Redesigning Reservoir Ecosystems

For improved water quality
& enhanced aquatic life

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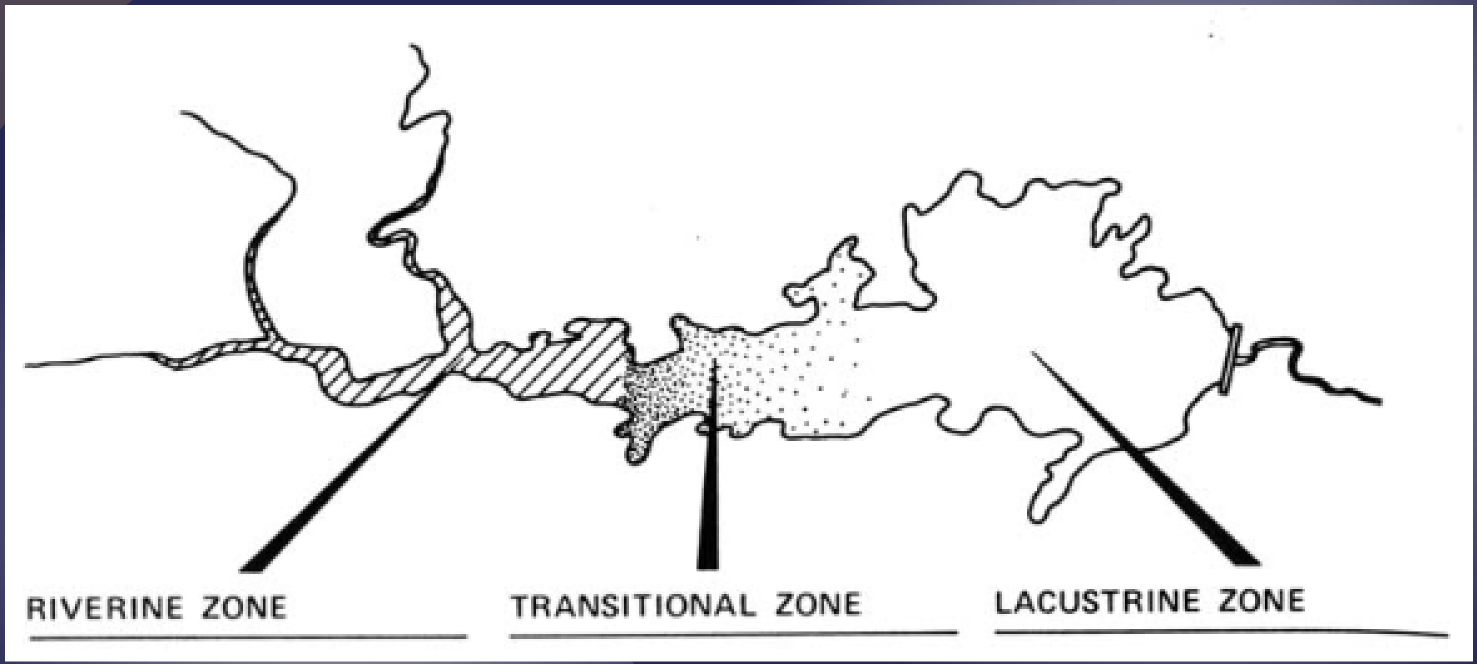
OCLWA, Stillwater
April 2, 2014

- In-reservoir restoration
  - Why/when is it required?

