

Typical pattern has 2 periods of mixing → *Dimictic* (spring/fall)

Possible to have more than one metalimnion e.g. heat→wind→calm→more heat

Patterns of stratification and mixing:

1. *Dimictic*: most common type

2. *Amictic*: no mixing e.g. lakes covered permanently by ice (poles)

3. *Cold monomictic lakes*: water temp never > 4°C
- winter: covered by ice, summer: 1 mixing period
- found in arctic, mountain tops

4. *Warm monomictic lakes*: water temp never < 4°C
- cool to 4°C in winter → mix, stratify in summer
- e.g. in central/eastern NA, central Europe

Other vocabulary :

Oligomictic: mixes rarely, every few years

Polymictic: mixes all the time, subject to high winds

Variation in the degree of mixing:

Holomictic: the whole water body mixes at turnover

Meromictic: the lower levels never mix

- deep layer = *monimolimnion* (stagnant)
- upper layer = *mixolimnion* (part that mixes)
- division between the two strata = *chemocline*

e.g. Deming Lake, Itasca State Park

Deep, small surface area, shoreline sheltered from wind



Dissolved Oxygen (DO)

- solubility of gases in a liquid affected by temp, (Table 8-1 Wetzel), pressure, salinity
- saturation at low temps > saturation at high temps
- saturation at high pressure > saturation at low

$$P_z = P_o + 0.0967 z \quad (z = \text{depth in m})$$

- increase in salinity → decrease in DO
- full sea water has 20% less DO than FW

TABLE 8-1 Solubility of Oxygen in Pure Water in Relation to Temperature from Saturated Air at 760 mm Hg Pressure^a

Temperature, °C	Oxygen mg l ⁻¹	Temperature, °C	Oxygen mg l ⁻¹
0	14.16	18	9.18
1	13.77	19	9.01
2	13.40	20	8.84
3	13.05	21	8.68
4	12.70	22	8.53
5	12.37	23	8.38
6	12.06	24	8.25
7	11.76	25	8.11
8	11.47	26	7.99
9	11.19	27	7.86
10	10.92	28	7.75
11	10.67	29	7.64
12	10.43	30	7.53
13	10.20	31	7.42
14	9.98	32	7.32
15	9.76	33	7.22
16	9.56	34	7.13
17	9.37	35	7.04

Distribution of DO in Lakes (fig 8-1)

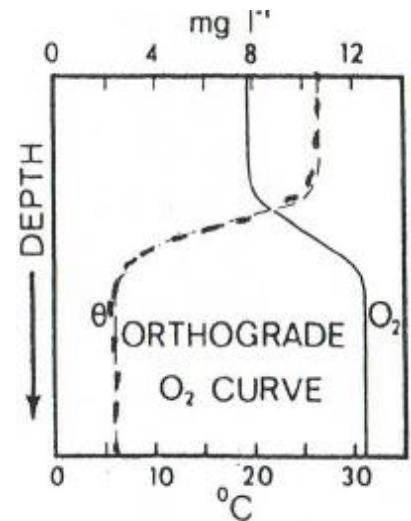
- **oligotrophic** lakes (low nutrients, low organic production): DO remains at 100% saturation throughout the year

- during summer stratification:

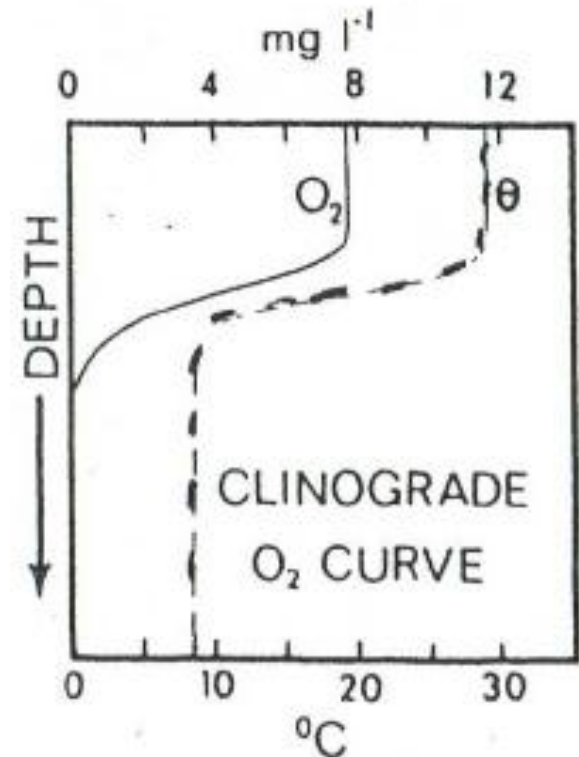
DO in epilimnion < hypolimnion

= *orthograde*

- ideal orthograde DO is rare because of Biochemical Oxygen Demand (BOD) in hypolimnion



- in **eutrophic** lakes (high nutrients with high organic production) → high BOD in hypolimnion
- low DO in hypolimnion after stratification
- = *clinograde*
- Low DO in hypolimnion because of
 - Respiration (BOD)
 - No access to atmospheric O_2



Positive heterograde =

- low DO in epilimnion due to high temp and consumption by biota
- low DO in hypolimnion due to BOD
- high DO in metalimnion due to low temp, high nutrients and high 1° productivity
- fairly common

Negative heterograde

- rare
 1. result from high rates of sedimentation into metalimnion
BOD incr with temp (meta > hypo)
 2. Concentrations of zooplankton at metalimnion deplete DO
 3. Oxidation of methane rising to the metalimnion

