Light and oxygen in lakes

Limnology

Lecture 7

Outline

- Light
- Diffusion
- Oxygen gradients

Vertical Gradients in Lakes

Properties of Water

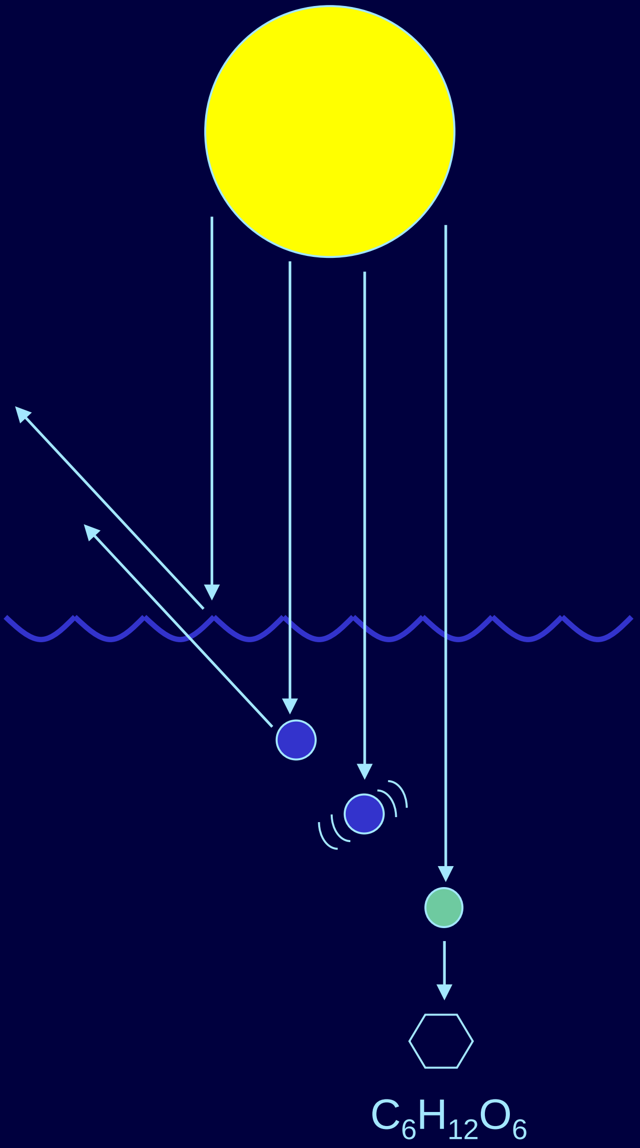
Properties of Lake Basins

Vertical Gradients

- Light
- Heat
- Dissolved gases
- Dissolved nutrients

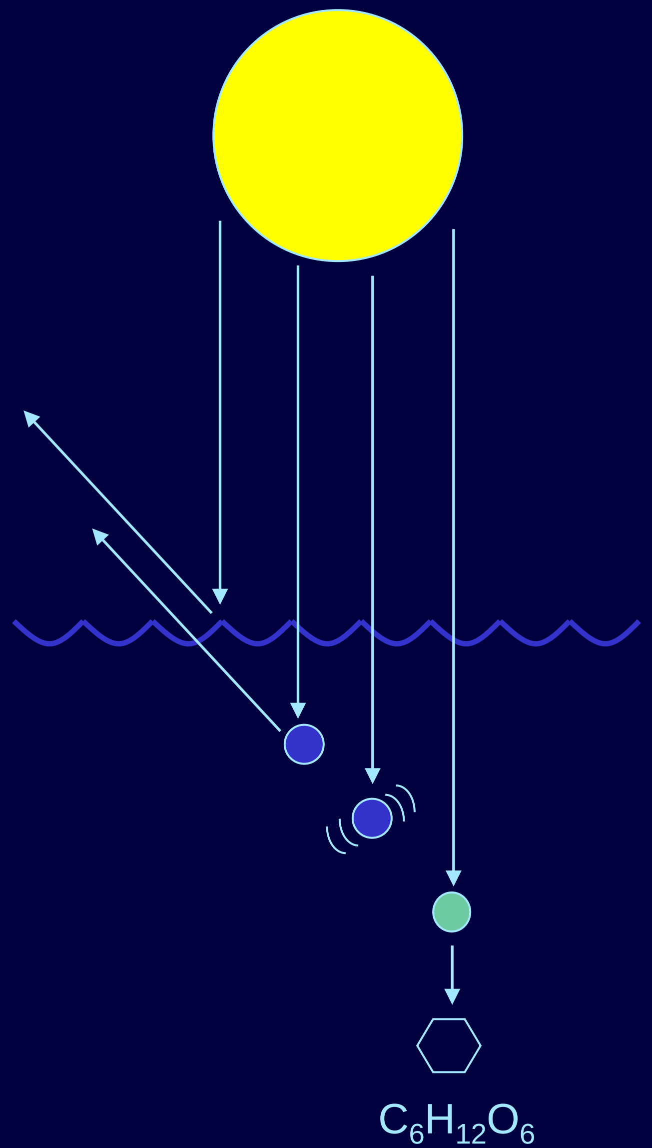
Light and Water

- Reflection
- Absorption

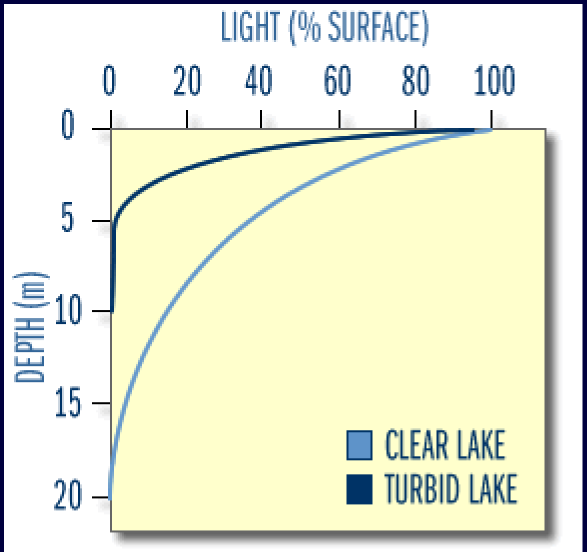


Light and Water

- Reflection
  - Surface
  - Scatter
- Absorption
  - Heat
  - Potential Energy
    - Stored in chemical bonds via Photosynthesis



Light and Water



LIGHT VERSUS DEPTH PROFILES FOR A CLEAR LAKE ($k=0.2\ M^{-1}$) AND A TURBID LAKE ($k=0.9\ M^{-1}$).

Attenuation equation

$I_z = I_0\, e^{-kz}$

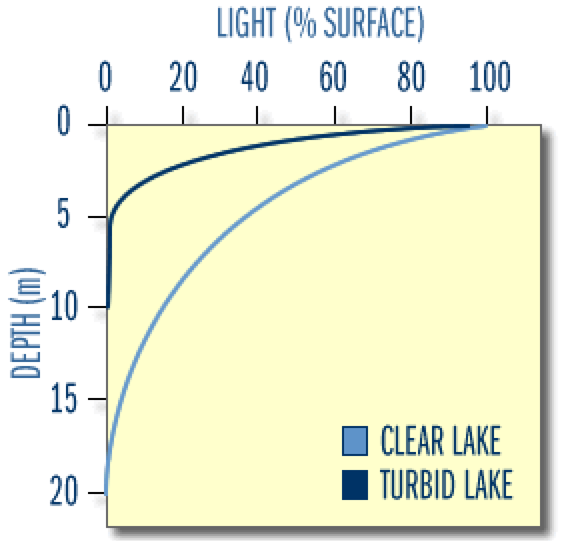
where e = natural logarithm

k = <u>attenuation coefficient</u>

characteristic for each water body and each wavelength

$K = K_{water} + K_{dissolved\ organics} + K_{particulates}$

Light Gradients in Water

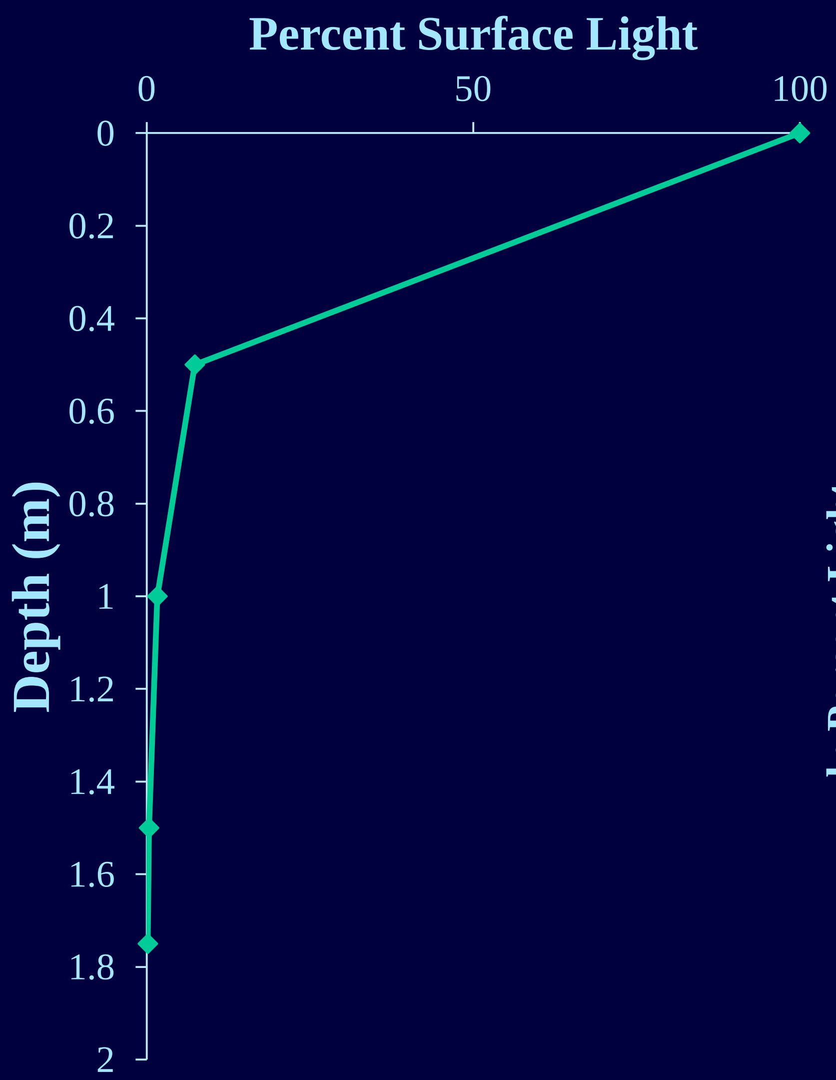


LIGHT VERSUS DEPTH PROFILES FOR A CLEAR LAKE ($k=0.2\ M^{-1}$) AND A TURBID LAKE ($k=0.9\ M^{-1}$).