- 17 ways to restore a lake:
  - Circulation
  - Alum
  - Food web management



Reservoir Ecosystems

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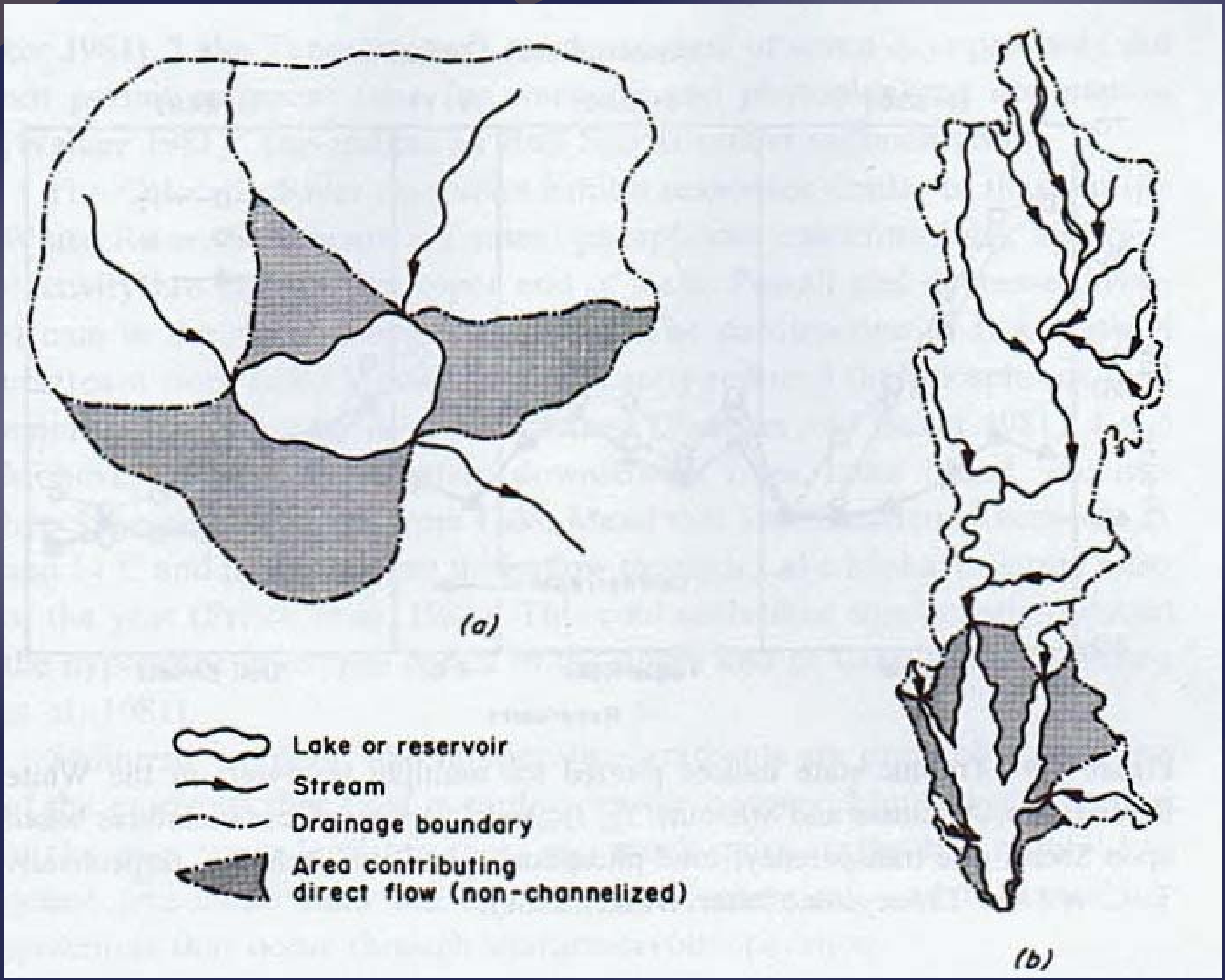
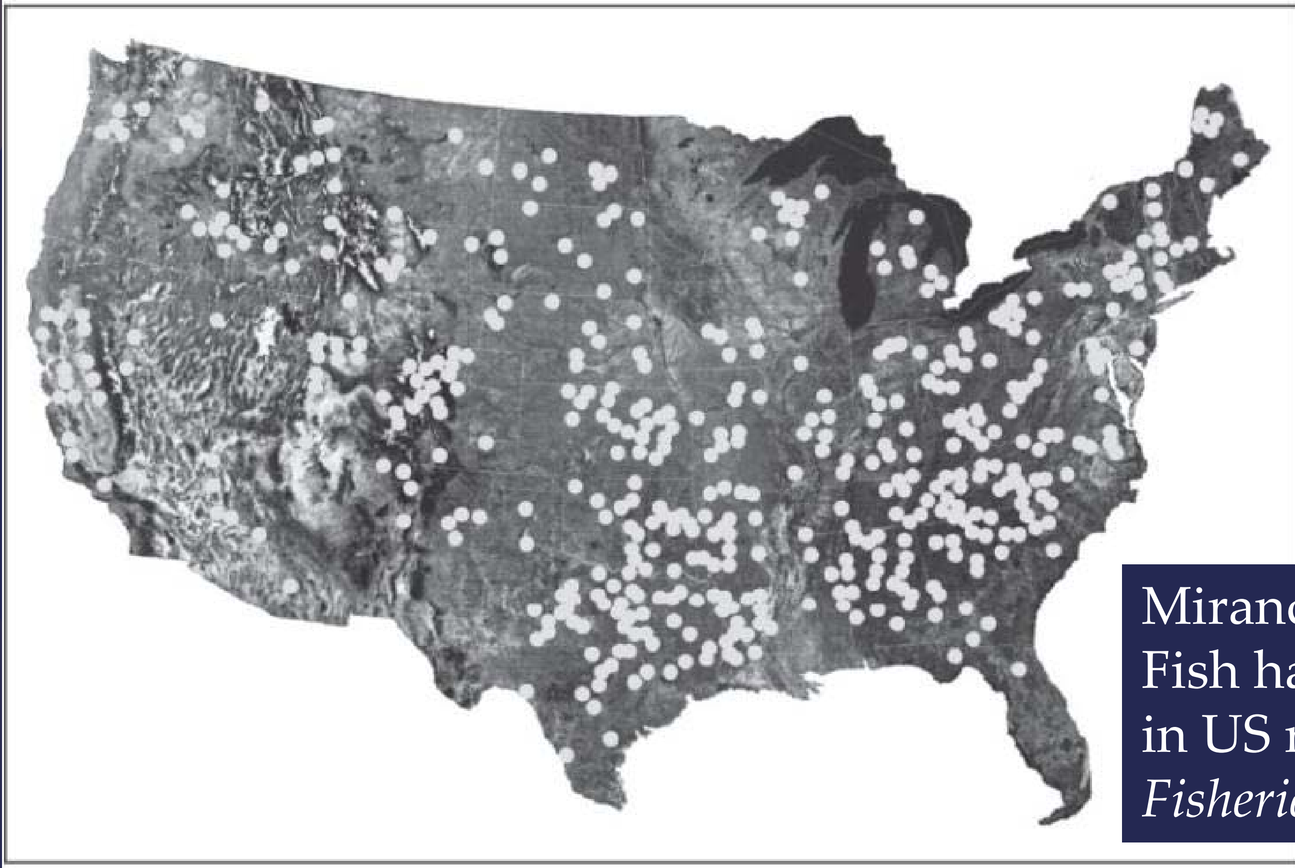


