

# New Emphasis on Water Clarity as Socio-Ecological Indicator for Urban Water – A SHORT ILLUSTRATION

*Katrin Teubner, Irene E. Teubner, Karin Pall, Wilfried Kabas,  
Monica Tolotti, Thomas Ofenböck, Martin T. Dokulil*

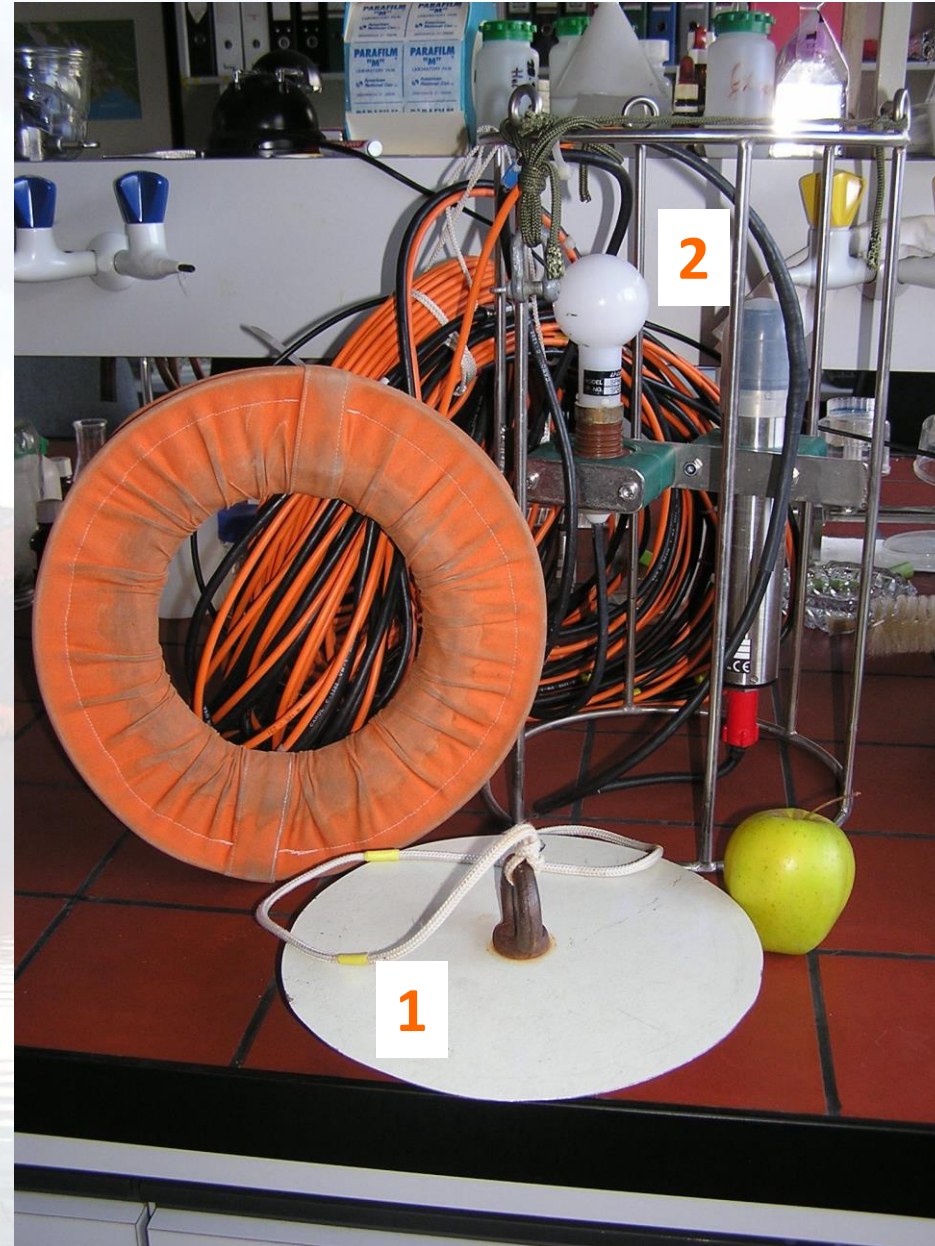
43<sup>rd</sup> IAD-conference, Aueninstitut Neuburg a.d. Donau,  
Germany: Rivers and Floodplains in the Anthropocene – Upcoming  
Challenges in the Danube River Basin, 9 – 11 June 2021



# Measuring Water Transparency by light attenuation under water:

1 Secchi Disk

2 Light Sensor



from FBA by Irene Teubner (2006)



# Measuring Water Transparency by light attenuation under water:



1 Secchi Disk



2 Light Sensor

# Measuring Water Transparency by light attenuation under water:



**Black-and-white Secchi Disk**



Photo: K Teubner

**1 Secchi Disk**



Photo: K Teubner



Photo: K Teubner

**2 Light Sensor**





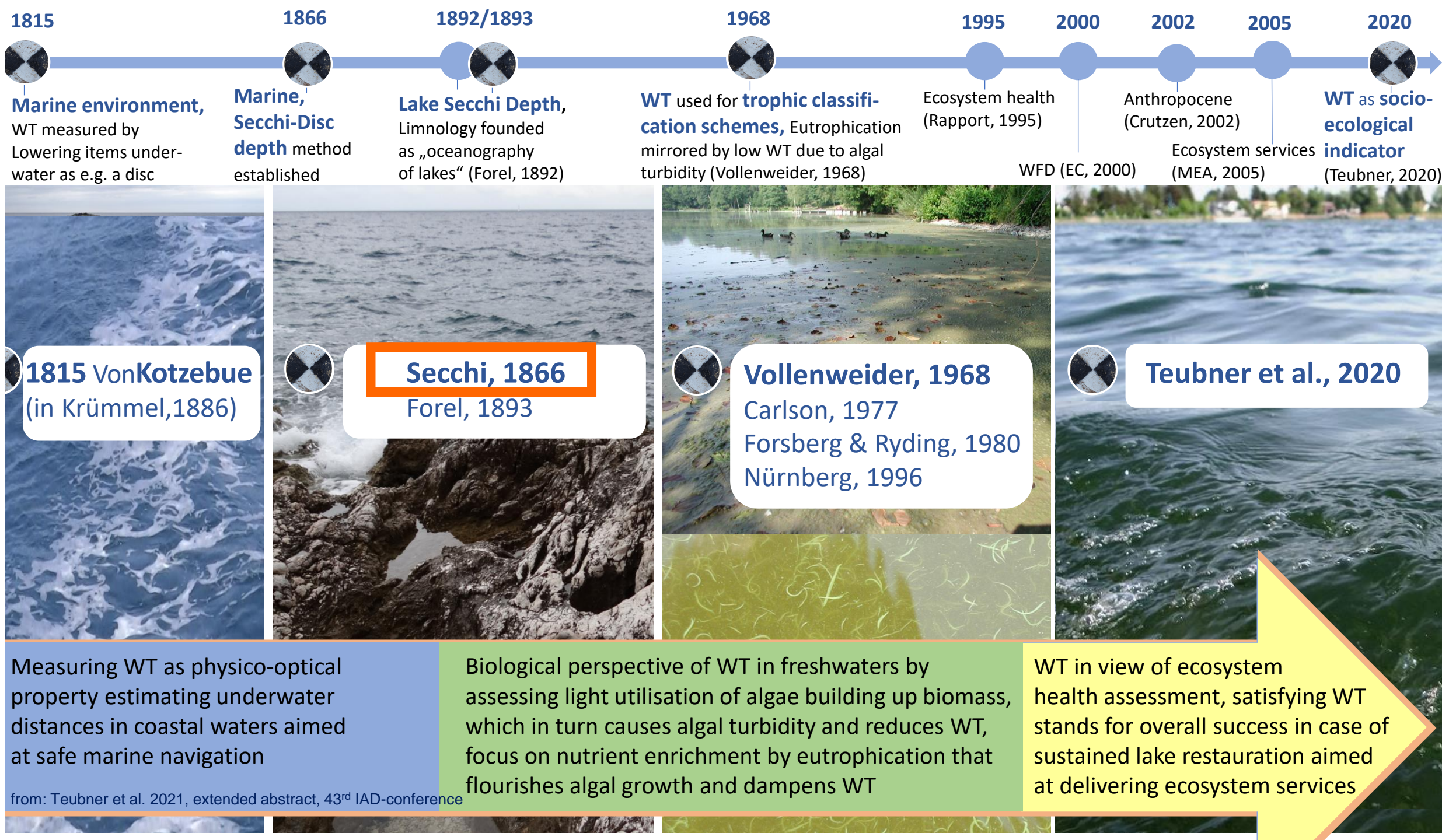




...thinking about such a disk,  
that begs the question:

Who was the  
first measuring  
water visibility  
by lowering  
items under  
water, like a disk  
– and for what  
this is good for?

