealand mudsnail
- Crayfish
- Mysis shrimp

Not Currently Present in Lake Tahoe:

- Zebra mussel
- Quagga mussel

Tahoe Science Advisory Council (TSAC) Collaboration

Science is needed for:

- Linking research to future management decisions
- Rapid response
- Climate change
- Data/knowledge gaps
- Technical peer reviews
- Request For Proposals
- Prioritizing issues & funding

Nearshore Agency Challenges

- Extreme or changing weather patterns
- AIS that are not feasible to eradicate
- Research needs outweigh funding available
- Science is dynamic/lots of perspectives/do not always get consensus messaging

Accomplishments California Funded

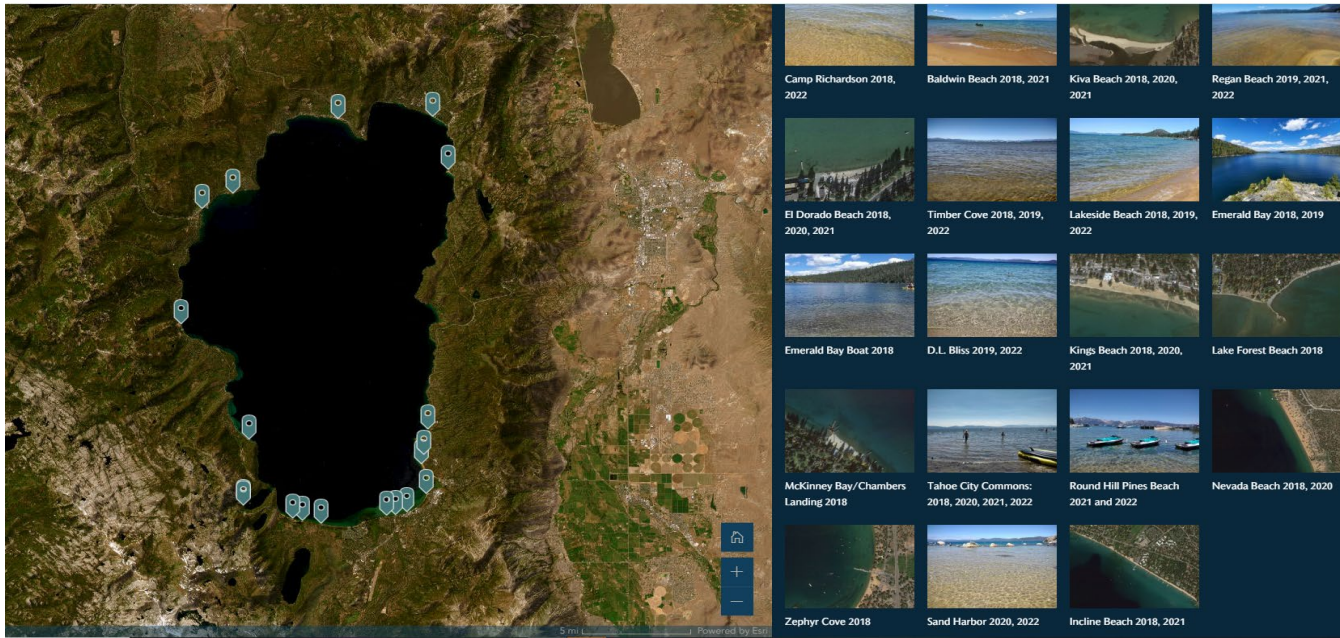
- Water temp – algal blooms
- Lake-wide macrophyte survey
- Nearshore human health
- Crayfish/algae
- Groundwater nutrients - nearshore algae
- Wildfire research
- Algae eDNA
- Science engagement

Accomplishments NV funded

- Delineation of Asian Clam Populations at Sand Harbor
- Pilot Implementation of Nearshore Monitoring Framework for Clarity Metrics
- Expansion of Asian Clams in Lake Tahoe
- Development of Nearshore Fish Indicators for Lake Tahoe
- Linking Onshore and Nearshore Processes: Nearshore Water Quality Monitoring
- Near-Shore Water Quality Monitoring at Lake Tahoe
- Real-time technologies and ecosystem models-nearshore greening
- Lake-wide Aquatic Plant (native and invasive) Monitoring
- 6 Mile Nevada State Lands SCUBA Clean-up
- 72-mile Lake Tahoe SCUBA Clean-up
- Algal workshop