Source: Thornton et al. (ed) 1990, Reservoir Limnology

	Lake Eufaula	Lake Tahoe
Surface area	159.4 sq. miles	191.6 sq. miles
Watershed area	47,522 sq. miles	501 sq. miles
Ratio	299:1	2.6:1

Over 50% of US reservoirs (>200 ha) are over 50 years old

Figure 1. Geographic distribution of the 482 study reservoirs in the contiguous United States. The reservoirs ranged in area from 202 to 131,000 ha.



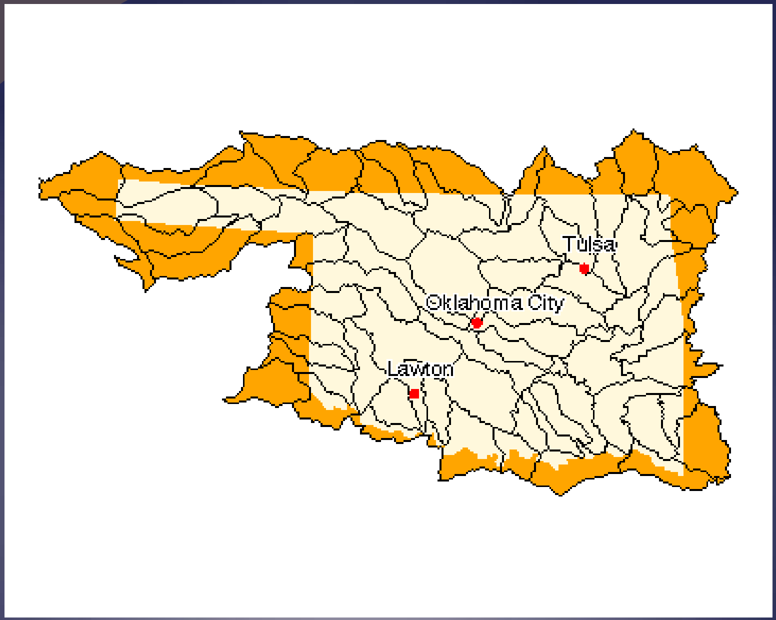
Fisheries • VOL 35 NO 4 • APRIL 2010 • WWW.FISHERIES.ORG 177