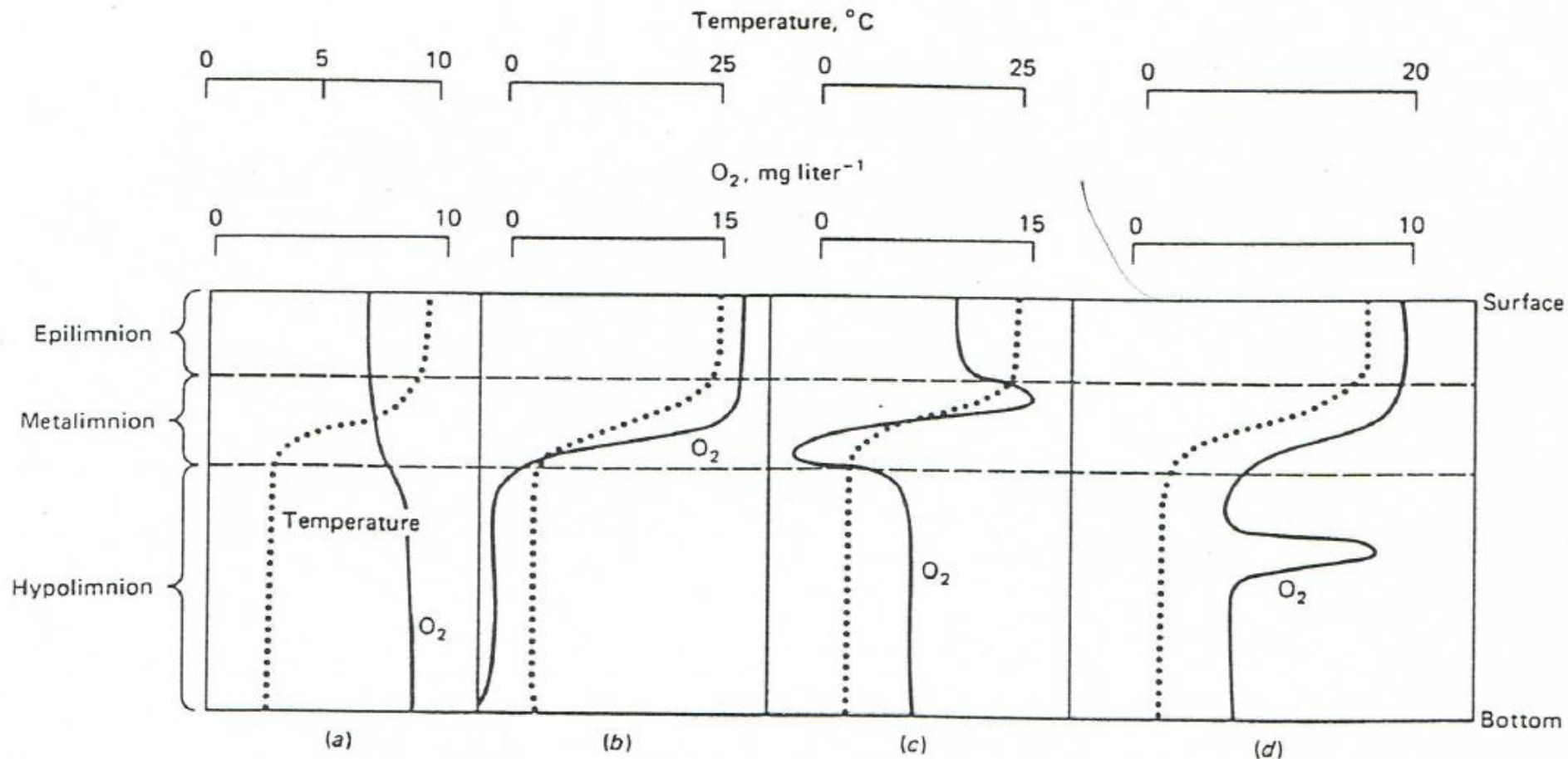


Figure 7-11 Types of oxygen distribution with depth in diagrammatic form. (a) An orthograde curve typical of an unproductive lake. (b) A clinograde curve from a productive lake. (c) Positive and negative heterograde curves. Here photosynthesis from a layer of algae just above the thermocline raises oxygen in the upper part of the metalimnion. Respiration occurring during decomposition lowers oxygen levels just below the thermocline (metalimnion minimum). (d) Anomalous curves due to the inflow of dense, cool, oxygen-rich stream inflows which form a discrete layer. In this example, the oxygen-rich stream inflow is in midhypolimnion.