Internal and Public Outreach

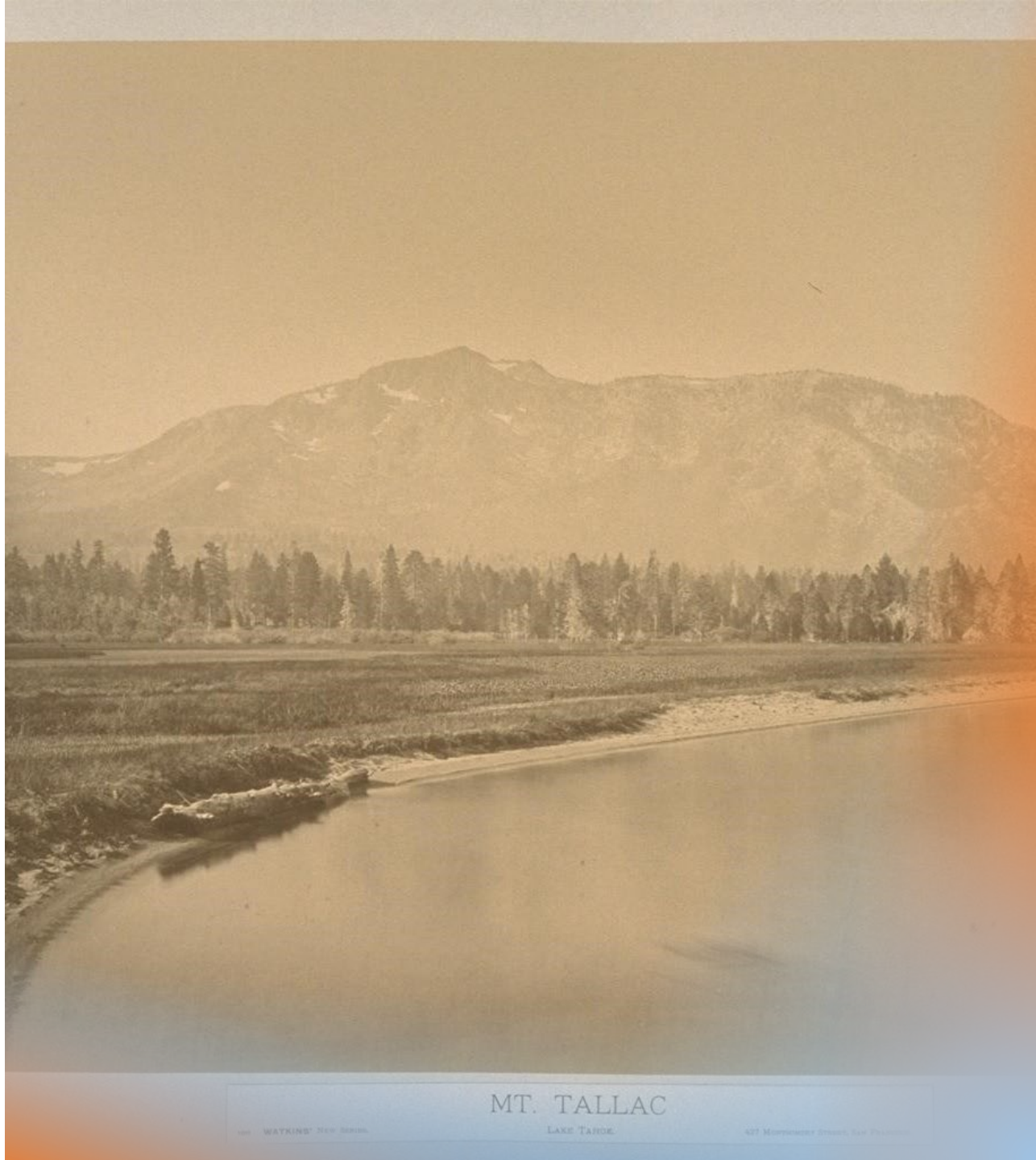
- Inform our boards and executive decision makers
- Citizen science
- HABs & nearshore human health
- Strive for unified messaging across agencies