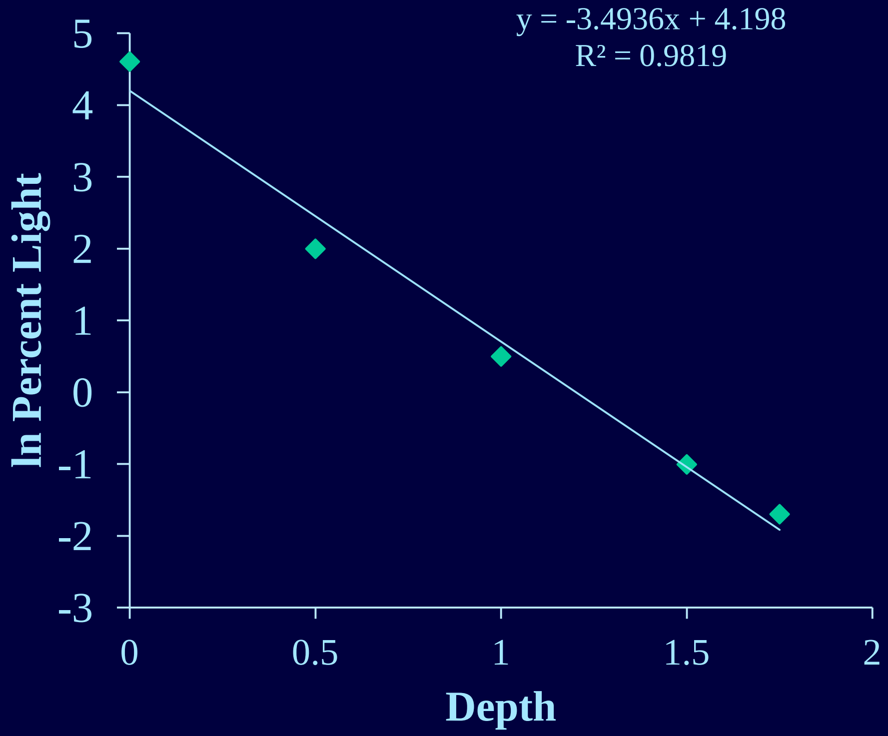
$K_{dissolved\ organics}$ – humic acids absorb short wavelengths (blue, UV)

Dunham Pond

Dunham Pond

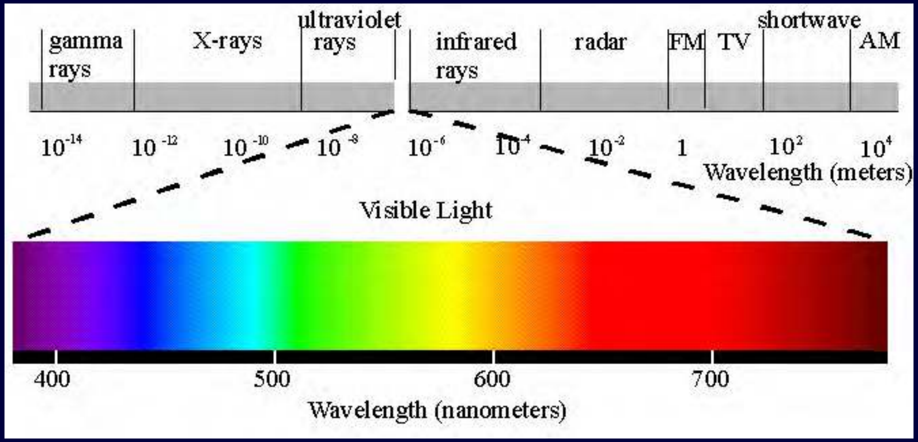


Percent Surface Light
0
50
100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Depth (m)



y = -3.4936x + 4.198
R² = 0.9819
5
4
3
2
1
0
-1
-2
-3
ln Percent Light
0
0.5
1
1.5
2
Depth

Why is deep water blue?



K_{water} – pure water absorbs long wavelengths

Blue absorbed the least, scattered the most

Water decreases light and changes colors

K_{water} – pure water absorbs long low energy wavelengths

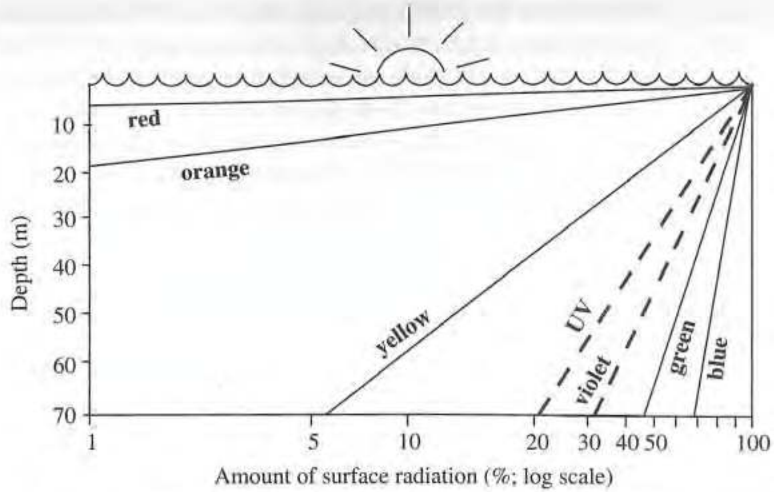
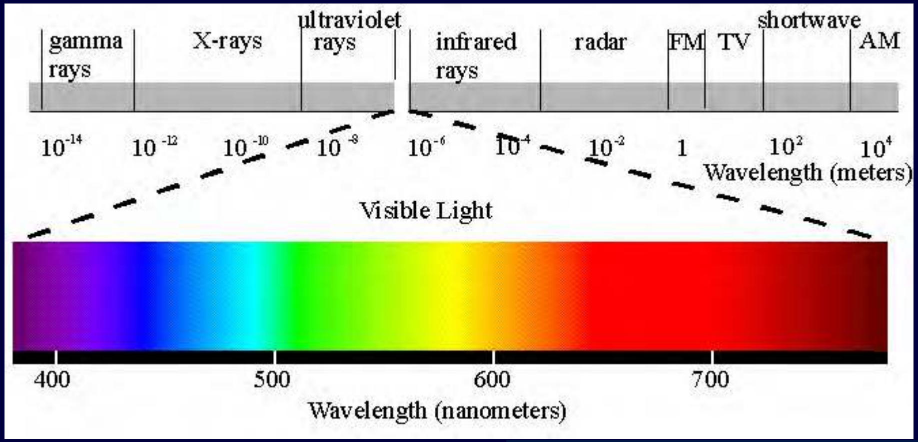
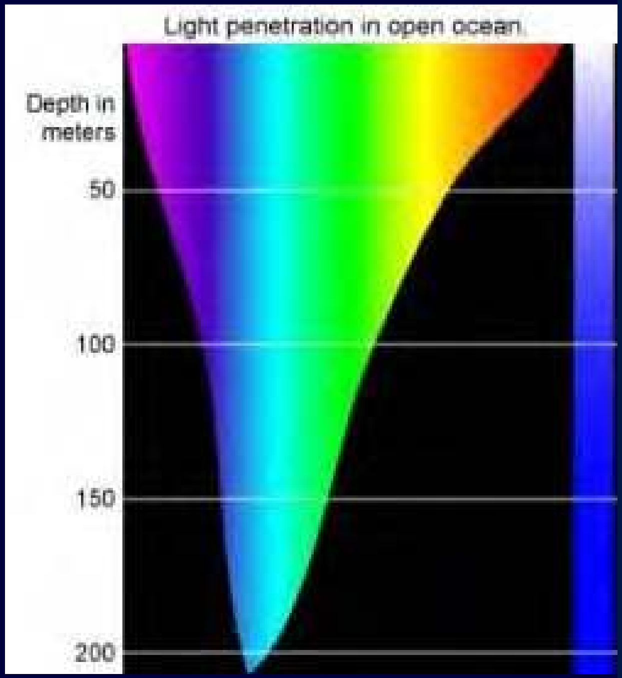


Fig. 2.9 Light transmission in distilled water showing that red light (680 nm) is already attenuated at a few metres depth, followed by orange (620 nm) reaching less than 20 nm depth. About 5% of the yellow (580 nm), 46% of the green (520 nm), and almost 70% of the blue (460 nm) light still remains at 70 m depth. Note that violet and UV radiation, which have the shortest wavelengths (400 nm and <350 nm, respectively) do not reach as deep as green and blue radiation.