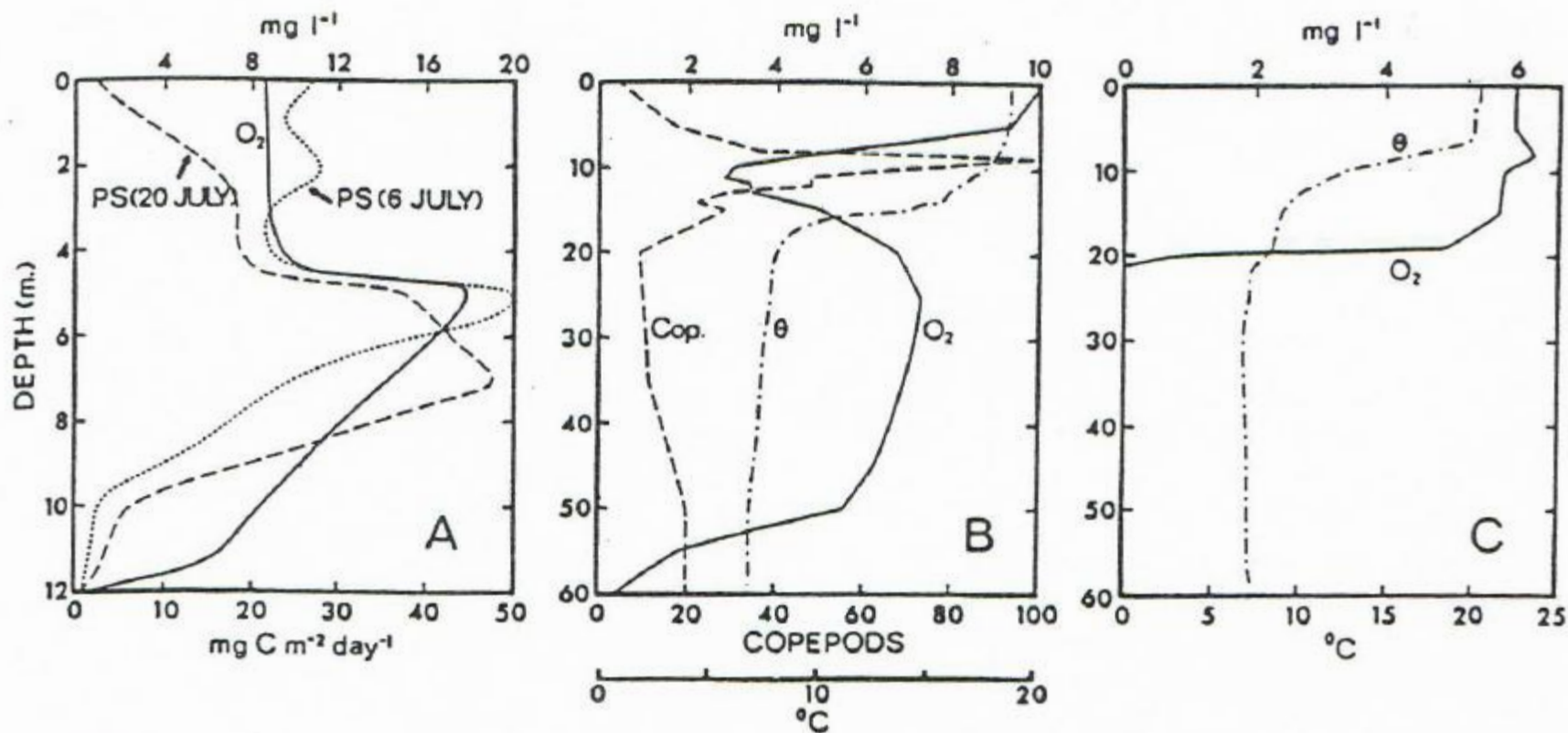


Figure 8-4 A, Metalimnetic oxygen maximum, showing a positive heterograde curve, in relation to temperature (θ) and rates of phytoplanktonic photosynthesis (*PS*), Lawrence Lake, Michigan, 20 July 1971. (From Wetzel, *et al.*, 1972.) B, Metalimnetic oxygen minimum, showing a negative heterograde curve, in