PrimeWater

AUSTRALIAN END-USERS WORKSHOP: HAB'S EARLY WARNING TOOLS

THURSDAY 20TH APRIL 2023 | 11:30 AM – 2:30 PM AEST
DEP. OF CIVIL ENG., MONASH UNIVERSITY, MELBOURNE

SETTING UP AN EO-BASED FORECASTING SERVICE FOR PROACTIVE MANAGEMENT OF ALGAE BLOOM EVENTS IN A RECREATION AREA IN LAKE HARSHA

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EMVIS
WATER RESOURCES & ENVIRONMENT MANAGEMENT

Organized by:

IWA the international water association

In collaboration with:
Monash University &
CSIRO

PRIMEWATER WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

…the challenge

…with blooms becoming severe and chronic, the knowledge of the phytoplankton evolution ahead of time…

About Harsha Lake

Lake Harsha is located within the East Fork Watershed of the Little Miami River and serves as source for flood reduction, recreation and drinking water, supporting 30% of residents in Clermont County of 206,000 people. Harsha Lake has been projected to prevent ~$77.0 million in flood damage and generate ~$32.8 million from visitors.

…can minimize the risk of humans exposure to HAB toxins

Photo: Harsha Lake under recreational public health advisory, June 2016
https://clermontcountyohio.gov/2016/06/15/harsha-lake-under-recreational-public-health-advisory/

PRIMEWATER WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

Recreational Public Health Advisory posting strategy

Challenge

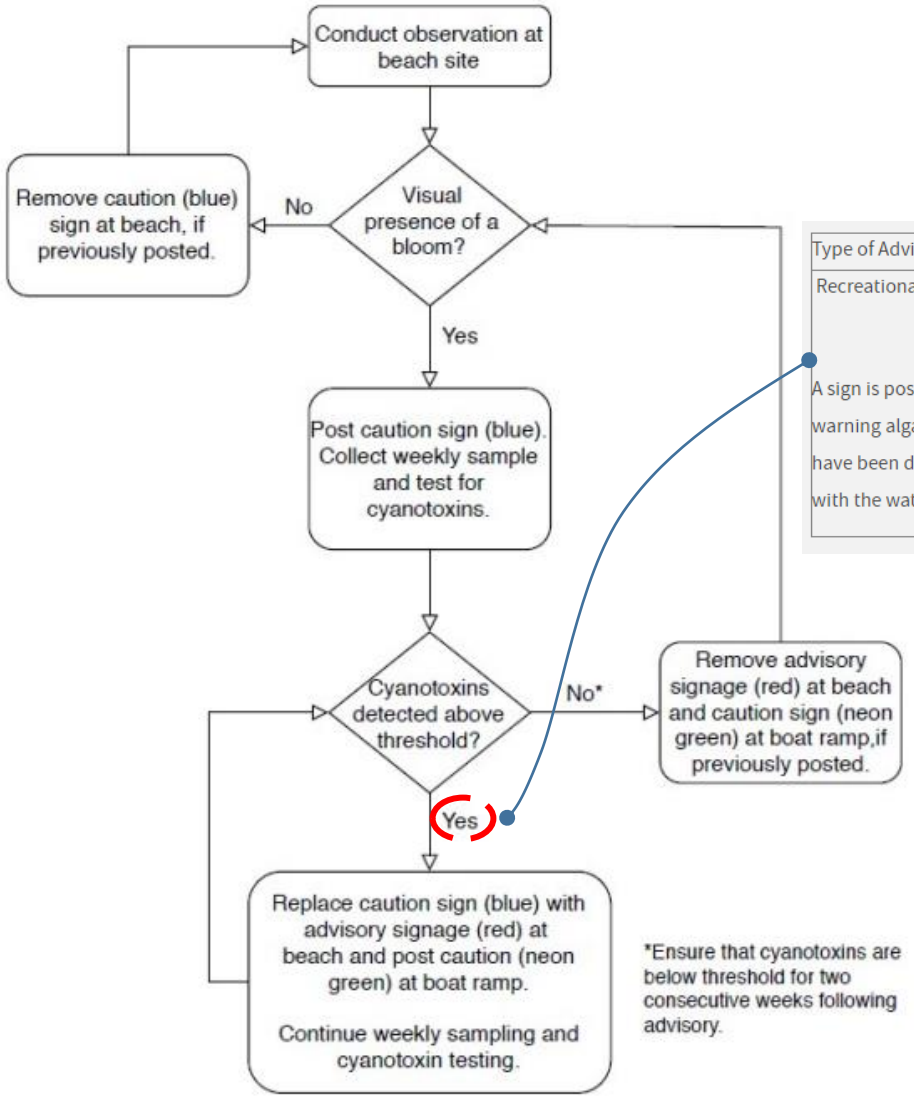
State recreation managers need to address harmful algal blooms (HABs) in recreational waters and to protect people from cyanotoxins produced by cyanobacteria