Solar Radiation as a Spectrum

Electromagnetic Spectrum

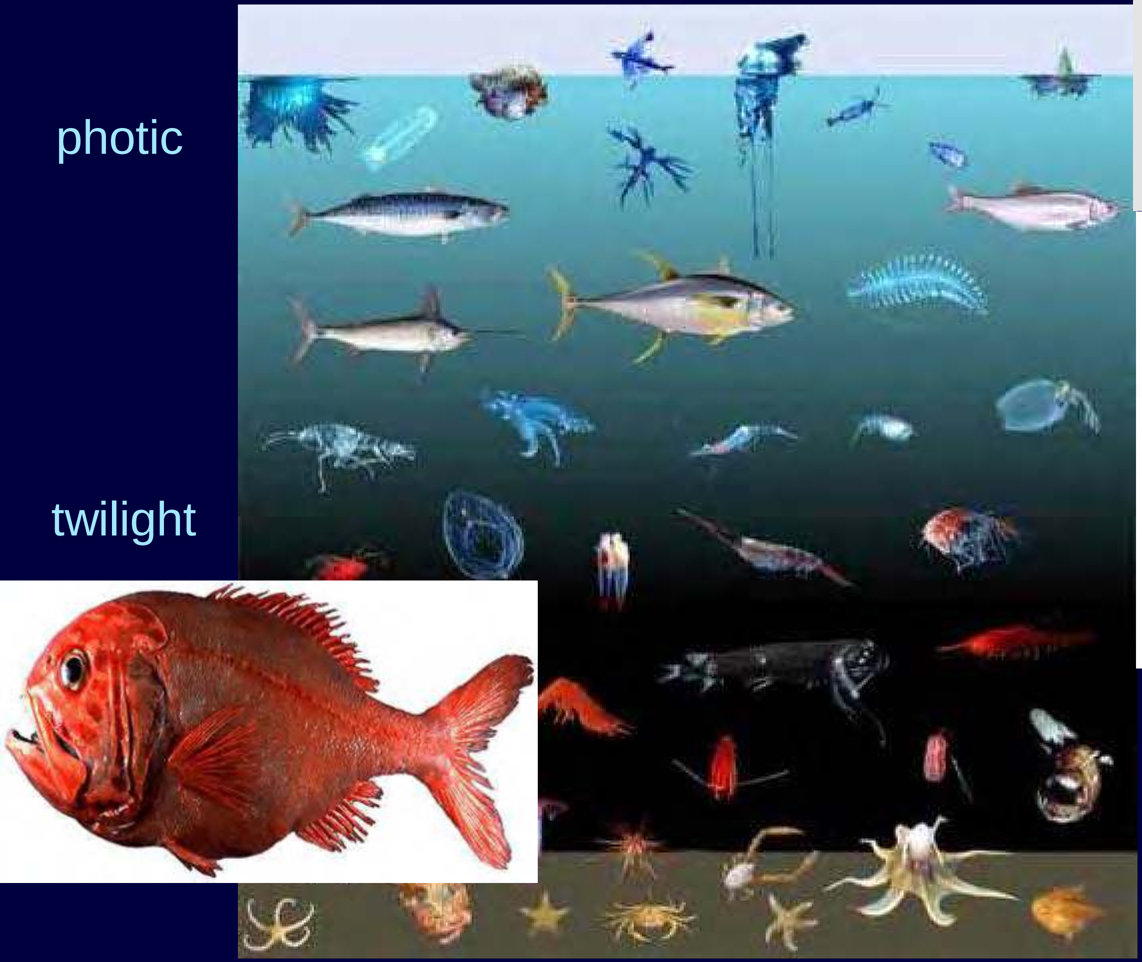


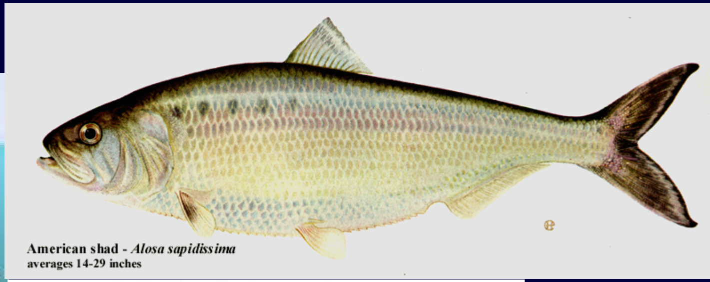


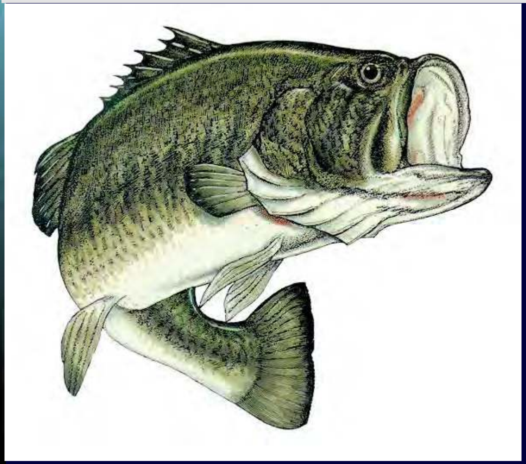
Light Gradients and aquatic coloration

photic

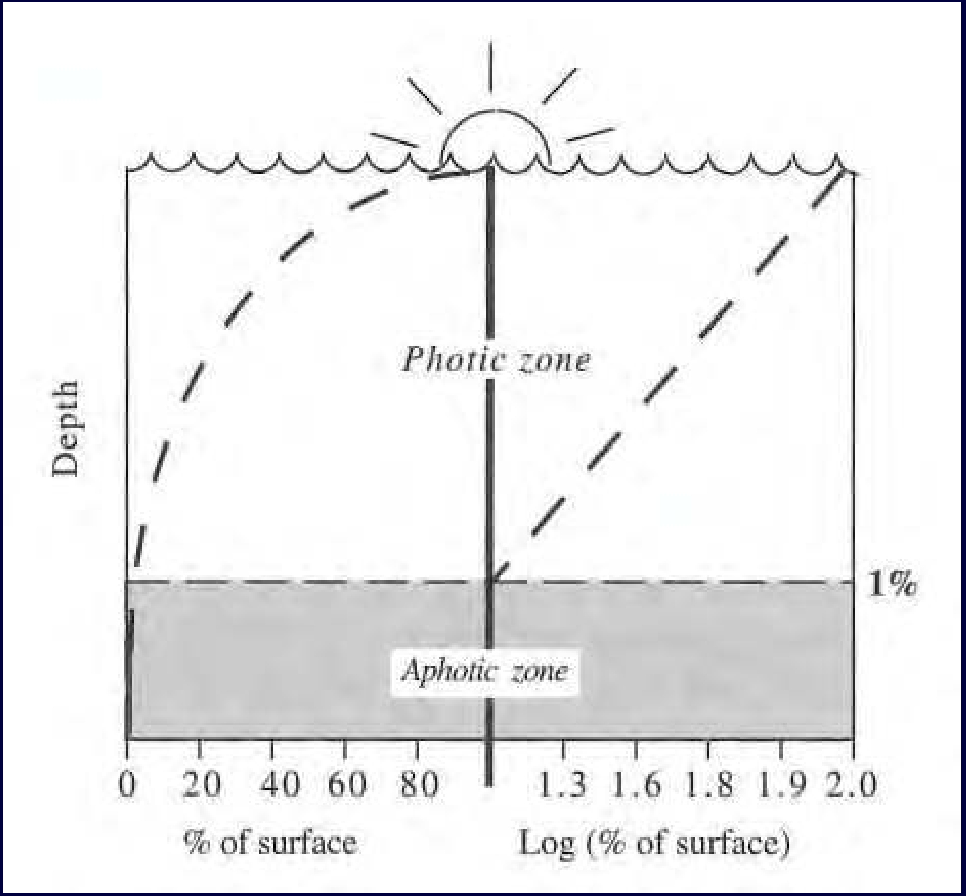
twilight







Light and habitat

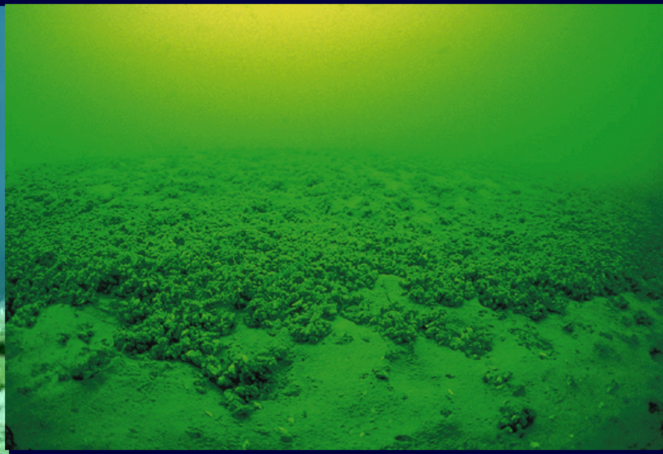


Secchi disk ~ 10% of surface light
Photic zone – light is > 1% of surface value

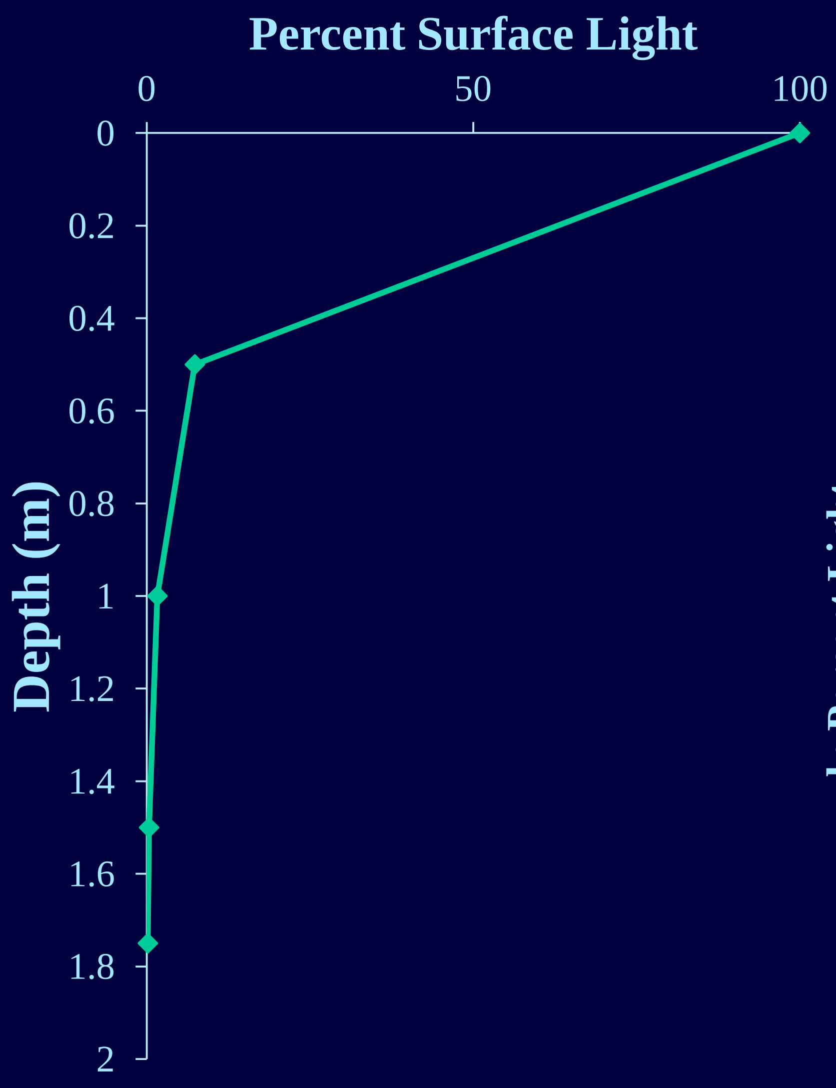