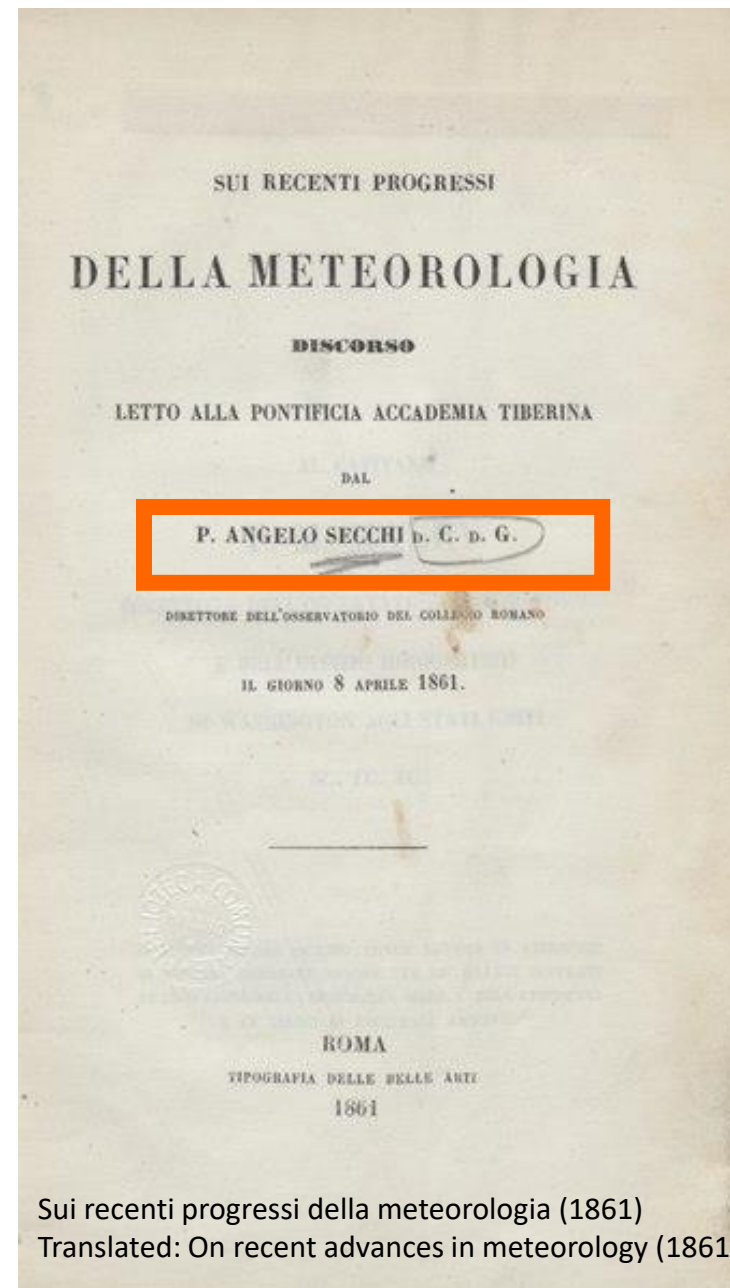




**Meteorology:** Visibility is a distance measure at which a landscape mark (e.g. tree, house) can be clearly seen – Visibility thus depends on transparency of the air in the environment –

In German we call this meteorological measure to look into the open landscape “**Sichtweite**”,

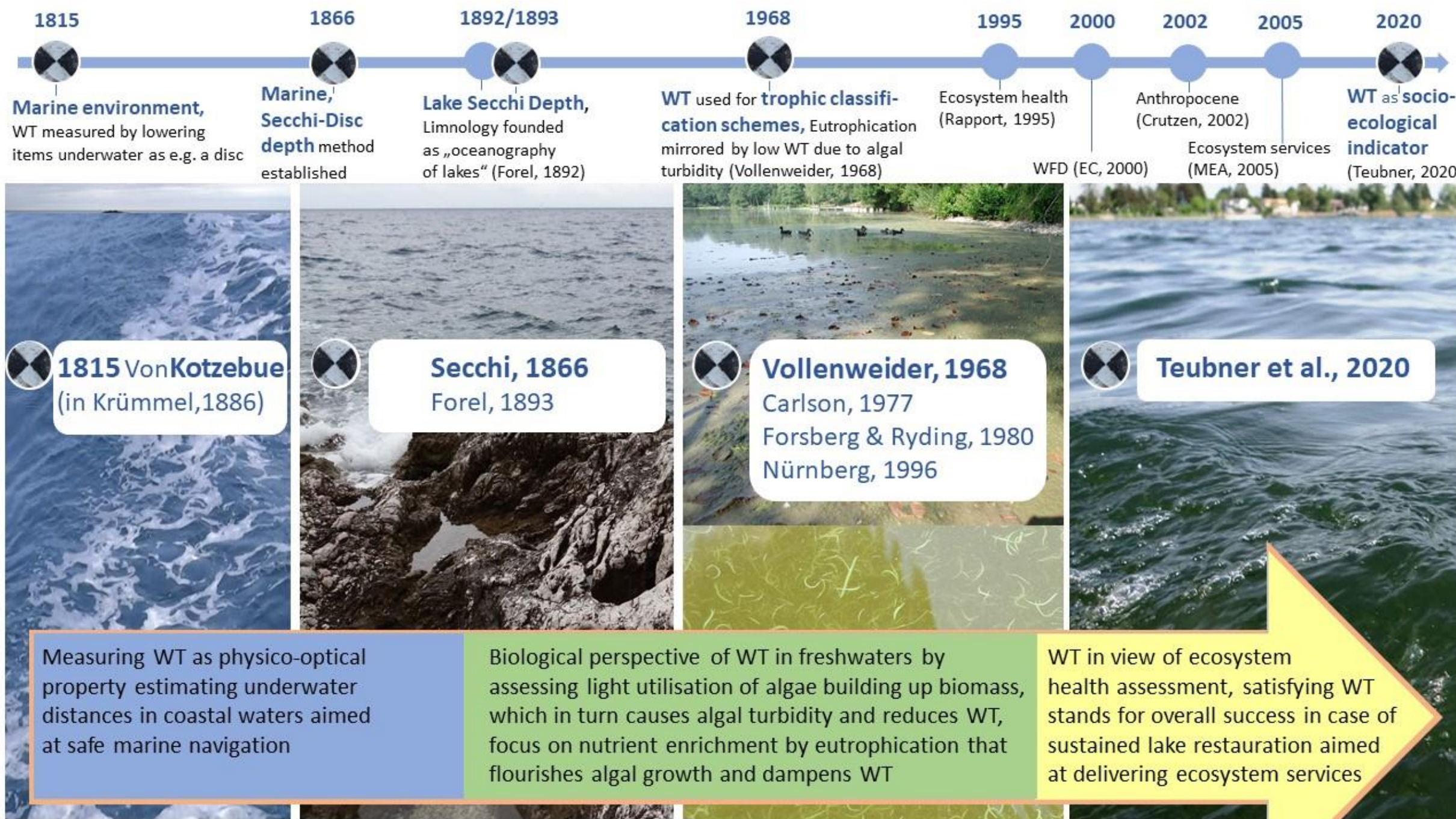
and in aquatic sciences it became named “**Sichttiefe**” measuring water transparency at water depths.