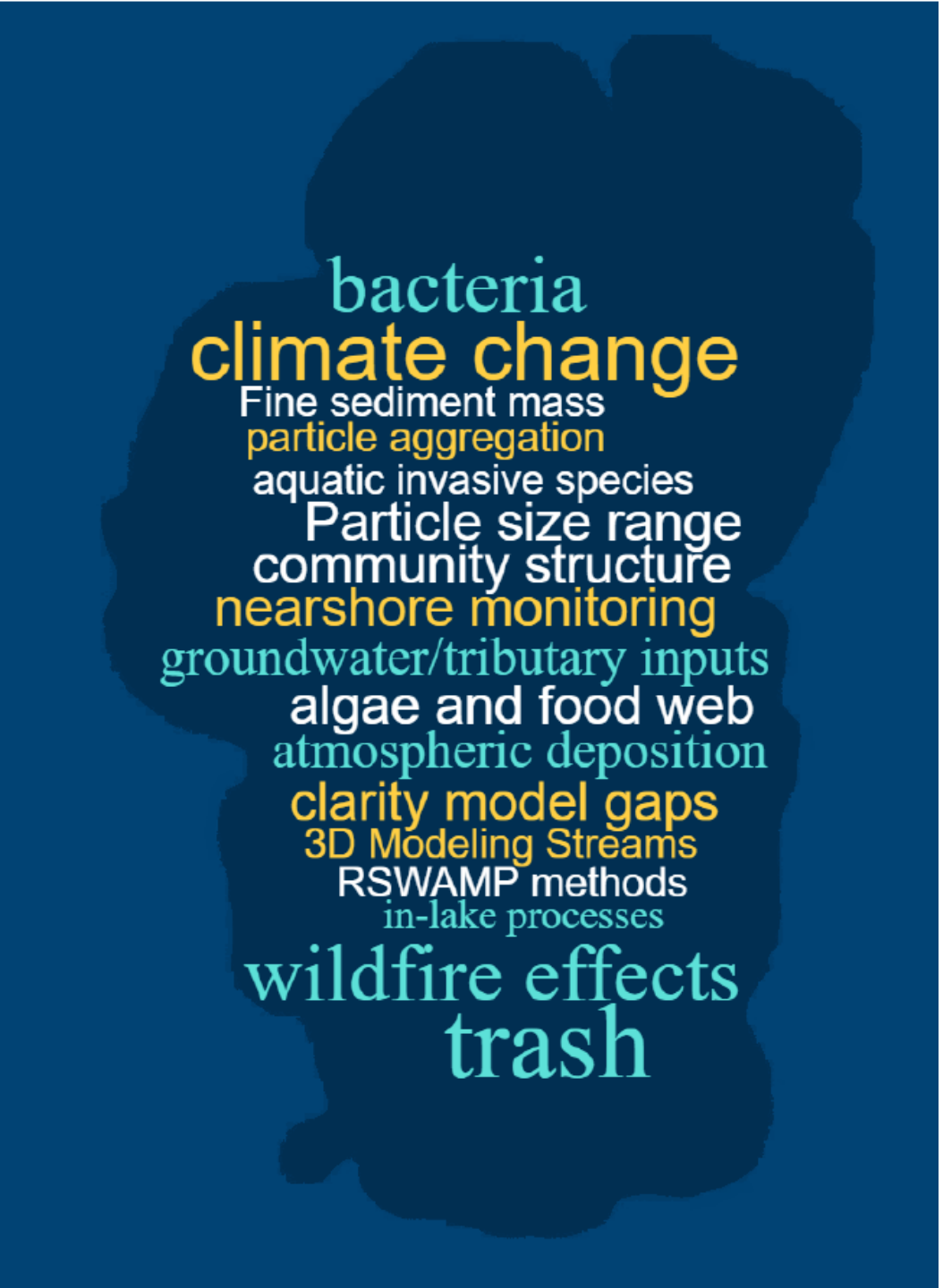


Summary & Conclusion

- Priority management challenges:
  - Aquatic invasive species (AIS)
  - Nearshore algae/litter
  - Water quality for human health
  - Climate change

- Key Questions:
  - How/where to manage AIS?
  - Causes of nearshore algae?
  - Is the water safe for recreational use?
  - Litter prevention?
  - Atmospheric inputs?





Clarification Questions

Small Group Discussion Questions

- Did anything stand out as new, surprising, or as an “a-ha moment?”
- What are the most pressing current issues for this topic?
- What are opportunities to advance science delivery?

THANK YOU!

Please join us Friday to synthesize key themes and discuss how the Science Council can advance science delivery for healthy Tahoe systems!