Light Gradients in Water

Lake	k	Secchi Depth	Euphotic
Crater Lake (OR)	0.06—0.12	25— 45	>120
Lake Baikal	0.2	5— 40	15—75
Lake Erie	0.2 — 1.2	2—10	12—26
Dunham Pond	3.5	?	?





Dunham Pond



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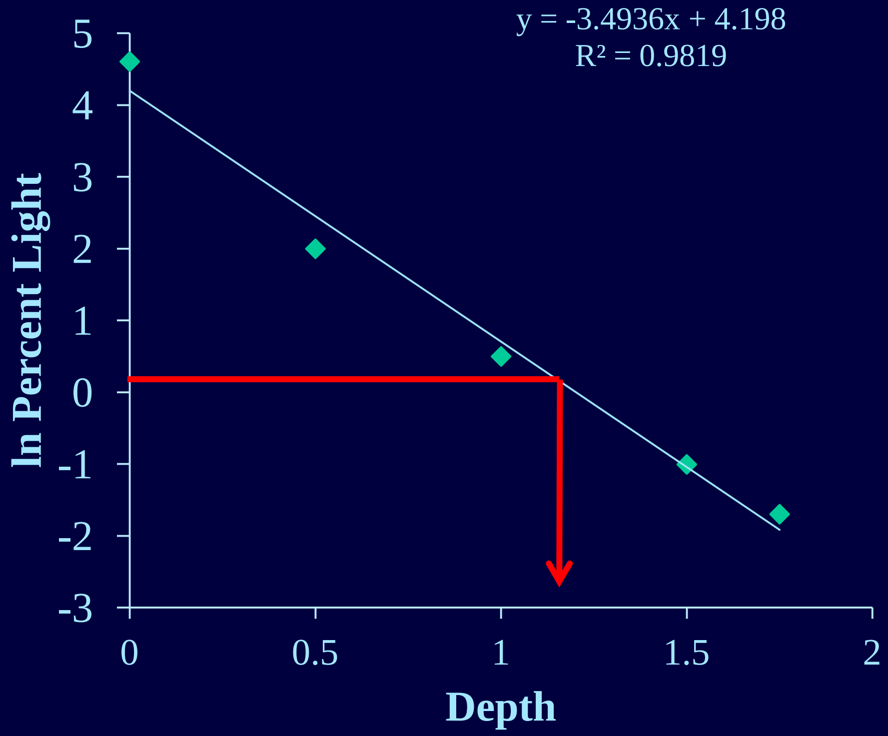

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Depth

Light and habitat

Light and habitat

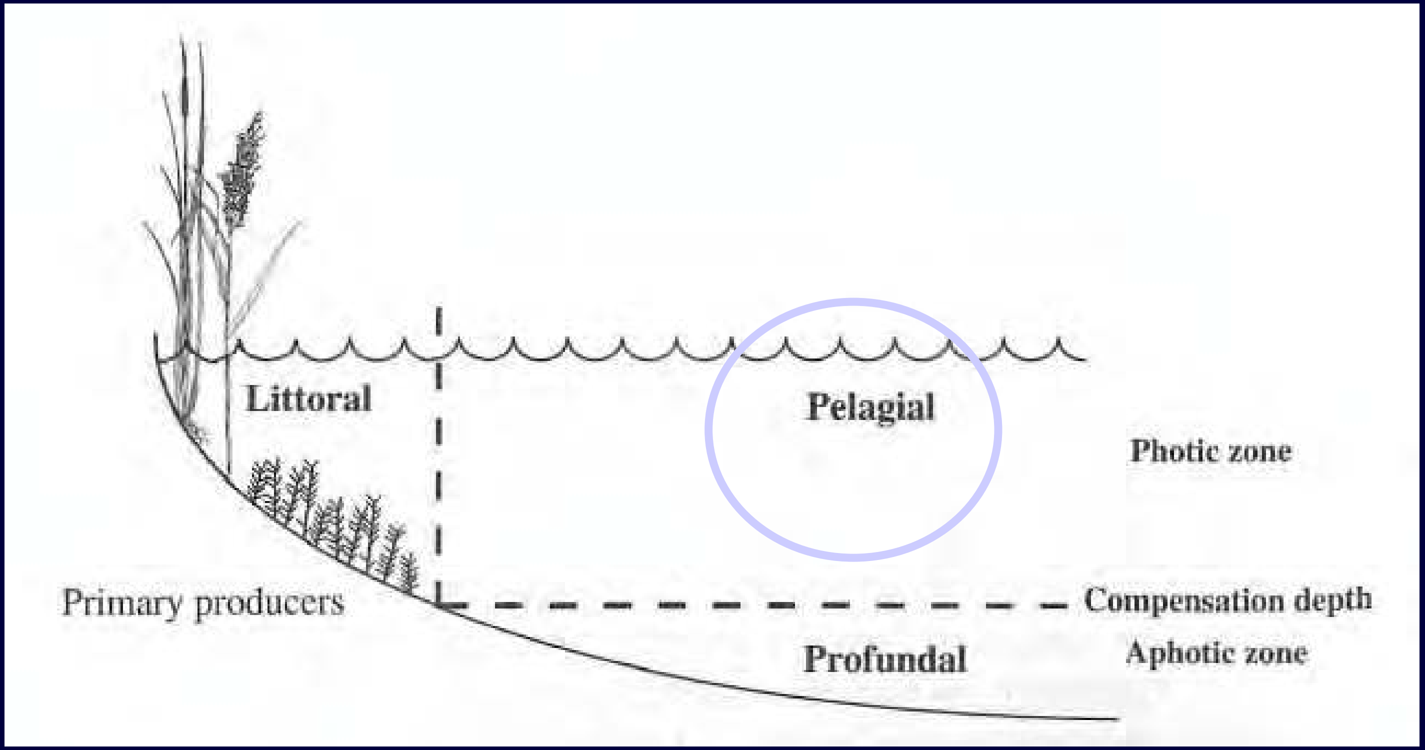
Compensation depth – where photosynthesis = respiration in plants