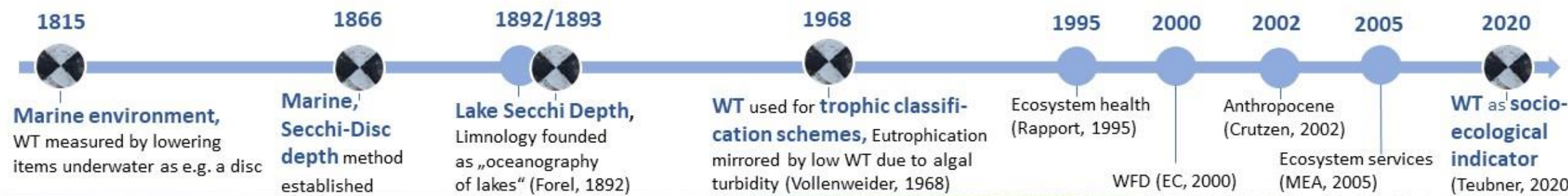
Sui recenti progressi della meteorologia (1861)  
Translated: On recent advances in meteorology (1861)

Source of photo of the book cover: [https://de.wikipedia.org/wiki/Angelo\\_Secchi](https://de.wikipedia.org/wiki/Angelo_Secchi)





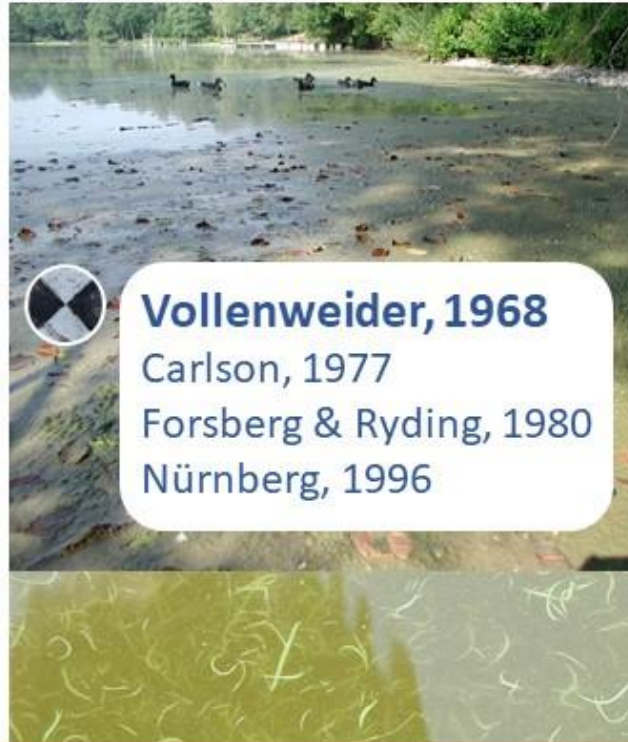




 **1815 VonKotzebue**  
(in Krümmel, 1886)



 **Secchi, 1866**  
Forel, 1893



 **Vollenweider, 1968**  
Carlson, 1977  
Forsberg & Ryding, 1980  
Nürnberg, 1996



 **Teubner et al., 2020**

Measuring WT as physico-optical property estimating underwater distances in coastal waters aimed at safe marine navigation

**1.**

Biological perspective of WT in freshwaters by assessing light utilisation of algae building up biomass, which in turn causes algal turbidity and reduces WT, focus on nutrient enrichment by eutrophication that flourishes algal growth and dampens WT

**2.**

WT in view of ecosystem health assessment, satisfying WT stands for overall success in case of sustained lake restoration aimed at delivering ecosystem services

**3.**



*Response to (algal) turbidity*

*Stimulation for macrophyte growth*





## *Response to (algal) turbidity*



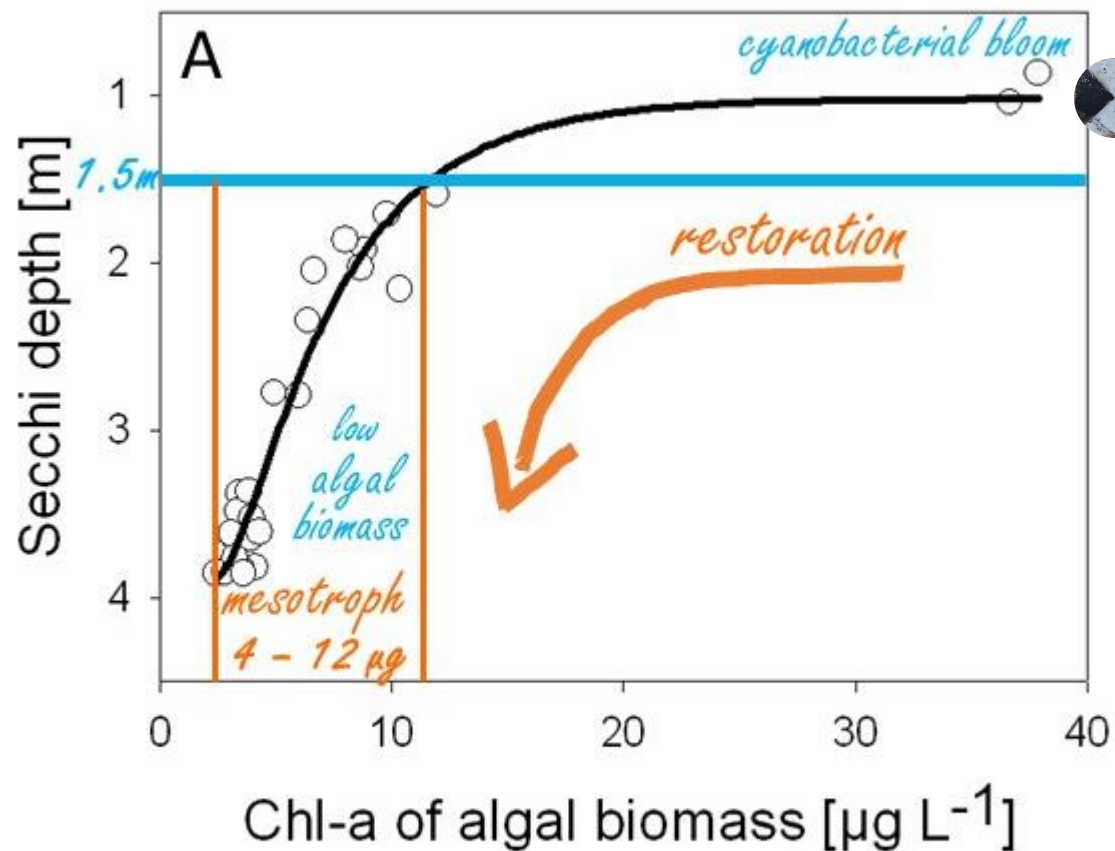
## *Stimulation for macrophyte growth*



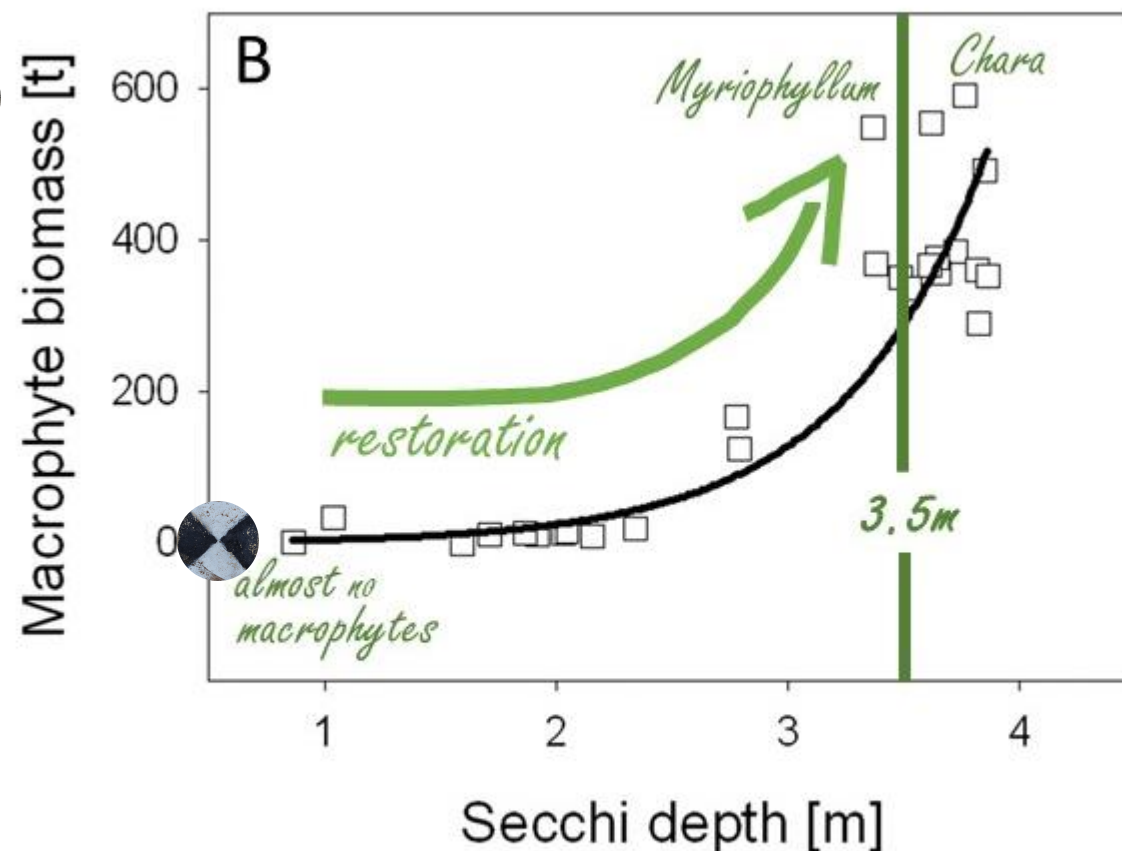
**Case study: Oxbow Lake Alte Donau, Vienna**