Harmful algae or cyanobacteria can produce toxins that make people and animals sick.

Current practice involve:

- ❑ Sampling or Collecting Observations and other information of Blooms
- ❑ Post advisories

Visitors' exposure window to toxins (period between a HAB event initiation and Advisory posting) should be kept minimum.



Type of Advisory	Microcystin	Anatoxin-a	Cylindrospermopsin	Saxitoxin
Recreational Public Health Advisory A sign is posted on beaches warning algal toxins at unsafe levels have been detected and that all contact with the water should be avoided.	8 µg/L	8 µg/L	15 µg/L	0.8 µg/L

State of Ohio, Harmful Algal Bloom Response Strategy for Recreational Waters

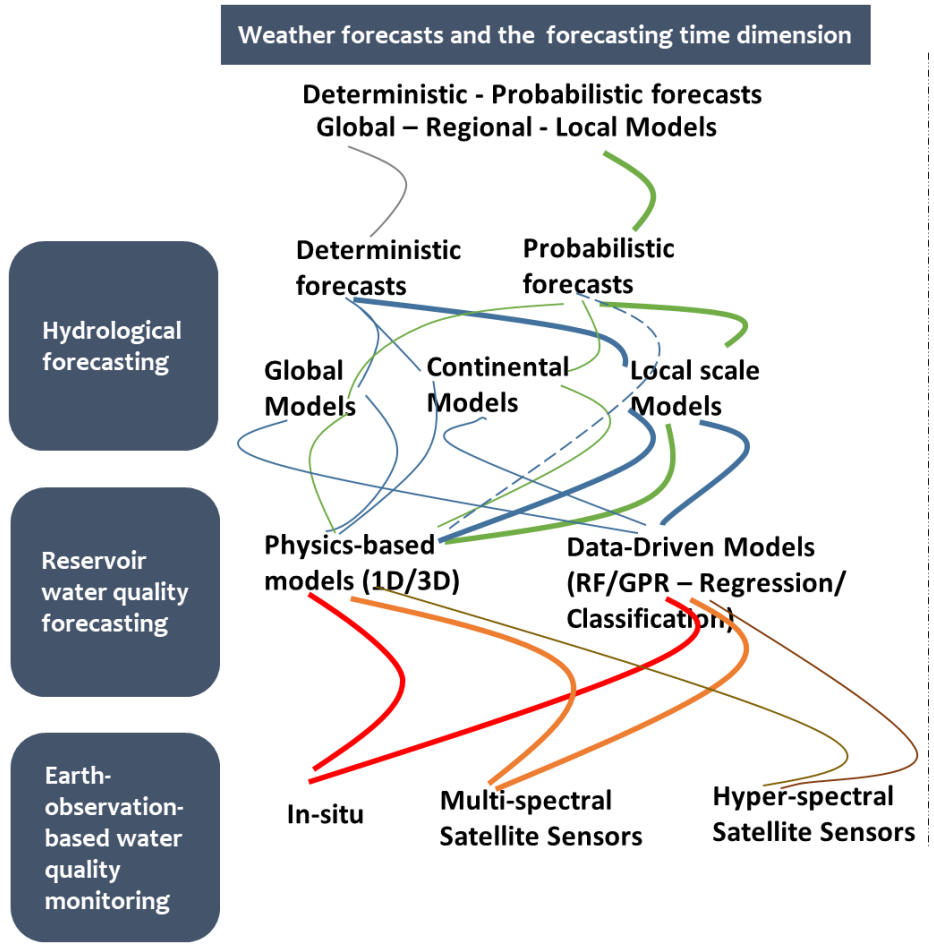
https://epa.ohio.gov/static/Portals/35/hab/HABResponseStrategy.pdf