Littoral – From shore to aphotic zone

- emergent and benthic plants

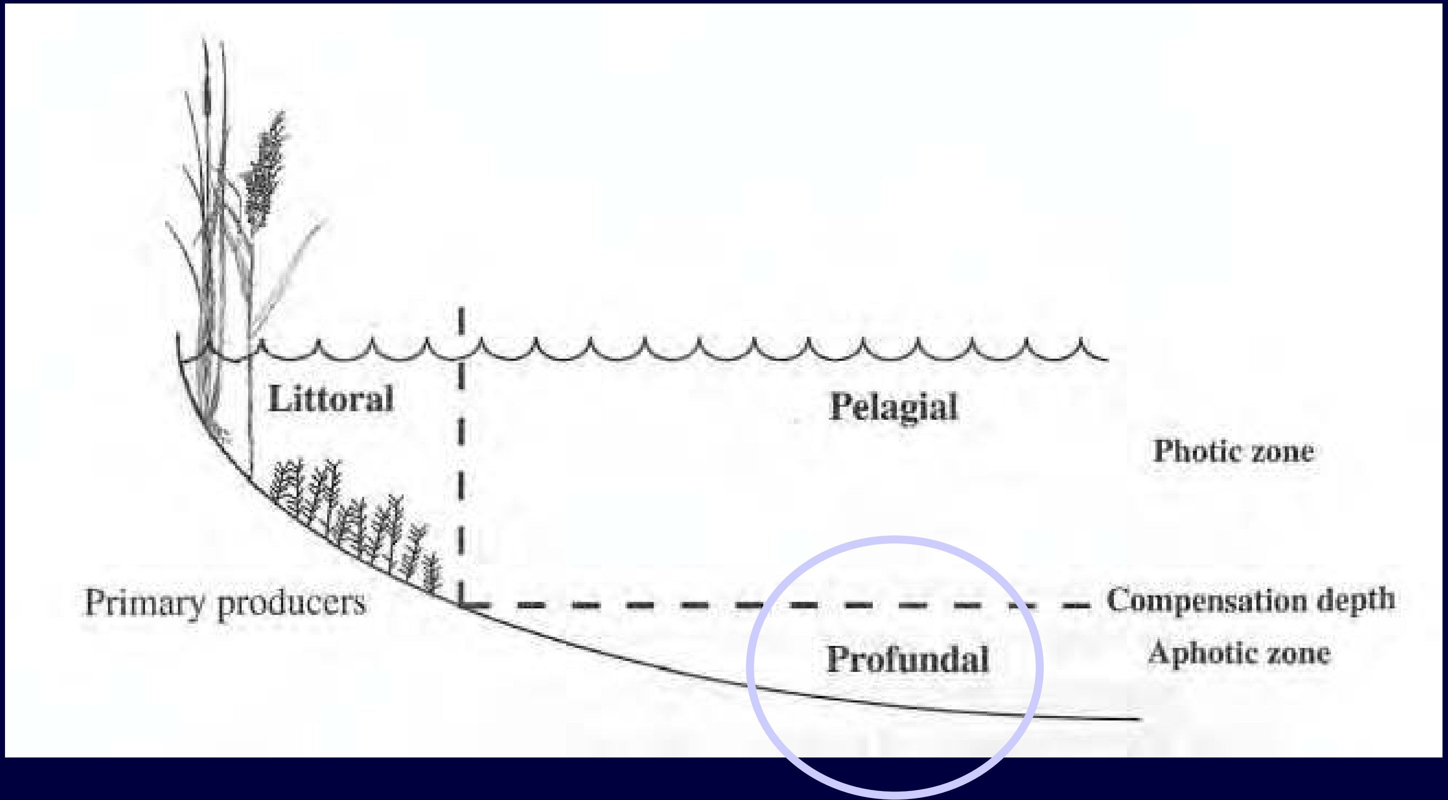
Limnetic – aphotic zone on benthos

Light Gradients in Water

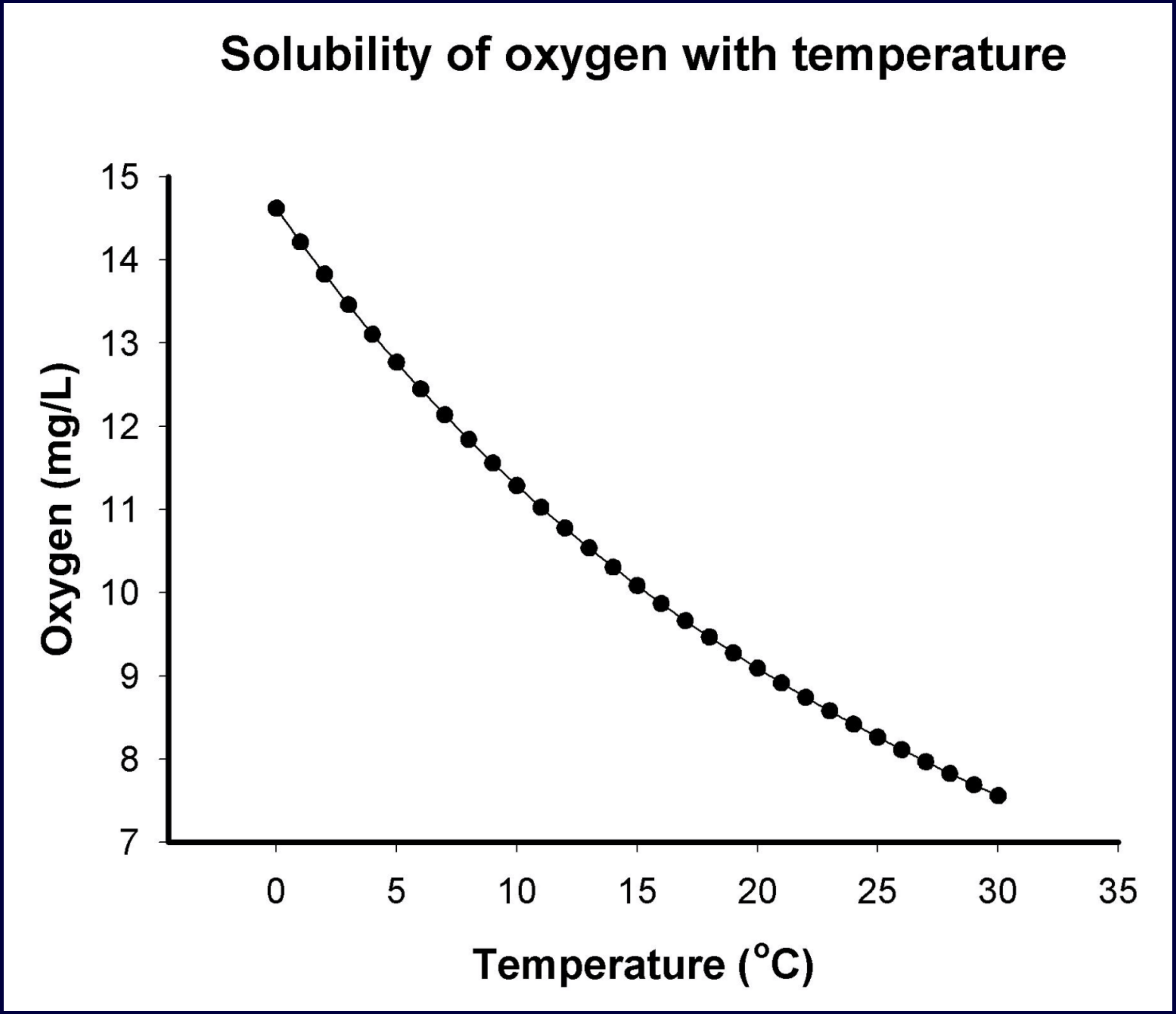


Pelagic – open water in limnetic zone
Compensation depth – where net photosynthesis = 0
photosynthetic production = respiration
photic or euphotic/aphotic

Light Gradients in Water



Oxygen and temperature



Diffusion Equilibrium

Henry's Law:

$C_s = K_H P_t$

C_s = amount of gas dissolved

K_H = solubility coefficient for a given temperature

P_t = partial pressure of gas in atmosphere

Oxygen in water

Diffusion from atmosphere

O_2 partial pressure = 0.203 atm

K_H (20C) = 1.39 mmol O_2/kg H_2O x atm

$C_s = K_H P_t$

O_2 (20C) = 1.39 * 0.20

= 0.28 mmol/kg

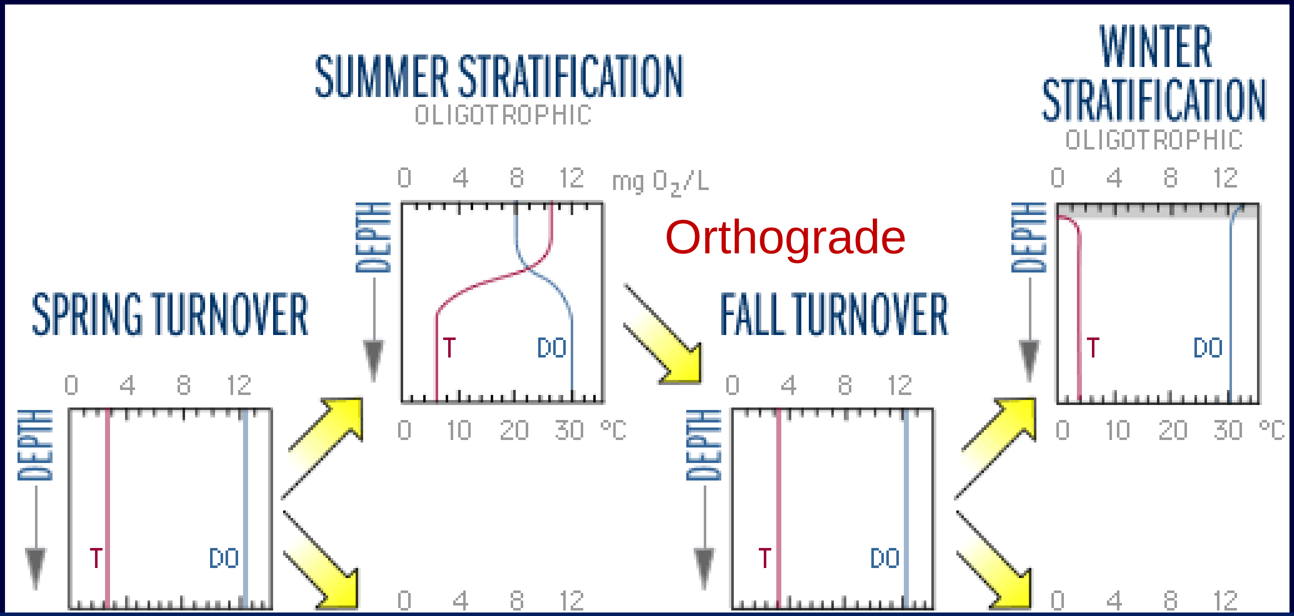
= 9.03 mg/L

Oxygen and species survival

Species	DO limit (mg/L)
Trout	7-8
Bass	5
Sunfish	4.7
Carp	4
Amphibian larvae	1-2
Amphipods	2
Chironomids	1
Worms	0.7