## Response to (algal) turbidity



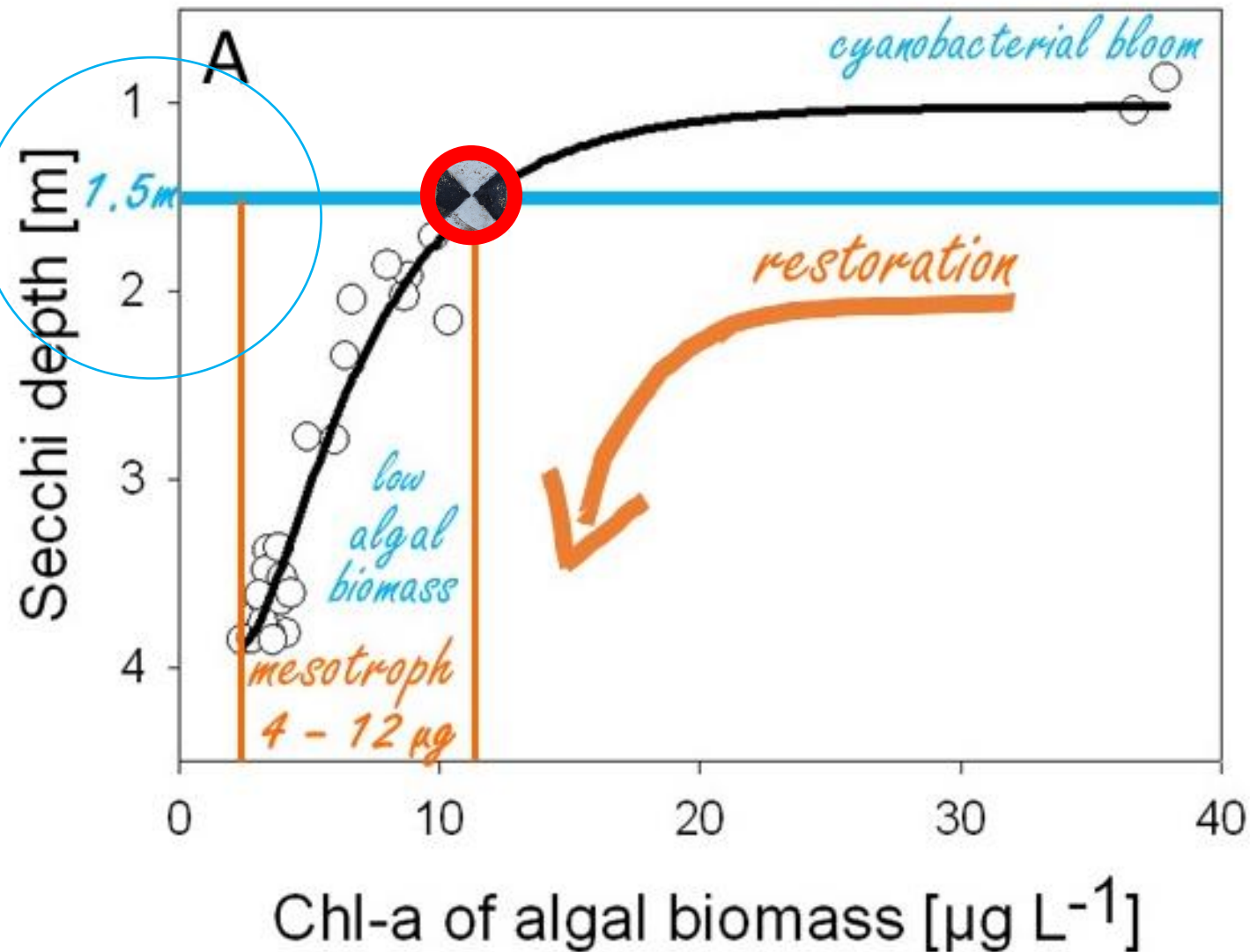
## Stimulation for macrophyte growth





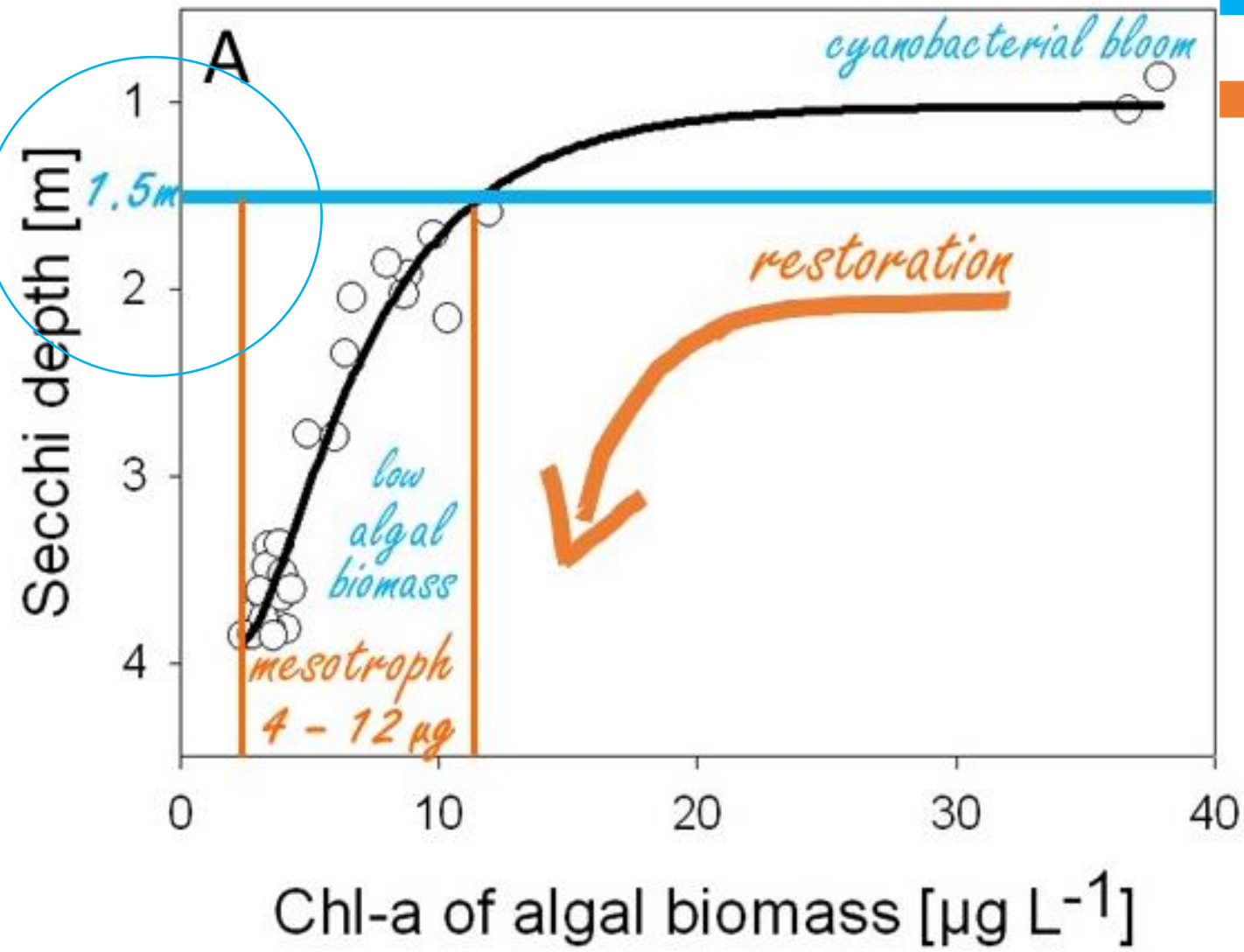
## Response to (algal) turbidity

1.5 m Secchi depth = critical point





*Response to (algal) turbidity*



*1.5 m Secchi depth = critical point*

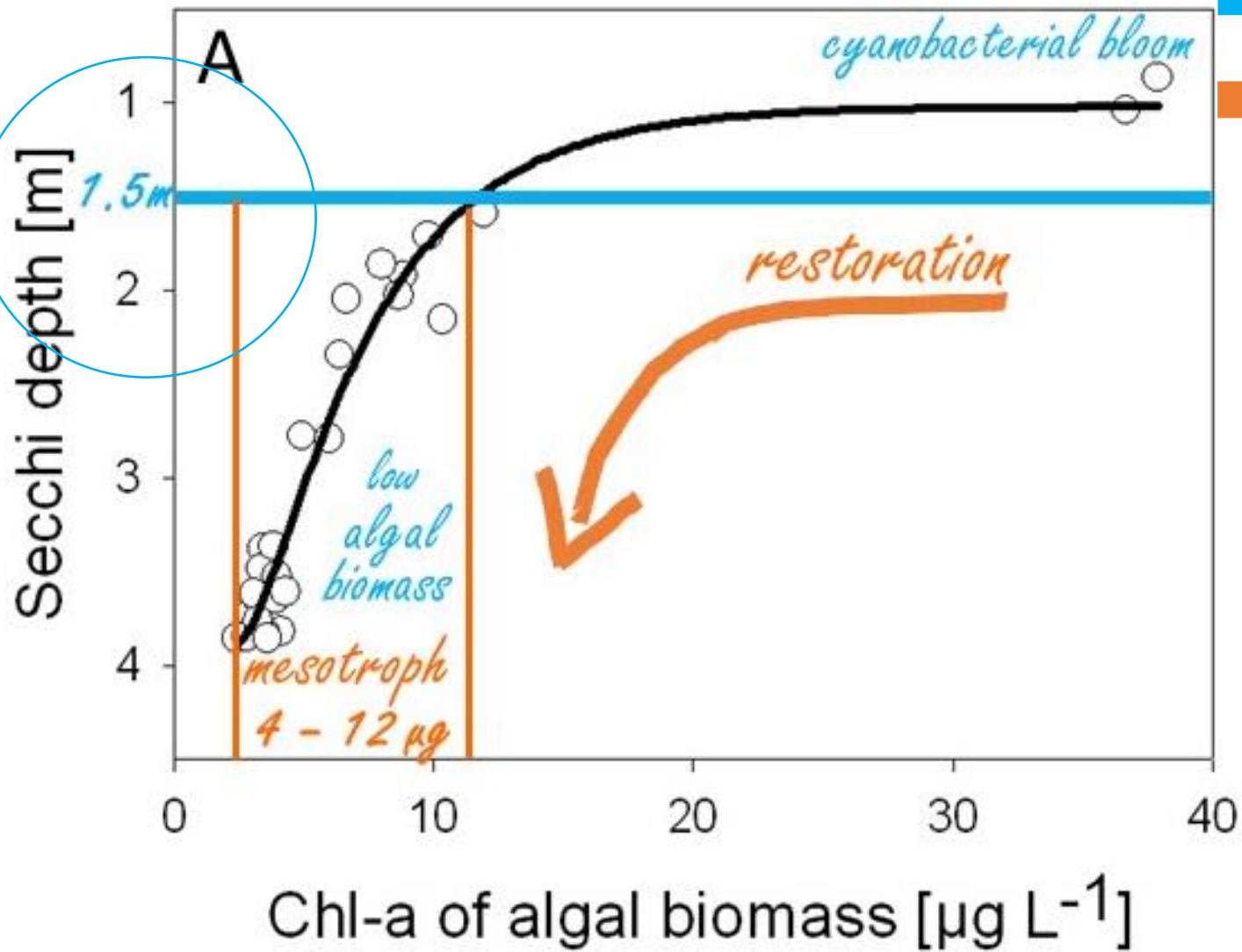
*shift from eutr. to mesotrophic state*

*judged as good water quality, satisfying bathing aesthetics by human perception,*