PRIMEWATER WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

Solution

Every day receive for the next 10-days in advance the estimated probability of exceeding the alert level 1 threshold for Chlorophyl-a concentration indicated by the WHO's guidelines for bathing waters (i.e., 12 µg/l) for the selected area of interest.

An ensemble learning method is used for estimating the probability of exceeding the selected limit. The model uses hydrometeorological drivers of the past 10 to 20 days to forecast the probability of exceedance of the WHO thresholds. Meteorological forecasts are obtained from Meteoblue while hydrological forecasts are produced by the HYPE model.



Meteoblue global weather forecasting services
GFS, GFS ensemble, NEMS, meteoblue

meteoblue
weather close to you

SMHI's Hydrological Simulation System (HYSS)
• HYPE Short-term forecasts (10days)

SMHI

EMVIS Water Automation Shell (wASH)
• Data-driven WQ forecasts

Quantile Regression Forests (QRFs)

EMVIS
WATER RESOURCES & ENVIRONMENT MANAGEMENT

EOMAP's Modular Inversion & Processing System (MIP)
• Sentinel-2 & Landsat

EOMAP

CyAN project
• Sentinel-3

CyAN

EO Data used for WQ ML models training

THE VALUE OF WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

Factors influencing the Value of Forecasting Information

Impact

What if we knew how a phytoplankton outbreak will evolve 10 d in advance

State recreation manager Perspective

"Boundaries of Analysis"

Can this information trigger early actions ?

- Are any actions that can be taken considering the information?
- Can the lead time available for the HAB event provide sufficient time to implement early actions and mitigate impacts in advance?