relation to abundance of copepod microcrustaceans (*Cop.*), Lake Washington, Washington, 18 August 1958. (Drawn from data of Shapiro, 1960.) C, Oxygen concentrations in permanently meromictic Fayetteville Green Lake, New York, 3 September 1935. (Data of Eggleton, 1956.)

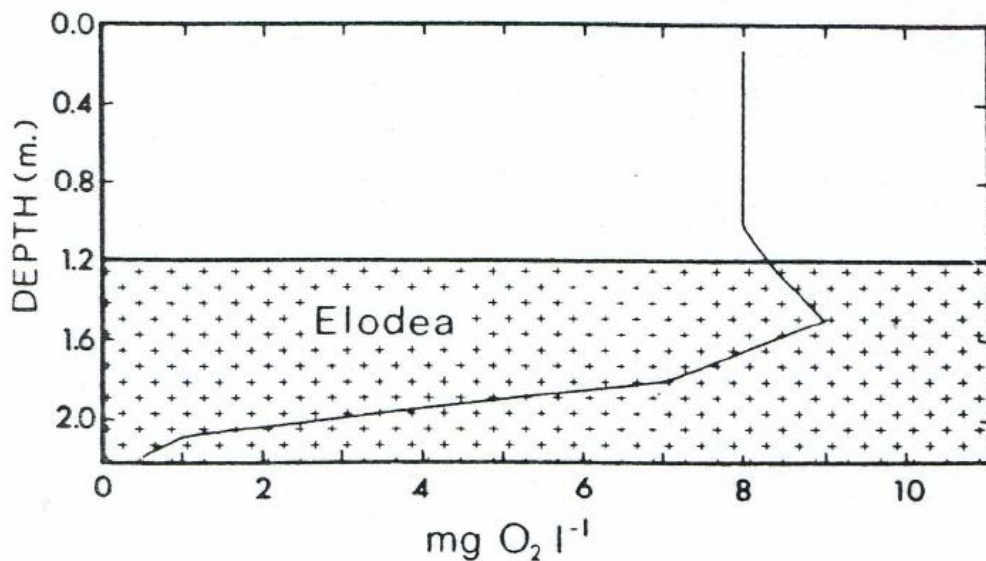
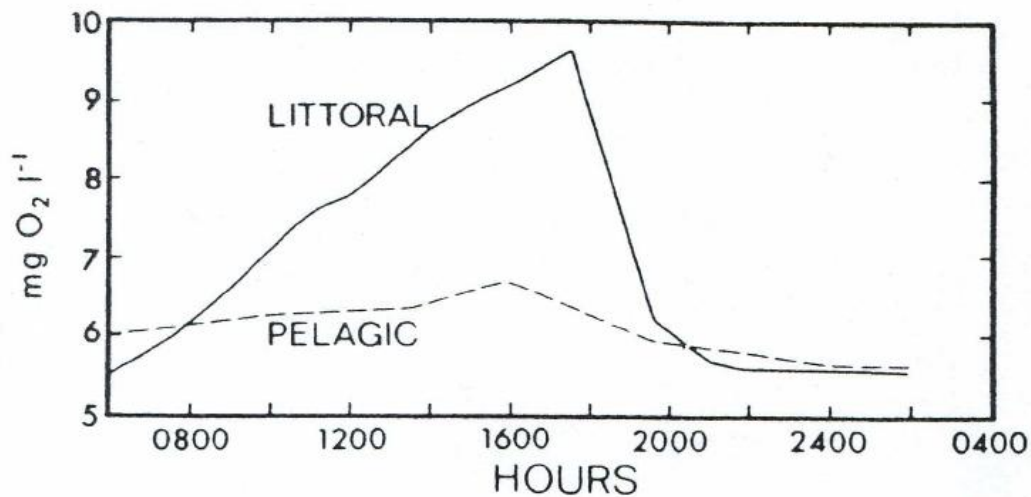