Miranda et al. 2010. Fish habitat degradation in US reservoirs. *Fisheries* 35(4): 175-184

In the US today,
over 70 % of lake and reservoir acres are reported as impaired for water quality

US EPA
epa.gov/waters/ir/index.htm

Oklahoma



Lakes, Reservoirs, Ponds (2010)

	Acres
Total	1,041,884
Assessed	604,593.5
Impaired	579,559.5

epa.gov/waters/ir/index.html

What is required to improve reservoir water quality?

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- Watershed management

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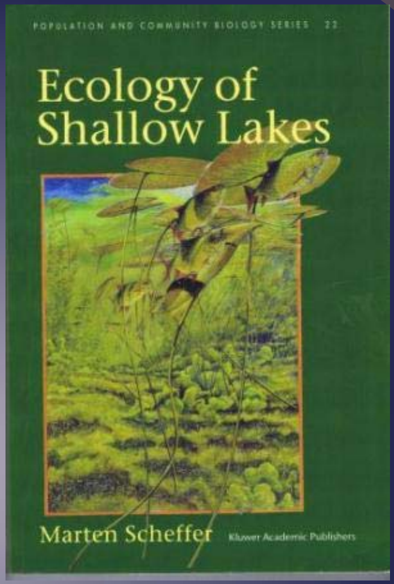
and

- **In-lake restoration & management**

Why?

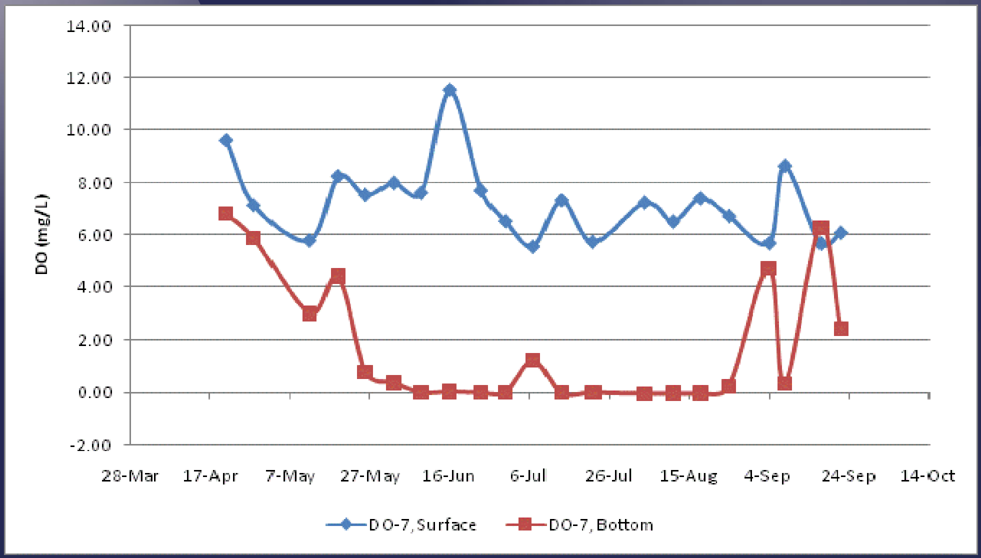
Even with nutrient reduction, many lakes don't return to their previous state:

- Recycling of phosphorus from lake sediments—"internal loading"
- Continued slow flux of phosphorus from over-fertilized watershed soils
- Interactions of aquatic vegetation, fish, zooplankton