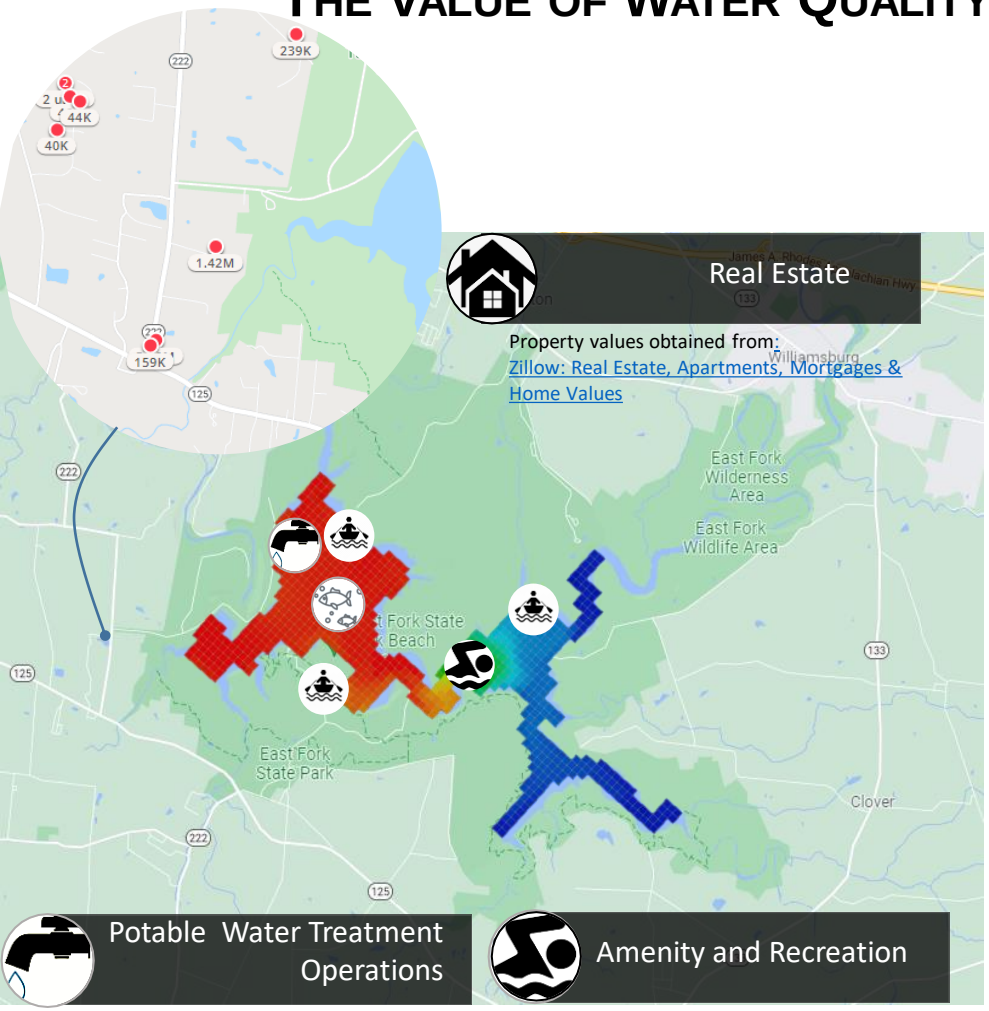
What is at stake as an outcome of a decisions?

What is the cost/benefit from using the next-best substitute for the information ?

How certain decisions are based on forecasts?