*Why?*



## Response to (algal) turbidity



1.5 m Secchi depth = critical point

→ shift from eutr. to mesotrophic state

→ judged as good water quality,  
satisfying bathing aesthetics  
by human perception,  
littoral “lake bottom view”

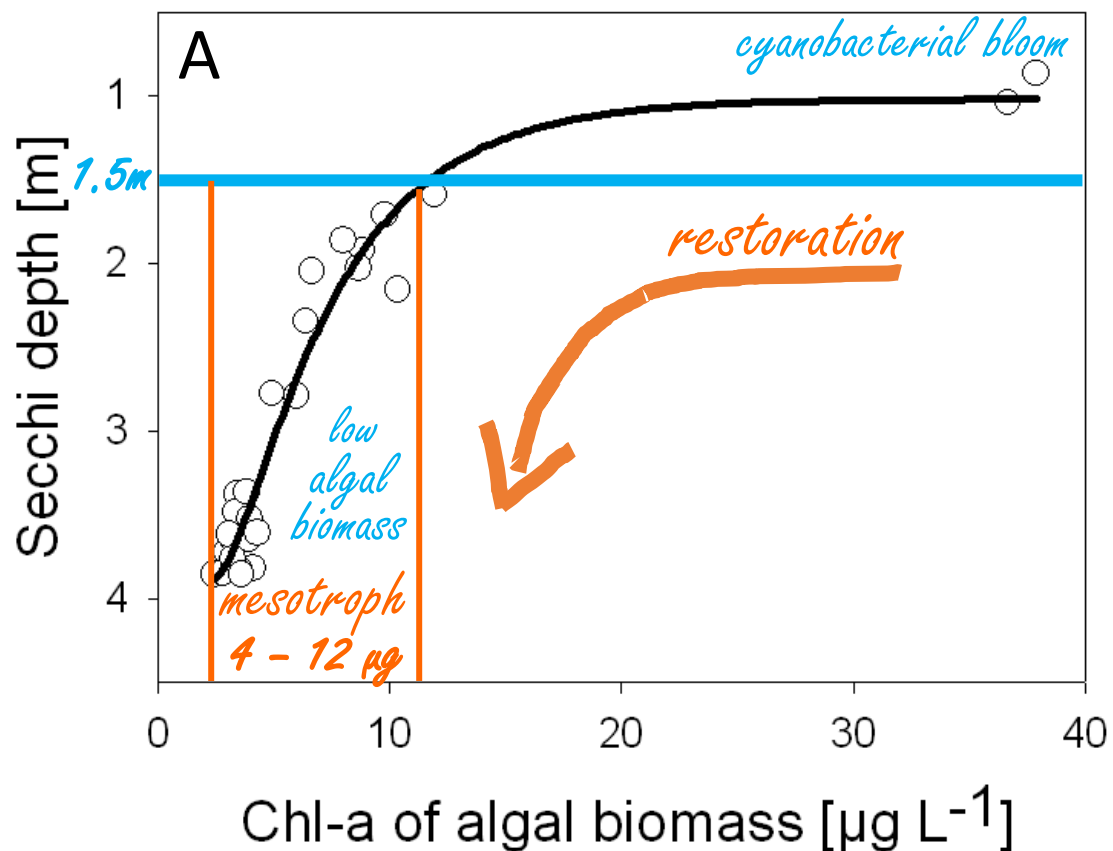


Photo: K Teubner

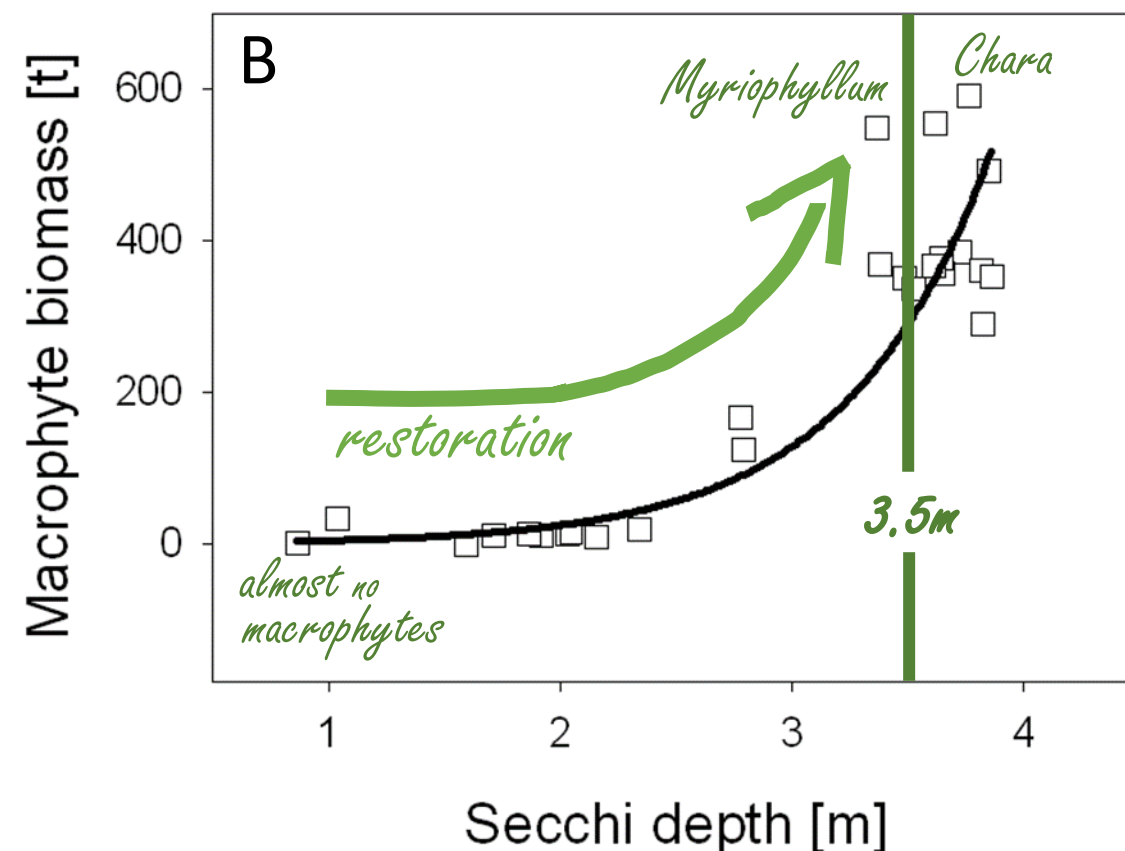
from: Teubner et al. 2021, extended abstract, 43<sup>rd</sup> IAD-conference