Mattson et el. 2007

Oxygen Gradients in Dimictic Lake

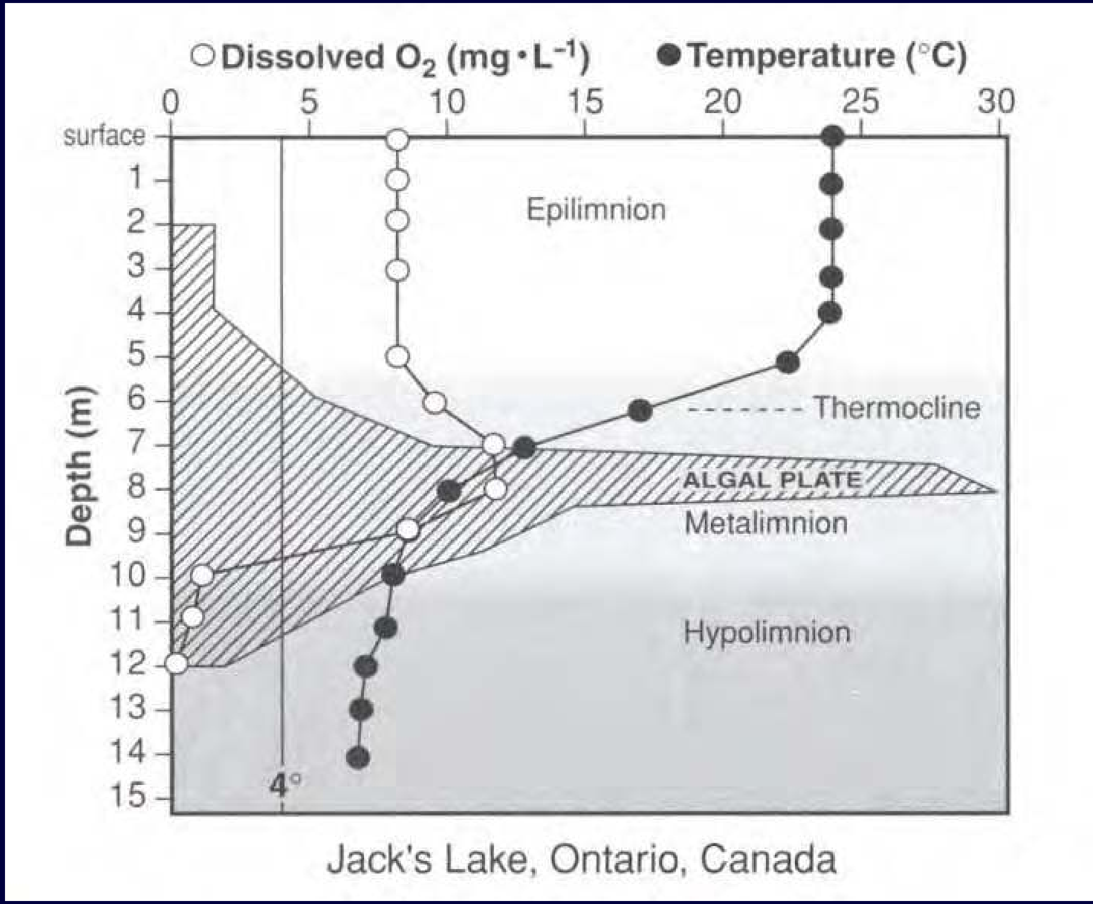


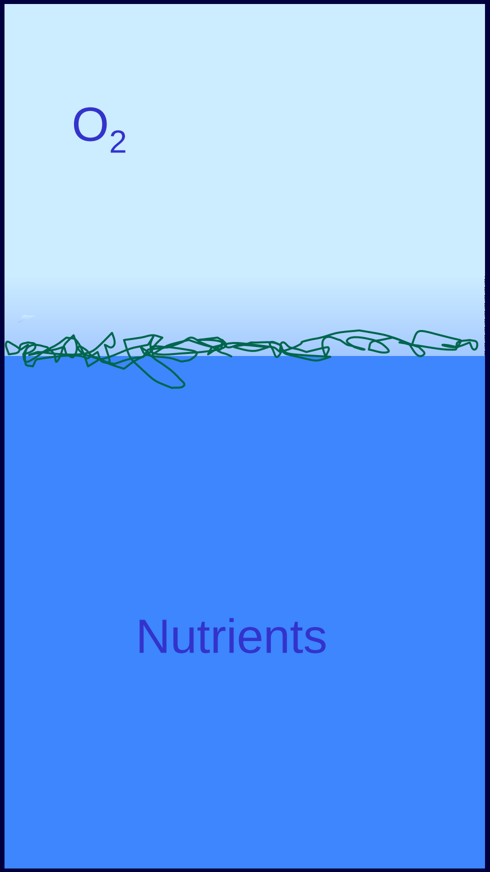
Biological oxygen demand

-Rate of oxygen uptake by aquatic organisms

From: Wetzel 1975

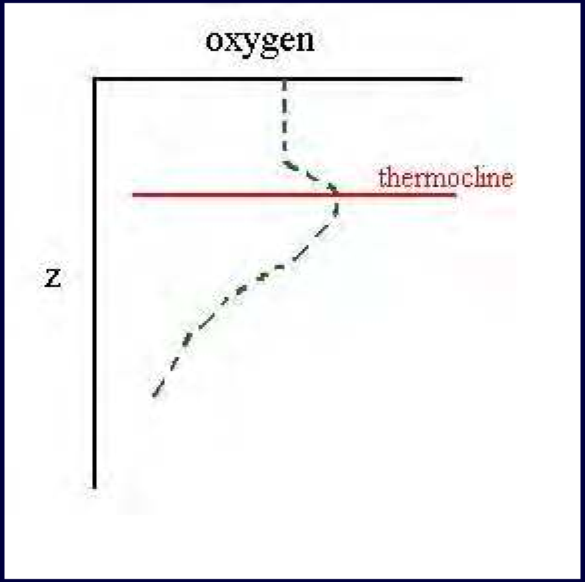
Thermocline effects

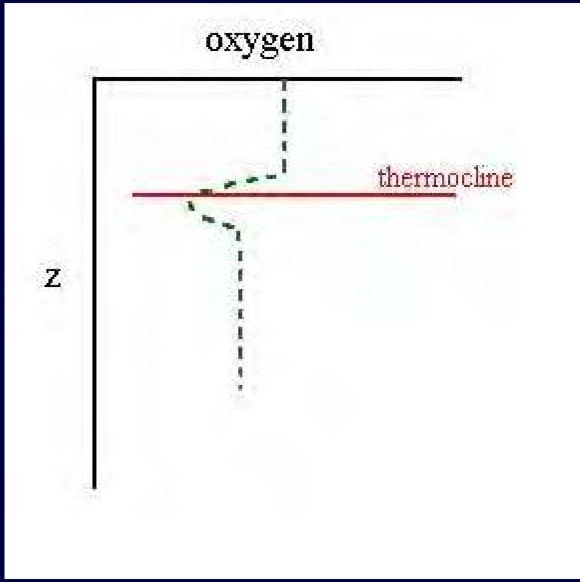




Dunham oxygen

Oxygen Gradients in Dimictic Lake





Positive heterograde

Negative heterograde

Algae sit on density "shelf"
More nutrients

Respiration of algae, zoop, decomposition of detritus rain on "shelf"