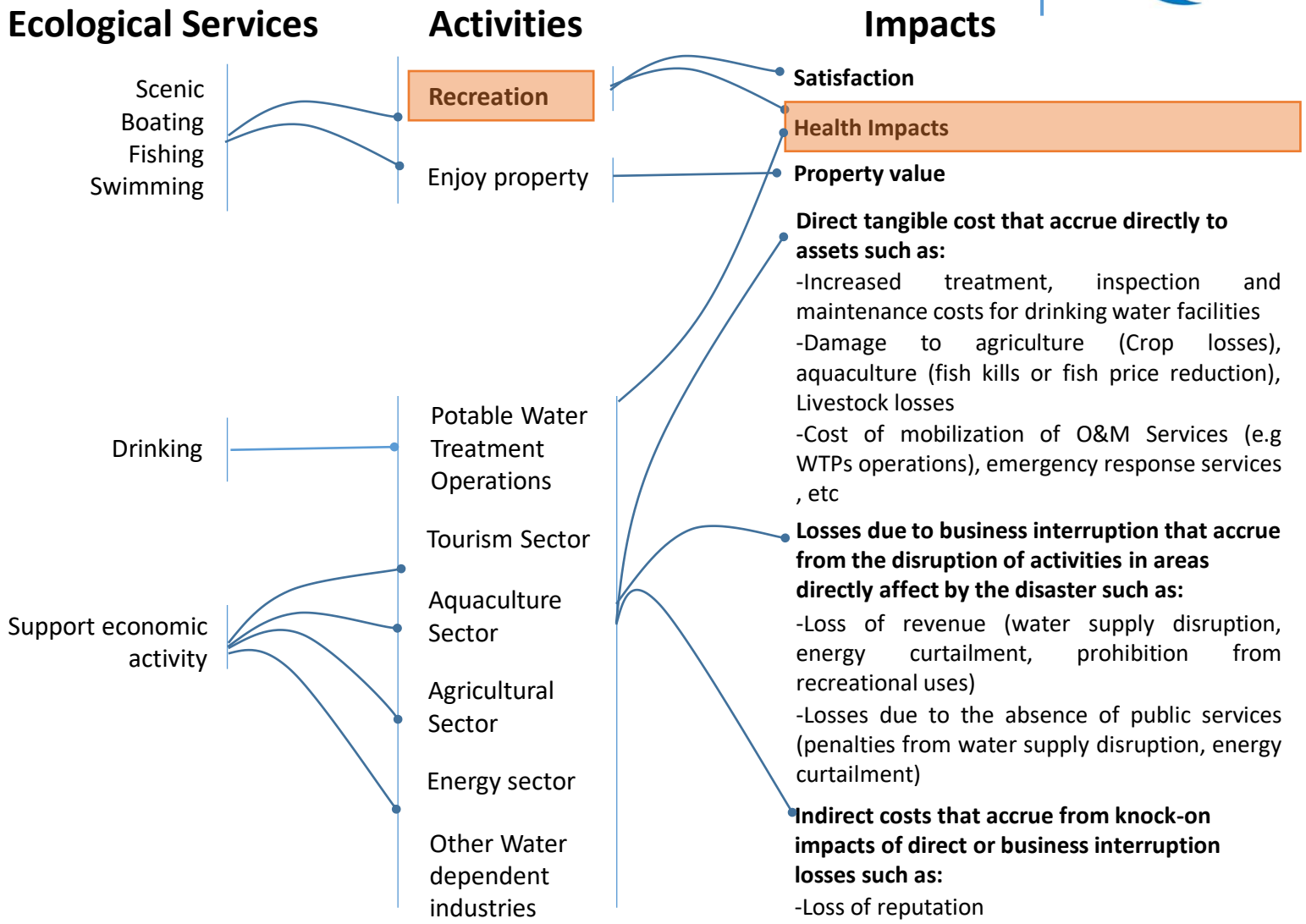
Factors influencing the Value of Forecasting Information

THE VALUE OF WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS



Can an Early Warning Forecasting System for Phytoplankton Bloom Alerts trigger any actions that could generate in the **short-term** Economic Benefits or Avoid losses ?

Boundaries of Analysis



THE VALUE OF WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

What is at stake as an outcome of a decision?

Health costs

Visitors possibly engaged with activities that could expose them in cyanotoxins) per day	1000
Percentage of exposed people that will get sick (%)	0,05
Health cost (euro per sick visitor**)**	900

Monitoring costs

Daily sampling campaign cost (euro/day)	5000

Losses from the closing down the activities in a recreational area

Economic benefit or cost generated by the visitors (euro per day per visitor**)**	100

Assumptions for the visitors:
1M visitors/year, 50% from May to Sep., 30% possibly engaged with activities that could expose them in cyanotoxins)

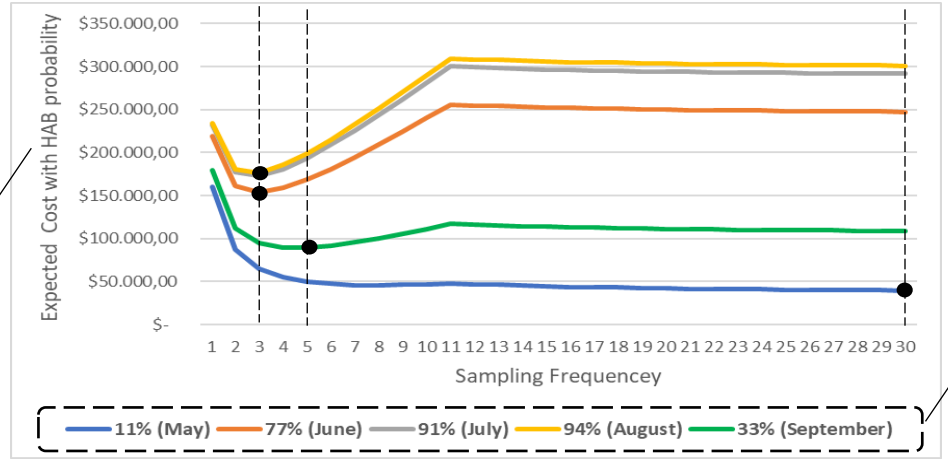
Assumptions for the impact model adapted by :
Signe Stroming, Molly Robertson, Bethany Mabee, Yusuke Kuwayama, and Blake Schaeffer, (2020). Quantifying the Human Health Benefits of Using Satellite Information to Detect Cyanobacterial Harmful Algal Blooms and Manage Recreational Advisories in U.S. Lakes, GeoHealth, AGU