## Response to (algal) turbidity



## Stimulation for macrophyte growth





## Underwater macrophyte cutting

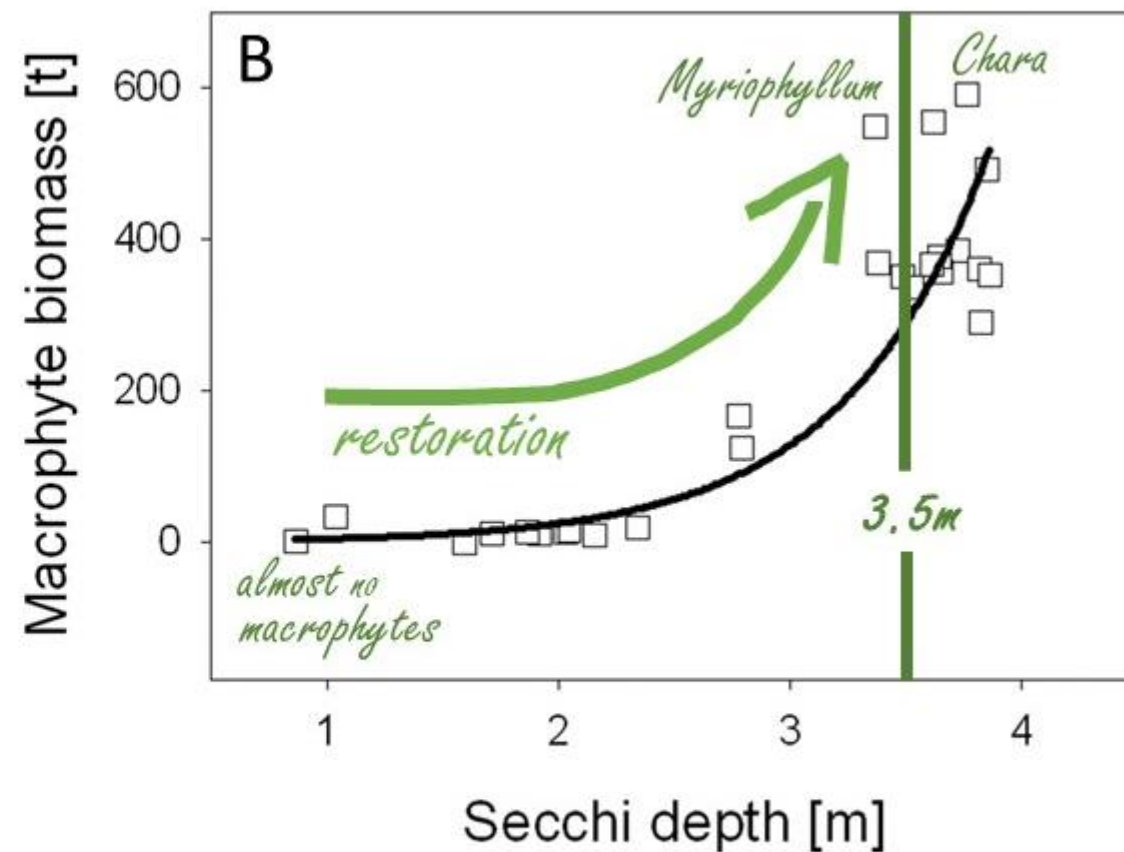


*Myriophyllum spicatum* – tall growing plant with canopy near water surface



Photo: K Teubner

## Stimulation for macrophyte growth



*Chara spec.* – bottom dwelling Charophytes

Photo: K Teubner





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## ORIGINAL RESEARCH article

Front. Environ. Sci., 01 October 2020 | <https://doi.org/10.3389/fenvs.2020.573724>

# New Emphasis on Water Transparency as Socio-Ecological Indicator for Urban Water: Bridging Ecosystem Service Supply and Sustainable Ecosystem Health

**Katrin Teubner<sup>1\*</sup>**, **Irene Teubner<sup>2,3</sup>**, **Karin Pall<sup>4</sup>**, **Wilfried Kabas<sup>5</sup>**, **Monica Tolotti<sup>6</sup>**, **Thomas Ofenböck<sup>7</sup>** and **Martin T. Dokulil<sup>8</sup>**<sup>1</sup>Department of Functional and Evolutionary Ecology, Faculty of Life Sciences, University of Vienna, Vienna, Austria<sup>2</sup>Research Group Climate and Environmental Remote Sensing, Department of Geodesy and Geoinformation, TU Wien, Vienna, Austria<sup>3</sup>Climatology Section, Division Customer Service, Zentralanstalt für Meteorologie und Geodynamik, Vienna, Austria<sup>4</sup>Systema GmbH, Vienna, Austria<sup>5</sup>Department of Limnology and Bio-Oceanography, Faculty of Life Sciences, University of Vienna, Vienna, Austria<sup>6</sup>Department of Sustainable Agro-ecosystems and Bioresources, Research and Innovation Centre, Fondazione Edmund Mach, San Michele all'Adige, Italy<sup>7</sup>Municipal Department 45 – Water Management, Vienna City Administration, Vienna, Austria<sup>8</sup>Research Department for Limnology, Mondsee, University of Innsbruck, Mondsee, Austria

Teubner et al. (2020). New Emphasis on Water Transparency as Socio-Ecological Indicator for Urban Water: Bridging Ecosystem Service Supply and Sustainable Ecosystem Health. *Frontiers in Environmental Science*, 8, 162. <https://www.frontiersin.org/articles/10.3389/fenvs.2020.573724/full>