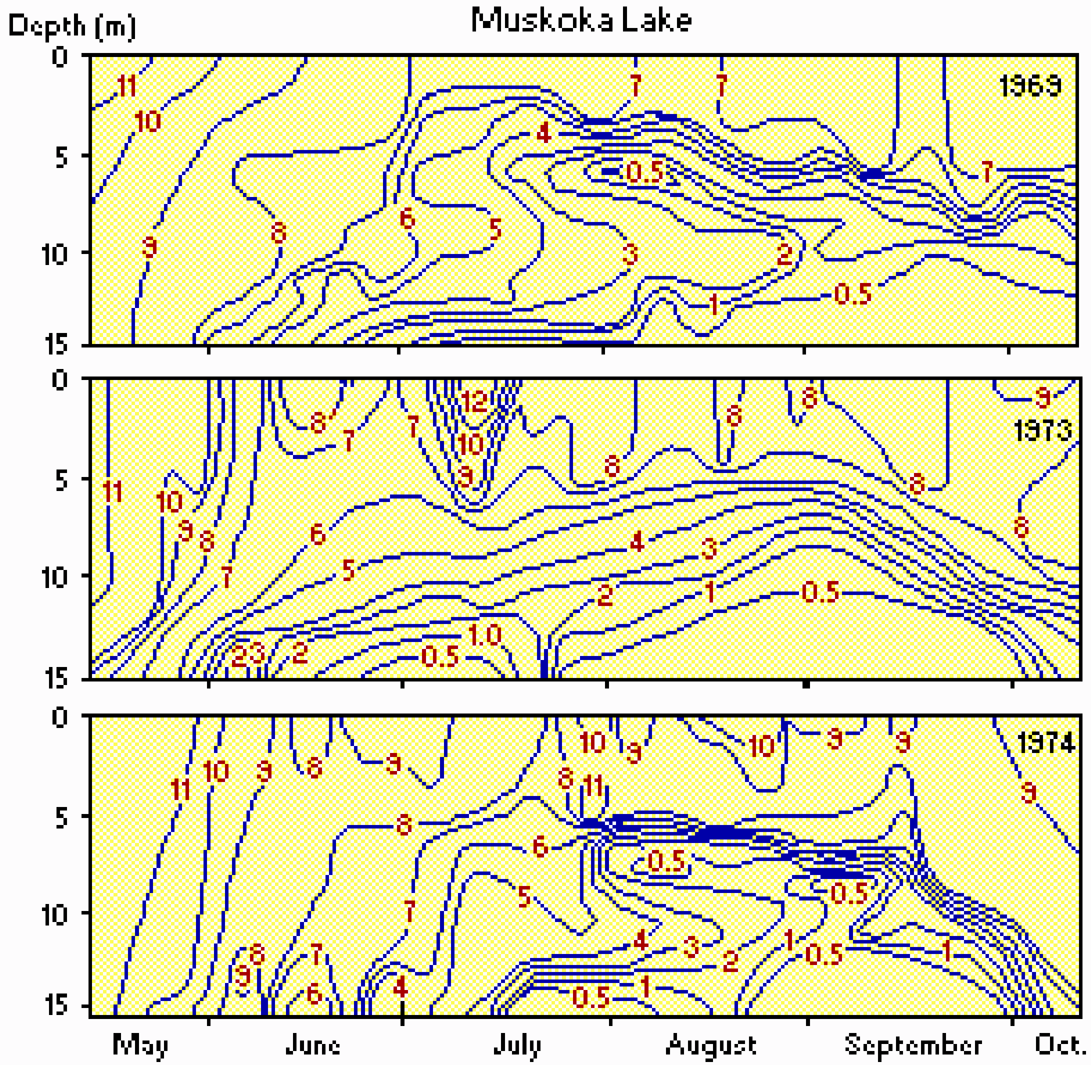


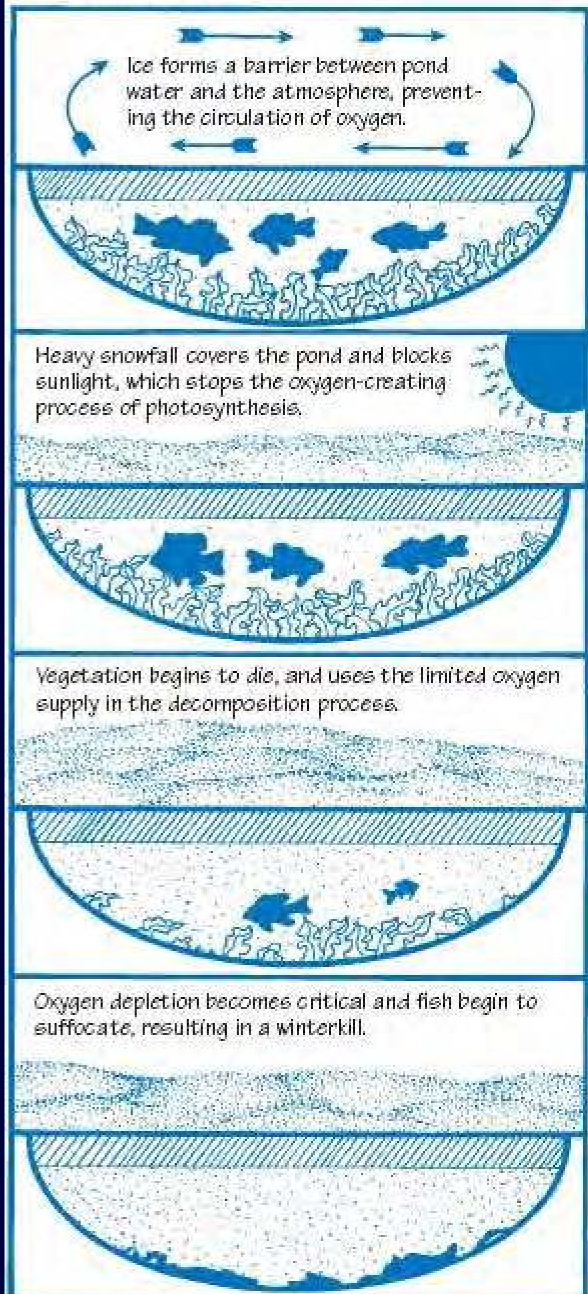
Fig. NAM-24-5 Seasonal isopleths of dissolved oxygen [mg l^{-1}] in Gravenhurst Bay based on weekly measurements, May-October 1969, 1973 and 1974 (10).

Muskoka Lake, Ontario, ILEC

Fish Kills (low O_2)

Occur often in small ponds in winter under ice cover – why?

The winterkill process.



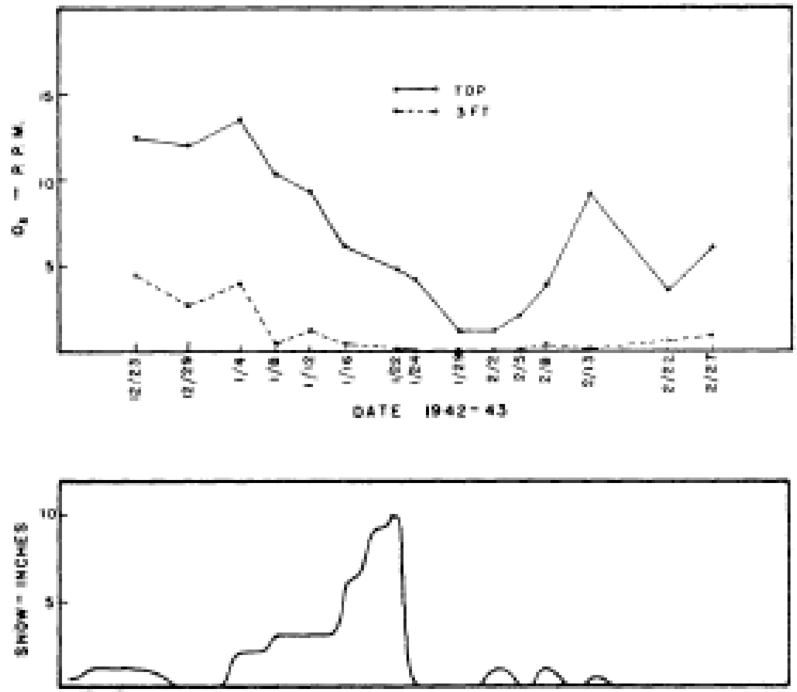


FIG. 15. Dissolved oxygen and snow cover, Green Lake, Station 1, 1940-41 and 1942-43.

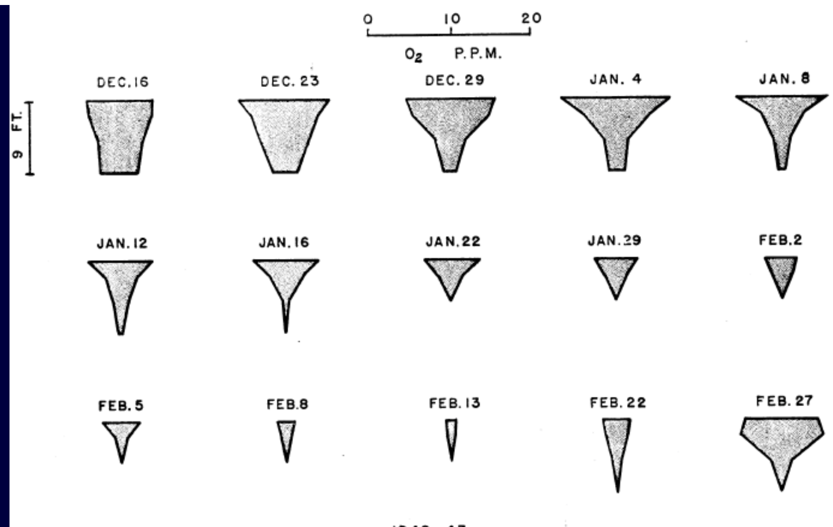


FIG. 21. Dissolved oxygen, vertical distribution. Green Lake, selected dates, 1942-43. The width of the block diagram at any given depth indicates the amount of oxygen present at that depth.