Phosphorus internal loading

- P accumulates in lake sediments over years/decades from external sources
- P released from those sediments, often 3 to 4 times higher rate under anoxic conditions than oxic
- Oxygen-phosphorus-algae feedback loop



Phosphorus internal loading

Lake Eucha:

- Internal P load of 12 Mg/year was equal to 25% of the external P load

Haggard et al. 2005. Phosphorus flux from bottom sediments in Lake Eucha, OK. *Journal of Environmental Quality* 34(2):724-728

Continued slow flux of phosphorus from watershed soils

Lake Eucha Watershed:

- Soil test phosphorus averaged 250 lb/ac
- Complete cessation of litter applications would reduce STP by 18 lb/ac in 30 years.

Storm et al. 2001.
Modeling phosphorus loading for the Lake Eucha Basin.
Oklahoma State University.

Continued slow flux of phosphorus from watershed soils

Carpenter modeled Lake Mendota watershed

- cycling rate of P in agricultural soils
- cycling rate of P in lake water
- cycling rate of P from lake sediments

Ran the model out 1,000 years

- The eutrophic state persisted for hundreds of years

- While internal recycling was important, it was the slow depuration of soil P that retarded recovery from eutrophication

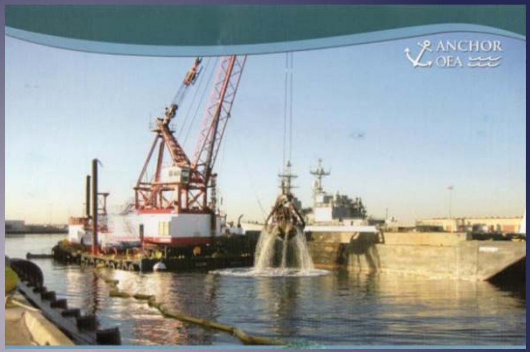
(Carpenter 2005, Eutrophication of aquatic systems: bistability and soil phosphorus.)

17 Methods of Lake Restoration & Management

		Method	Problems Addressed
1	Physical Methods	Dredging--remove sediment	High algae & cyanobacteria levels, internal loading from nutrient-rich sediments; lost capacity from sedimentation
2		Aeration, oxygenation, & circulation--improve oxygen conditions directly, reduce nutrients, algae, & cyanobacteria; improve circulation making conditions less desirable for cyanobacteria (physical-chemical)	Low dissolved oxygen levels that increase internal nutrient loading & metals release, & creates poor conditions for fish and aquatic life; internal nutrient loading that increases algae & cyanaobacteria levels; stagnant water that provides good habitat for cyanobacteria
3		Manipulate water levels--drawdown or fluctuate lake level to dry or flood selected areas	Problem plants in lake edge/shallow areas
4		Selective withdrawal (of water from the lake)--remove nutrients by removing nutrient-rich water	Internal nutrient loading, high nutrient levels in the hypolimnion
5		Dilution and/or flushing--increase flow of water into and out of the lake	High algae or cyanobacteria levels, high concentrations of nutrients, sediments, or other undesirable materials
6		Harvest (cut or pull) plants; till lake sediments	Remove problem plants, disrupt their establishment and growth
7		Install liners or other barriers--seal sediments, prevent plant establishment, kill plants, kill other pests (eg, clams)	Internal nutrient loading, problem plants, other bottom dwelling pests
8		Build breakwaters--reduce shoreline erosion from waves; reduce turbidity in shallow, turbid lakes	High turbidity, shoreline erosion

17 Methods of Lake Restoration

- Physical controls: Change the lake bottom, change water/nutrient residence times, or the light regime. Harvest weeds, algae, trash, & fish.



- Chemical controls: Poison the undesirables or **restrict** anoxia, light or nutrient recycling; change sediment chemistry.

- Biological controls: Eat or harvest the undesirables; manipulate the food web.