FIGURE 9-8 Upper: Changes in dissolved oxygen in the littoral and open-water areas over a diurnal period in eutrophic Winona Lake, Indiana, 9 August 1922. (From data of Scott, 1924.) Lower: Vertical stratification of oxygen within the littoral zone of Parvin Lake, Colorado, 9 July 1955, in a luxuriant stand of the submersed macrophyte *Elodea*. (Generated from data of Buscemi, 1958.)

Diel and seasonal cycles

- pelagic (open water) DO usually fairly stable
- littoral zone fluctuates with 1° productivity

“Summer Kill”

- when high temp (low DO saturation) coincides with die off of macrophytes → creates very high BOD → anoxia

"Winter Kill"

- ice cover cuts off O₂ diffusion with surface
- Thick snow cover reduces light available for 1° production
- BOD continues, albeit slowly
- DO reduced to < 2 ppm → fish death

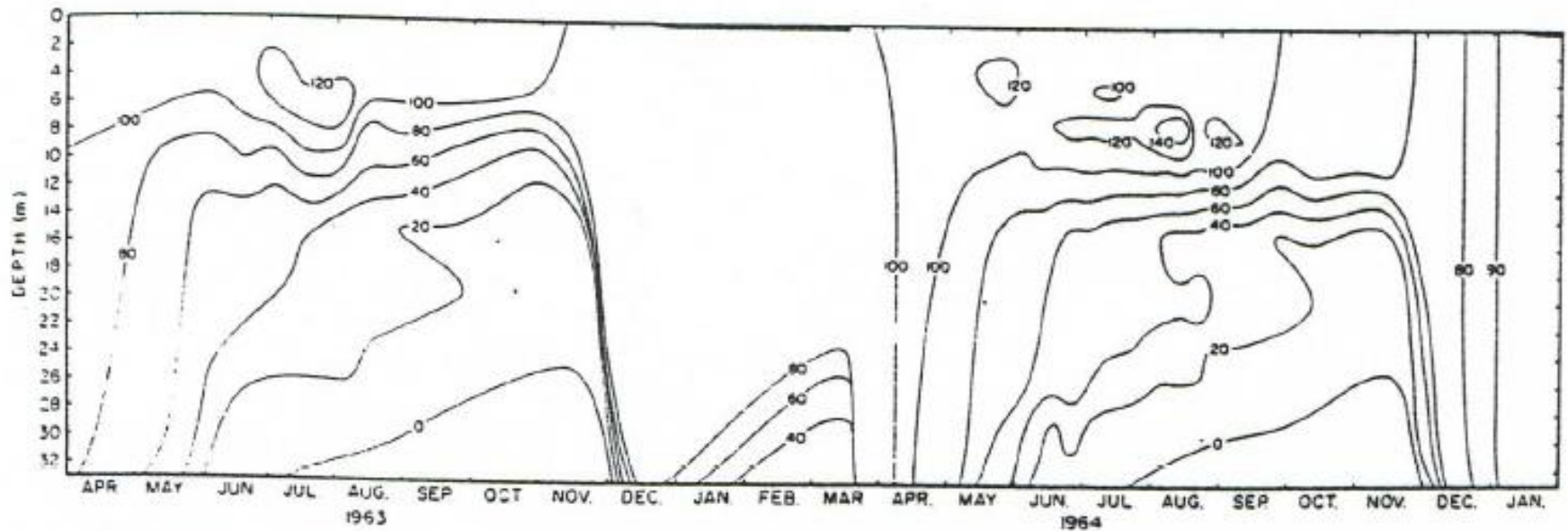
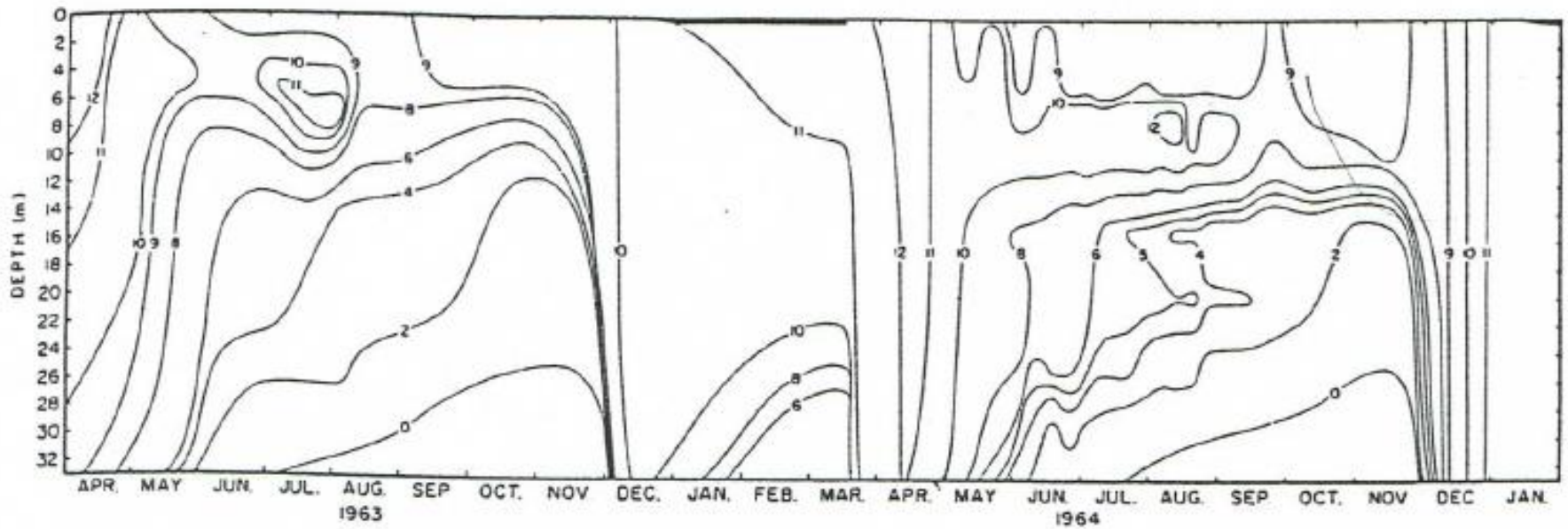


Figure 8-2 Depth-time diagram of isopleths of dissolved oxygen concentrations in mg l⁻¹ (*upper*) and percentage oxygen saturation (*lower*), Crooked Lake, Noble-Whitley counties, north-eastern Indiana. Ice-cover drawn to scale. (From Wetzel, unpublished data.)