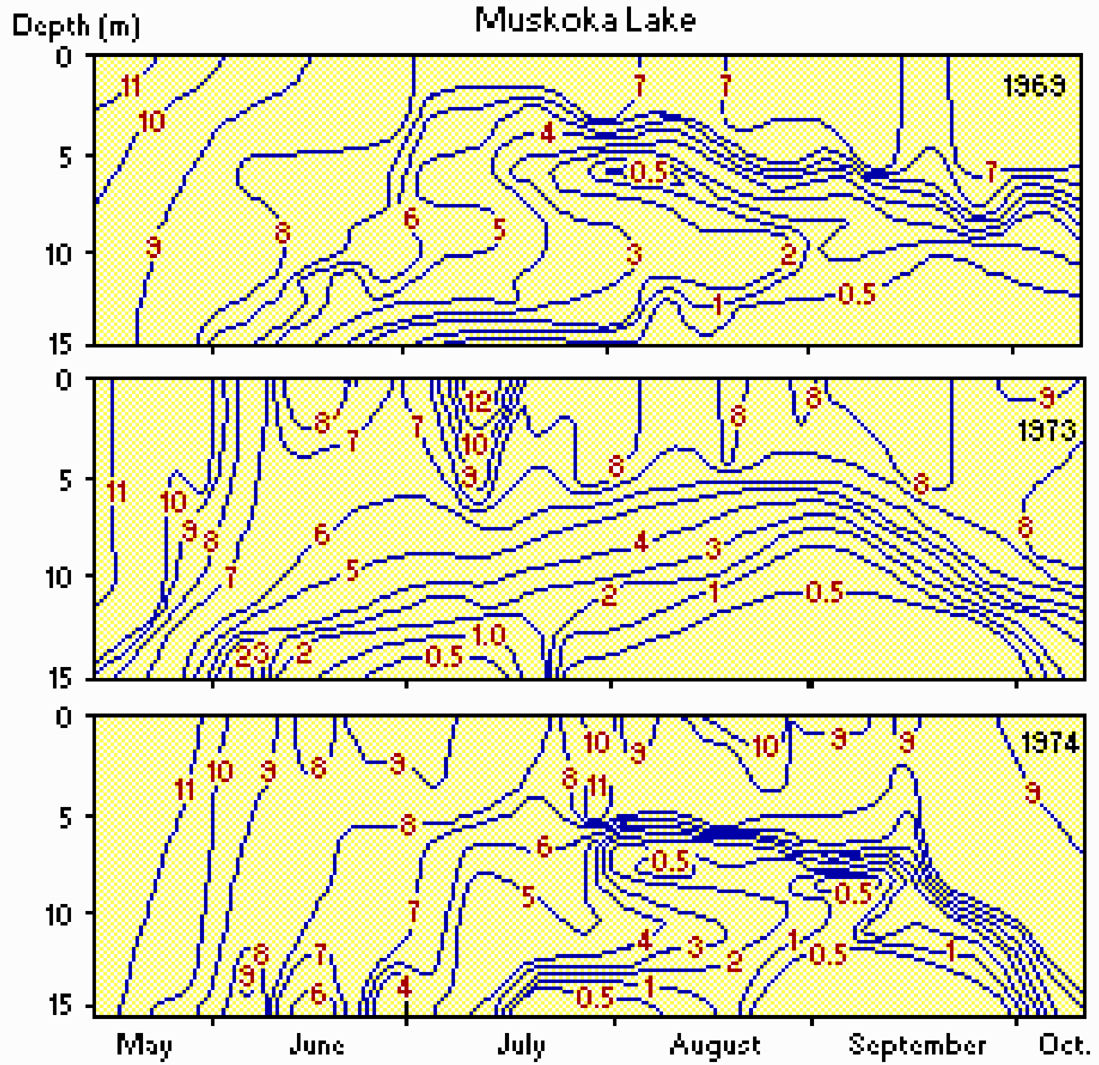
Greenbank 1945

Fish Kills (low O_2)

Also occur often in large lakes in late summer

– why?

Late summer



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Muskoka Lake, Ontario, ILEC

Fish Kills (low O_2)

Also occur most often at dawn
– why?

At dawn

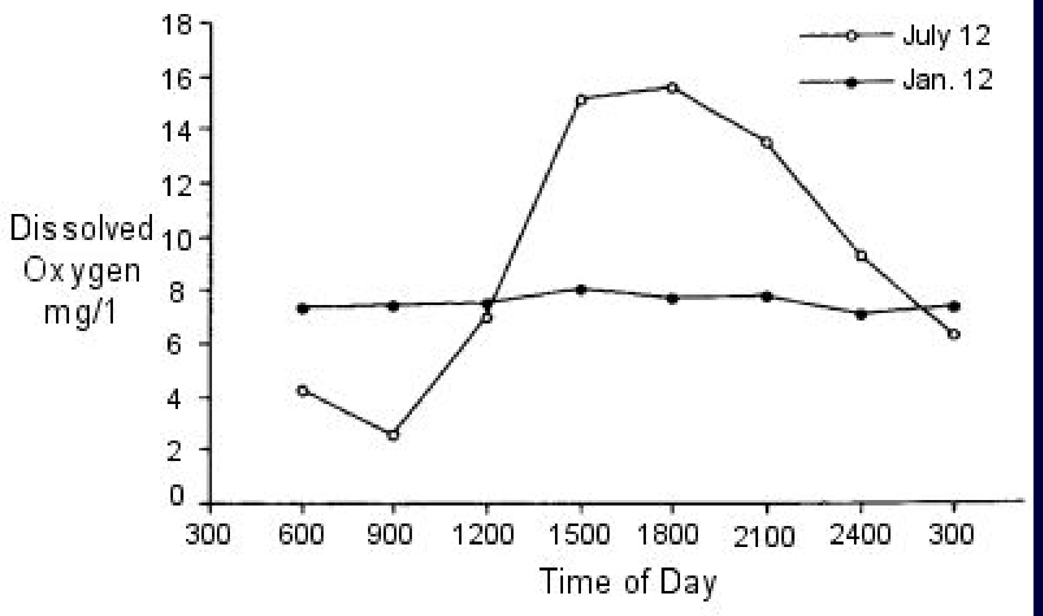


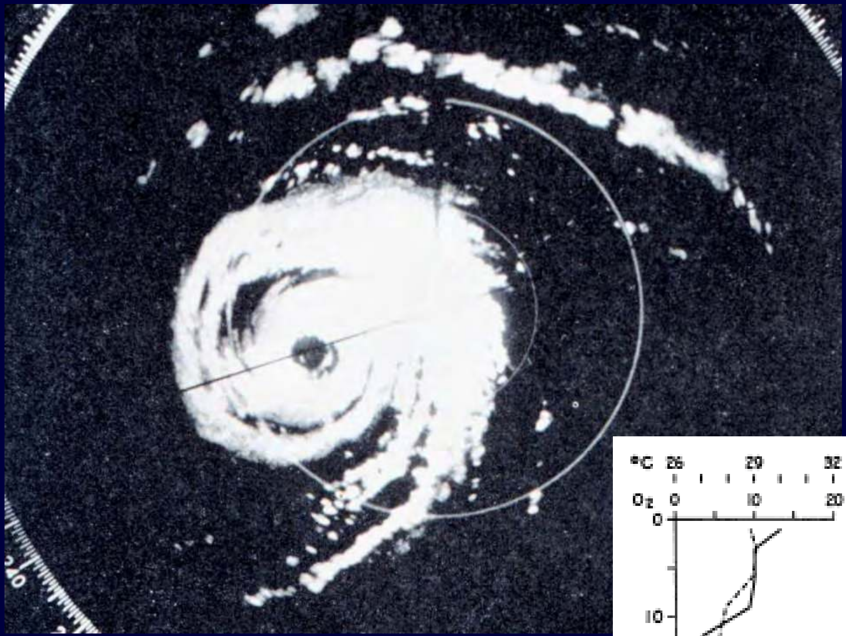
Figure 1. Diurnal oxygen pulse

Eutrophic Timber Ridge Pond in OK, Freimuth and Bass 1994

Fish Kills (low O_2)

Also occur often after summer storm – why?

Storm disruption of stratification



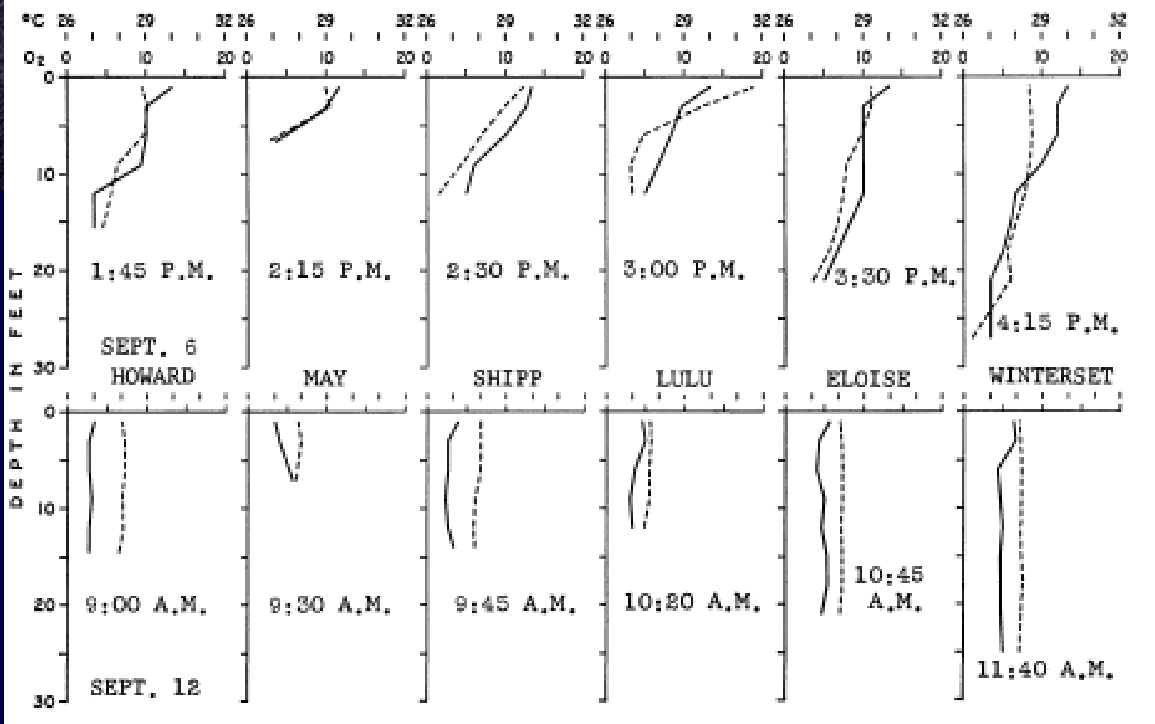


Fig. 2. Distribution of temperature (——) and oxygen (- - -) in Winter Haven lakes before and after hurricane "Donna."

Yount, 1961