Oxygenation, aeration, & circulation

BlueInGreen Demo at Lake Wister, OK

Image Source: Eco2 Oxygen Technologies

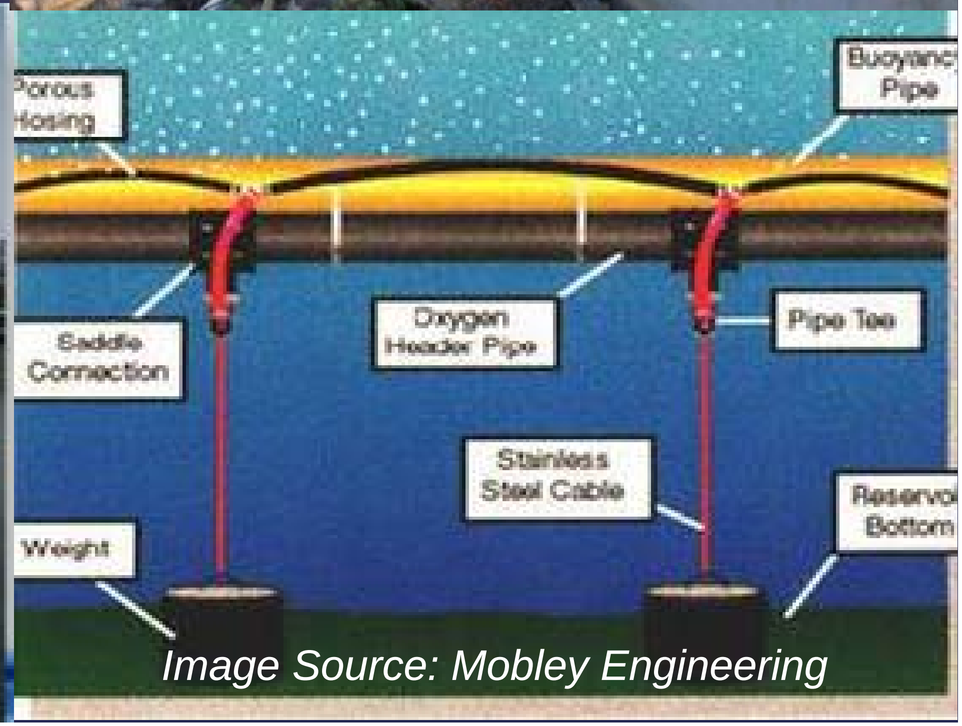
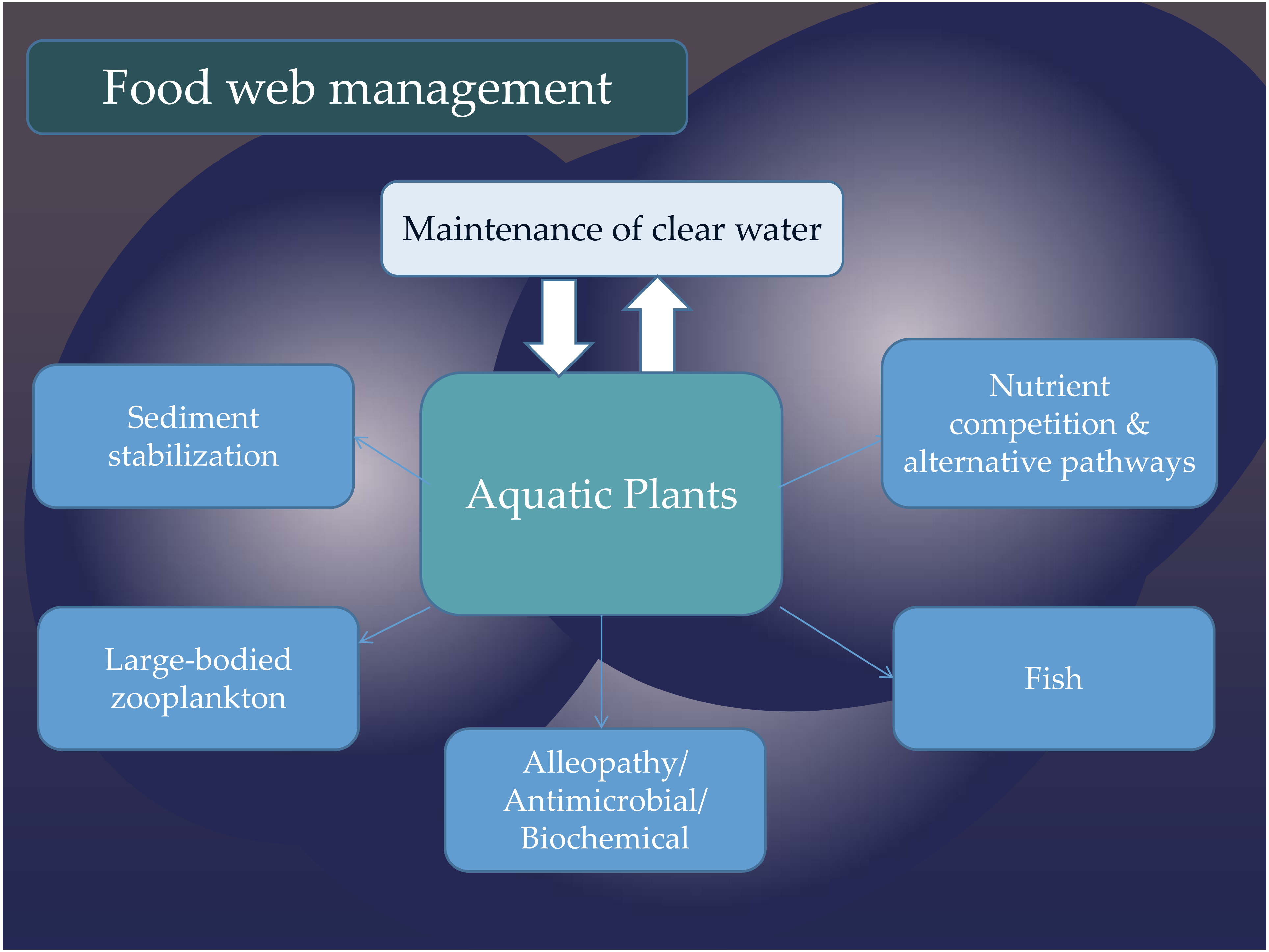