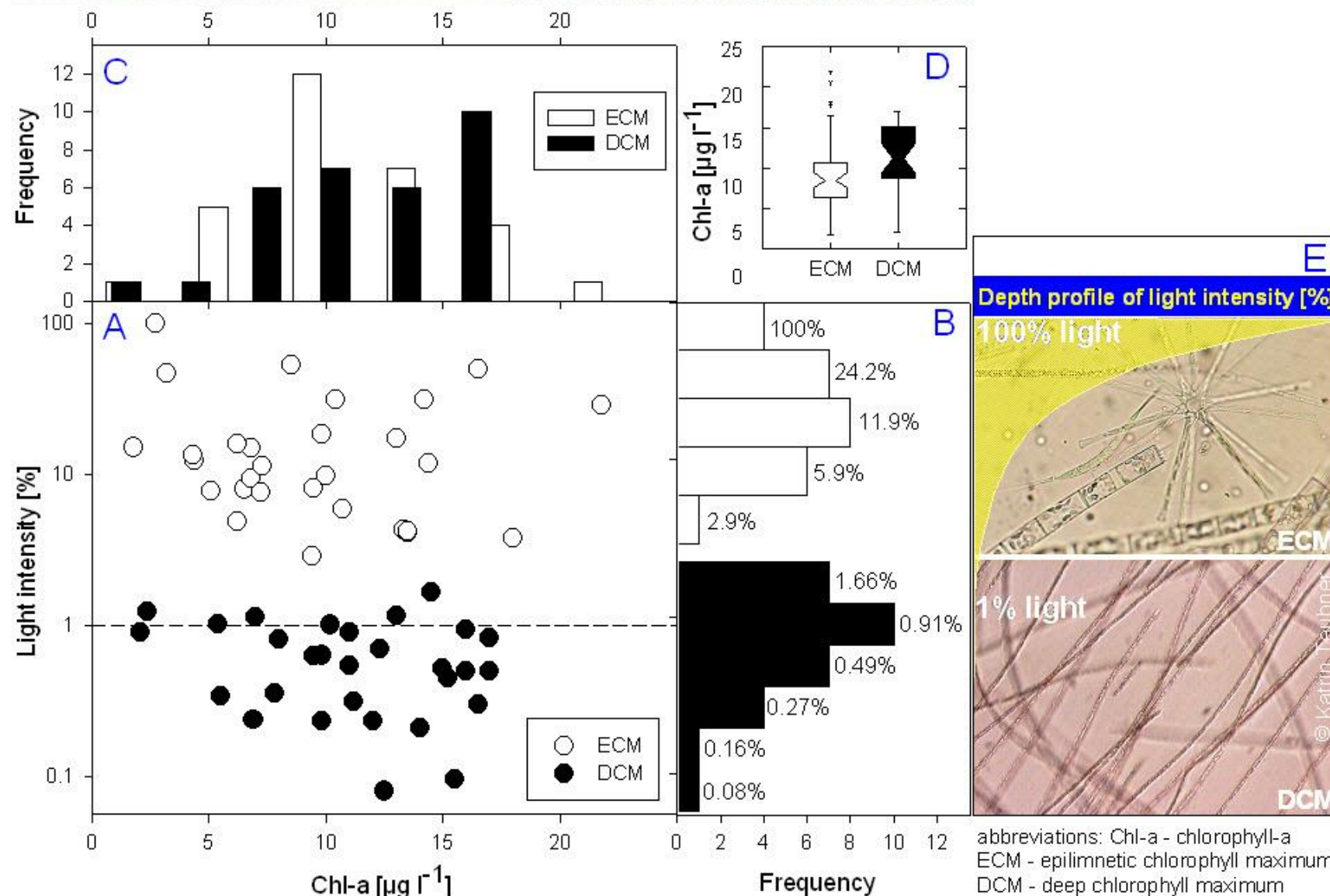


Category	(A) all	(B) Seasonal development				(C) Trophic lake classification scheme			(D) Human water-quality perceptions for bathing		
		Spring	Summer	Autumn	Winter	Oligo-trophic	Meso-trophic	Eu-trophic	$z_{Secchi} > 1.55\text{ m}$	$z_{Secchi} 1.45-1.55\text{ m}$	$z_{Secchi} < 1.45\text{ m}$
$z_{Secchi}$ [m]	1.62	1.75	1.36	1.56	2.3	2.45	1.72	1.17	2.07	1.50	1.17
$I_{z_{Secchi}}$ [%]	26	27	28	24	21	21	26	28	23	25	29
$k_{PAR}$ [m <sup>-1</sup> ]	0.918	0.796	0.981	1.012	0.802	0.728	0.838	1.149	0.747	0.934	1.096
$z_{eu}$ [m]	<b>5.35</b>	<b>6.04</b>	<b>4.93</b>	<b>4.82</b>	<b>6.2</b>	<b>6.62</b>	<b>5.72</b>	<b>4.18</b>	<b>6.33</b>	<b>5.02</b>	<b>4.40</b>
$f_{eu}$	3.45	3.58	3.65	3.24	2.99	3.05	3.42	3.62	3.17	3.35	3.78
$z_{macrophytes}$ [m]	<b>4.08</b>	4.60	<b>3.75</b>	<b>3.67</b>	<b>4.83</b>	<b>5.04</b>	<b>4.36</b>	<b>3.19</b>	<b>4.82</b>	<b>3.82</b>	<b>3.35</b>
$f_{macrophytes}$	2.63	2.73	2.78	2.48	2.28	2.32	2.60	2.76	2.42	2.55	2.88
$z_{peak-phyto}$ [m]	<b>2.47</b>	<b>2.78</b>	<b>2.27</b>	<b>2.22</b>	<b>2.92</b>	<b>3.05</b>	<b>2.64</b>	<b>1.93</b>	<b>2.91</b>	<b>2.31</b>	<b>2.03</b>
$f_{peak-phyto}$	1.59	1.65	1.68	1.49	1.38	1.41	1.58	1.67	1.46	1.54	1.74
Chl-a [µg L <sup>-1</sup> ]	10	7.5	11	12.5	5.9	3.1	7.7	17	6.6	11	13
$n$	131	38	43	37	13	11	82	38	55	16	60

Depth of surface ambient light at 1% refers to minimum light requirements of phytoplankton (euphotic depth,  $z_{eu}$ ), at 3% to minimum light requirements of submerged macrophytes (maximum colonization depth,  $z_{macrophytes}$ ) and at 12% referring to light required for phytoplankton optimum indicated by epilimnetic phytoplankton peak ( $z_{peak-phyto}$ ) (see section “Materials and Methods”). Euphotic depth ( $z_{eu}$ ) exceeds  $z_{Secchi}$  by the factor  $f_{eu}$  (more details in Kabas, 2004). Analogous factors for  $z_{macrophytes}$  and  $z_{peak-phyto}$  exceeding  $z_{Secchi}$  are  $f_{macrophytes}$  and ( $f_{peak-phyto}$ ), respectively. Mean values are shown for the whole data set (A), the four seasons (B) along three trophic states (C), and for threshold of bathing aesthetics (D). Further for (C) Trophic classification scheme refers to samples of chlorophyll-a (Chl-a) concentrations which were simultaneously taken when measuring  $z_{Secchi}$  and  $k_{PAR}$ , and applies here to ÖNORM M6231 (2001): oligotrophic:  $Chl-a < 4\text{ }\mu\text{g L}^{-1}$ , mesotrophic:  $4\text{ }\mu\text{g L}^{-1}$  to  $12\text{ }\mu\text{g L}^{-1}$ , eutrophic  $> 12\text{ }\mu\text{g L}^{-1}$ . Further for (D) To correspond water-quality perceptions for bathing (threshold of  $z_{Secchi} = 1.5\text{ m}$  according to Smith et al., 1991, 1995a), a narrow range of sampling dates with  $z_{Secchi}$  between 1.45 and 1.55 m is compared with those of higher and lower  $z_{Secchi}$ , respectively (D). Depth [in m] of critical light requirements for phytoplankton and macrophytes growth are plotted in bold. Data based on mean values from biweekly to monthly measurements of  $z_{Secchi}$ ,  $k_{PAR}$ , and Chl-a, in Alte Donau (1995–2001,  $n = 131$ ).



## Lake Ammersee



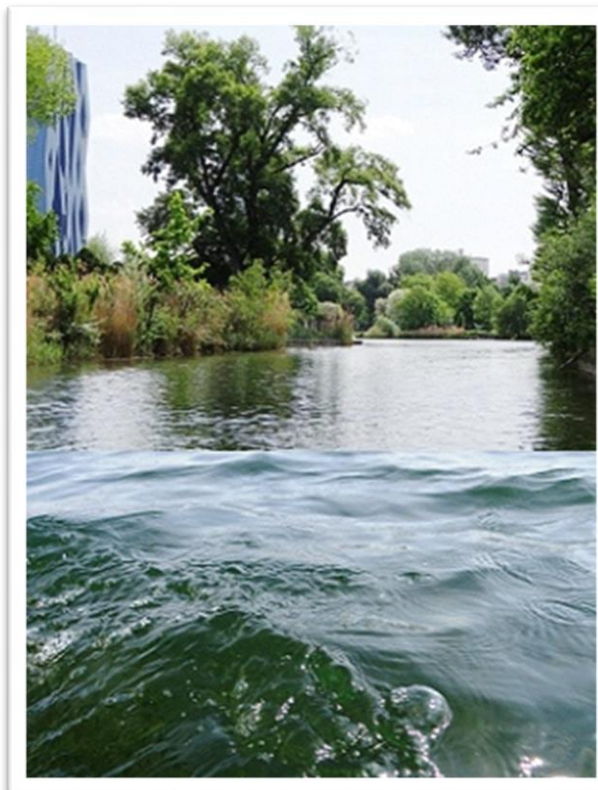
Under water light intensity and chlorophyll maxima near the surface (ECM) and in the deep layer (DCM). A-D: Ammersee, modified from Teubner *et al.* 2004; phytoplankton ECM, DCM in Teubner *et al. Hydrobiologia* 2003); E: Illustration of the two different phytoplankton assemblages.