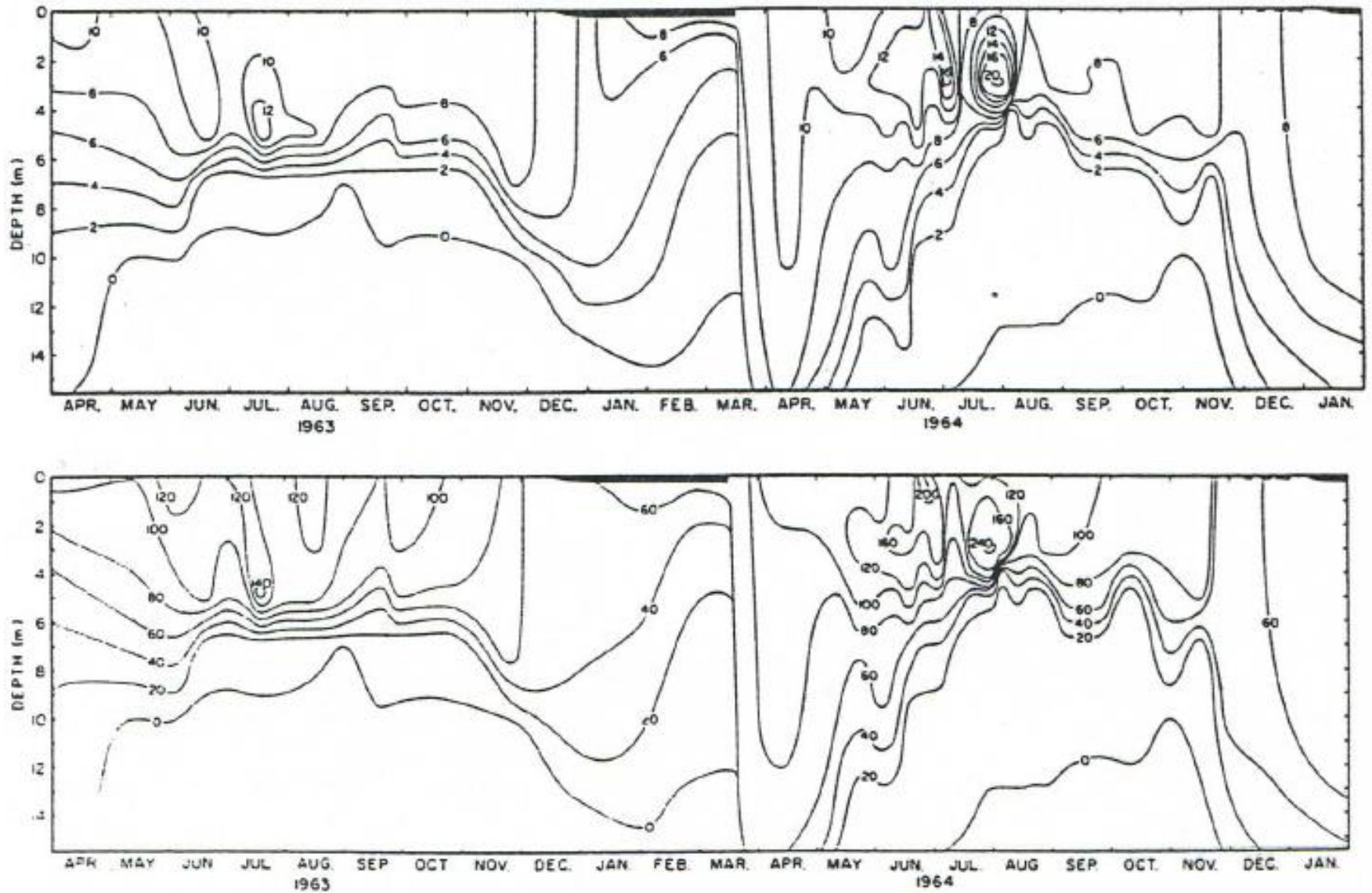


Figure 8-3 Depth-time diagram of isopleths of dissolved oxygen concentrations in mg l^{-1} (upper) and percentage oxygen saturation (lower), Little Crooked Lake, Whitley County, north-eastern Indiana. Ice-cover drawn to scale. (From Wetzel, unpublished data.)