Image Source: Mobley Engineering

Alum
(and other flocculents)


Food web management
Maintenance of clear water
Aquatic Plants
Sediment stabilization
Nutrient competition & alternative pathways
Large-bodied zooplankton
Alleopathy/ Antimicrobial/ Biochemical
Fish

Sediment stabilization by vegetation

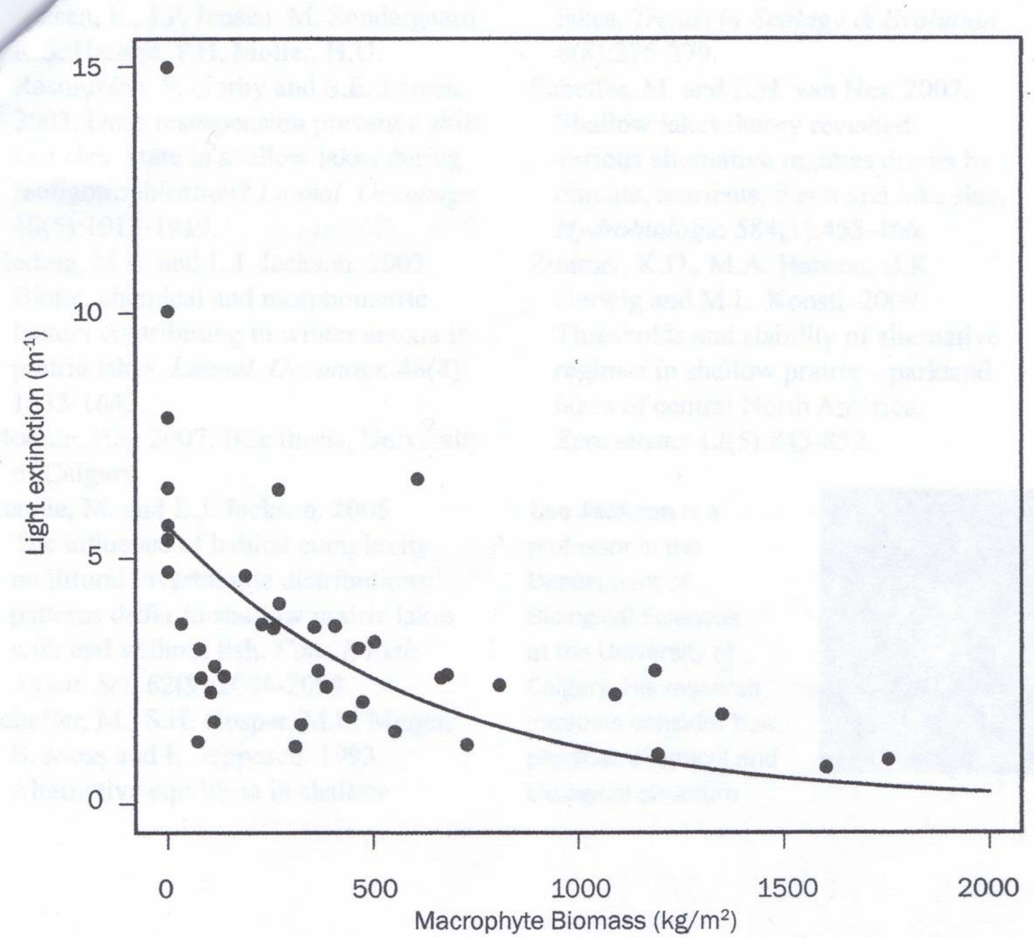


Figure 5. Relationship between the light extinction coefficient (λ) and submerged macrophyte biomass throughout summer, 2006 in eight lakes that vary in turbidity and macrophyte biomass (Moquin, unpublished data).

Jackson & Moquin 2011

Zooplankton & fish

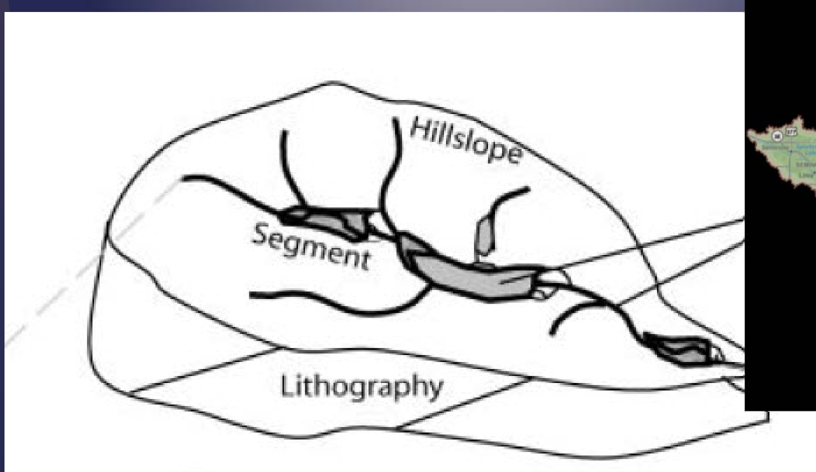
Submerged aquatic vegetation	Floating wetlands
Large-bodied zooplankton production & refuge	**Large-bodied zooplankton production & refuge?**
Fish refuge & spawning	**Fish-food, yes; refuge? spawning?**

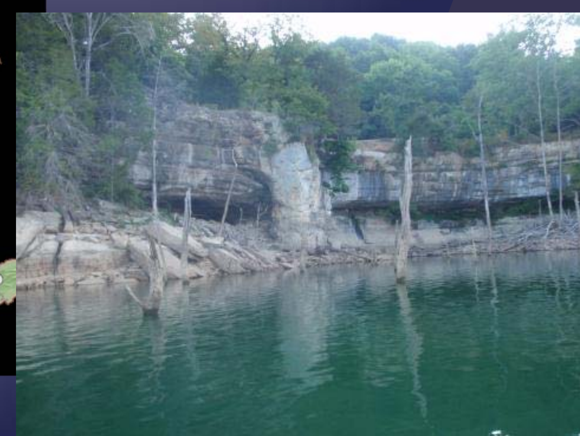
- In the absence of fish, a clearwater state can maintained by zooplankton grazing alone (Peretyatko et al 2012)
- In ponds with fish, SAV buffered their effect
- Except, at the high end of nutrient levels and high fish numbers

Summary

To restore water quality & aquatic life in reservoirs:

- requires an integrated, whole-systems approach (watershed + lake)
- In-lake techniques are available; there is still much to learn to make them predictably effective; new approaches also desirable





Questions?