Figure from: [www.lakeriver.at](http://www.lakeriver.at)





Water Transparency  
= socio-ecological indicator  
in urban blue space



*In conclusion:*

**Water transparency** is identified as a key parameter which is important far beyond how we see it in limnology. It is the only parameter that the public can use by human perception for assessing the water quality or the progress of a lake restoration. In turn, a good status of water transparency close to ecosystem reference conditions attracts public awareness to take advantage of various ecosystem services enhancing well-being in urban life. In this view "green-blue" spaces are ranked higher for a better quality-of-life in cities than "green" spaces.

*Thanks for your attention!*





*In conclusion:*

**Water transparency** is identified as a key parameter which is important far beyond how we see it in limnology. It is the only parameter that the public can use by human perception for assessing the water quality or the progress of a lake restoration. **In turn, a good status of water transparency close to ecosystem reference conditions attracts public awareness to take advantage of various ecosystem services enhancing well-being in urban life. In this view "green-blue" spaces are ranked higher for a better quality-of-life in cities than "green" spaces.**

*Thanks for your attention!*



# Book about restoration & management of Alte Donau

Dokulil MT, Donabaum K, Teubner K (Eds). (2018). *The Alte Donau: successful restoration and sustainable management: an ecosystem case study of a shallow urban lake* (Vol. 10). Springer.

## Chapter 5

### Restoration and lake man

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**Abstract:** At the beginning of the 19th century, the river Danube suffered from severe eutrophication problems, leading to a macrophyte-dominated state characterized by high biomass of filamentous algae and a significant reduction in transparency. A management plan was developed to restore macrophyte dominance through internal and external measures. Improving the input of nutrients from contaminated waters. Internal measures included aeration and nitrate oxidation of the sediments. These measures were followed by biomanipulation, including the planting of macrophytes and weed removal. The simulation of low water levels was achieved by the construction of a weir. The restoration measures led to a rapid improvement of the water quality and the establishment of a macrophyte-dominated state.

## Chapter 10

### Phytoplankton photosynthesis and production

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**Abstract** Productivity of aquatic vegetation determines the trophic level of a freshwater ecosystem. Phytoplankton photosynthetic rates are particularly important in urban environments before, during and after restoration measures. Results are reported here on photosynthetic rates, primary production and associated parameters of phytoplankton from a polymictic, groundwater-fed lake in an urban environment before, during and after restoration measures. A simple regression model is presented to approximate daily production from column-integrated chlorophyll-a measurements. Calculated phytoplankton annual lake production is compared to production of submerged vascular plants. Results indicate that macrophytes played a role during the clear water phase preceding the eutrophication phase, with intense algal productivity and vanishing submerged plant production. Restoration measures led to rapidly decreasing phytoplankton production and re-appearing macrophytes. The rehabilitation phase following this is characterized by declining phytoplankton productivity and re-establishment of macrophyte production. Total lake production as the sum of phytoplankton and macrophyte production is discussed.

## Chapter 11

### The response of zooplankton to restoration and management in Alte Donau

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**Abstract** Water transparency, nutrients and biomass of phytoplankton are commonly used to assess the response to restoration measures in lakes. Information about zooplankton triggered by lake management is often missing in long-term zooplankton studies. We used the microzoan and metazoan zooplankton to document the effect of restoration measures in the shallow Alte Donau, a former side-arm of the Danube River which is most populated by cyprinid (Cyprinus) and angler (Cyprinus) species. The 19-year zooplankton study covers four management periods: before restoration, restoration (chemical phosphorus precipitation by Riplox treatment), the re-establishment of macrophytes and the sustained 'stable conditions'. We found a dominance of all zooplankton in the first year of the Riplox-treatment. Zooplankton abundance in following treatment periods associated with phytoplankton. In the long term, the main compositional shift from a cladoceran-rich to a copepod-rich zooplankton. Thus, the large-bodied zooplankton shifted from a community of mainly filter-feeding herbivorous cladocerans under eutrophic conditions to a community of mainly selective-feeding omnivorous and herbivorous copepods in transparent water conditions. While the carbon content of zooplankton increased significantly during the first three management phases, the mean body size of zooplankton remained high under 'stable conditions', the mean body size of zooplankton did not exhibit any long-term trend. Short-term increases of zooplankton biomass were observed during the first year of the Riplox-treatment and during the first year of the re-establishment of macrophytes.

## Chapter 14

### The effect of restoration measures on the benthic invertebrates of a Danube backwater (Alte Donau)

Berthold Janeček, Patrick Leitner, Otto Moog, and Katrin Teubner

University of Natural Resources and Life Sciences, Vienna

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**Abstract** The benthic invertebrates were used as bio-indicators to document the effect of restoration measures in the backwater Alte Donau, a former side-arm of the Danube. The study covers four periods of lake management: 1. the mesophilic year before eutrophication (1987), 2. the two years of chemical iron chloride treatment aimed at the phosphorus precipitation in the water column and the oxidation of nitrate-treated sediment surface layers (1995-96), 3. the further three years of other lake management measures during the restoration period (1995-19 and 2003), 4. an early stage of the re-establishment of underwater vegetation (2003). Over eight survey years from 1987 to 2003, about 330 benthic invertebrate taxa with three most abundant systematic groups were identified: 37 species of oligochaetes, 23 species of molluscs (18 gastropods and 5 bivalves), and 190 species of crustaceans.

## Chapter 15

### Fish assemblages of the 'Alte Donau' system: Communities under various pressures

Herwig Waidbacher, and Silke-Silvia Dreßler

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**Abstract** 'Alte Donau' was formerly a major arm of the braided Danube in Vienna and served as habitat for a cold-water river fish assemblage. After river regulation, the habitat types for fish changed towards a warm-water fish environment with a high proportion of benthic species.





# Book about restoration & management of Alte Donau

eds: Martin T. Dokulil, Karl Donabaum & Katrin Teubner



Dokulil MT, Donabaum K, Teubner K (Eds). (2018). *The Alte Donau: successful restoration and sustainable management: an ecosystem case study of a shallow urban lake* (Vol. 10). Springer.





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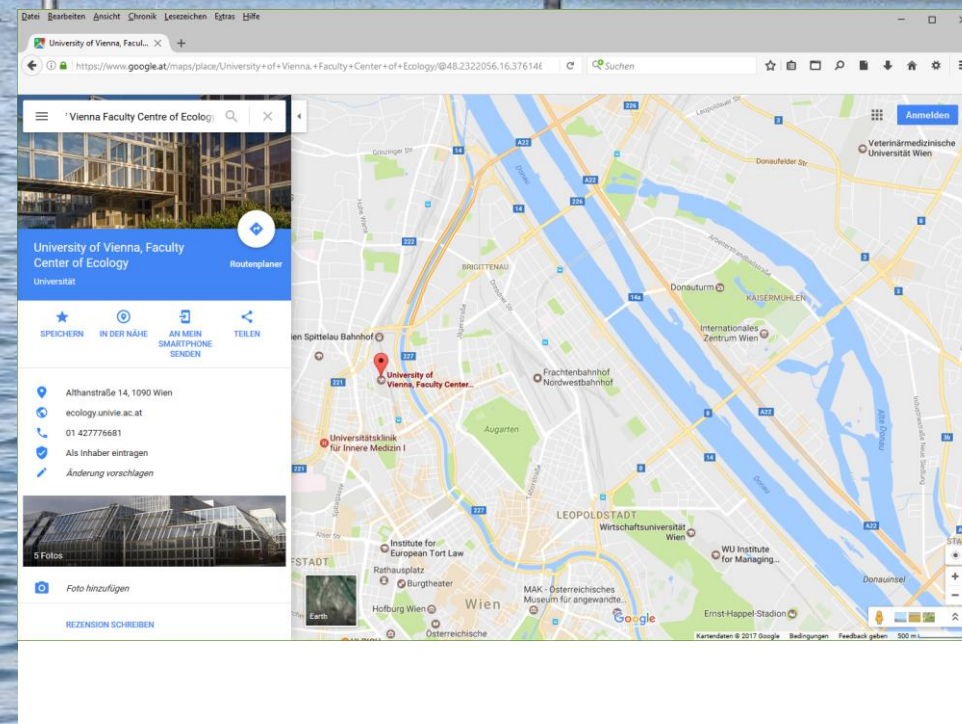






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Alte Donau, urban oxbow lake, Vienna





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43<sup>rd</sup> IAD-conference, June 2021

Alte Donau, urban oxbow lake, Vienna





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