THE VALUE OF WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

Can this information trigger early actions ?

	✖ Naive monitoring	✔ Optimized monitoring approach	✔ Using a forecasts based EWS
Actions to be taken	Action relies on "naïve" sampling campaigns with a constant frequency over time (e.g. every week)	Action relies on a monitoring campaign with a sampling rate estimated from the historical probability for harmful algal blooms (HABs) estimated for each month	Action relies exclusively on whether PrimeWater services indicate Alert level 1 concentrations (12 µg/l) to perform additional sampling and issue a warning and; if vigilance level concentrations are indicated, then no further actions are required.
Exposure window before posting an Advisory	**up to 7 days** (max duration before citizens report of algae bloom)	From **3 to 7 days** (depending on the optimum sampling frequency)	Down to **2 days** (min unavoidable exposure duration in a bloom - delay for closing lake after sampling)

Optimizing monitoring plan based on historical data



P x (MC+HC) + (1-P) x MC
P: Probability of HAB occurrence
MC: Monitoring Cost
HC: Health Cost

Probability of HAB occurrence for Lake Harsha based on the historical in-situ data
We considered that a HAB event is observed when chl-a concentrations exceed **12 µg/l** (alert level 1 concentrations) and cyanobacteria are dominant.

THE VALUE OF WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

What is the cost/benefit of existing best practice?

Action 1 - Rely on Optimized monitoring approach (best sampling frequency according to the historical probability for harmful algal blooms (HABs) estimated for each month

VS

Action 2 - Rely on PrimeWater forecasts-based EWS using Quantile Regression Forests (QRFs) predictive model using for training:

- ❑ Landsat-8 and Sentinel-2 data (Forecast solution 1)
- ❑ Sentinel-3 data (Forecast solution 2)

		HAB	NO HAB
Action1		- 320.000 €	- 5.000 €
Action2	Forecast says HAB – Issue Alert	- 90.000 €	- 200.000 €
	Forecast says NO HAB – No Alert	- 315.000 €	0 €

Estimated for each month

Months with at least one HAB occurance (2009-2019)	Probability of at least one HAB incidence (based on historical data 2009 -2019)	Expected value of Action (1)	Expected value of Action (2) with PERFECT forecast	Value of Perfect Forecast
May	11%	- 39.650 €	- 9.900 €	29.750 €
June	77%	- 153.950 €	- 69.300 €	84.650 €
July	91%	- 172.850 €	- 81.900 €	90.950 €
August	94%	- 176.900 €	- 84.600 €	92.300 €
September	33%	- 89.400 €	- 29.700 €	59.700 €
				357.350 €

Red: Doing always Action1 is preferable in the long run

Blue: Action2 is preferable in the long run

THE VALUE OF WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

How certain decisions are based on forecasts?

Compare chl-a concentrations provided by PrimeWater forecasting services to chl-a concentrations observed in situ for the monitoring point located near the main beach of Lake Harsha (period 2015-2019).

Classification problem in two levels (WHO's guidelines for bathing waters):

(a) vigilance level in which chl-a concentrations are in the range of 3-12 µg/l, and

(b) Alert 1 level in which chl-a concentrations are in the range of 12-24 µg/l.

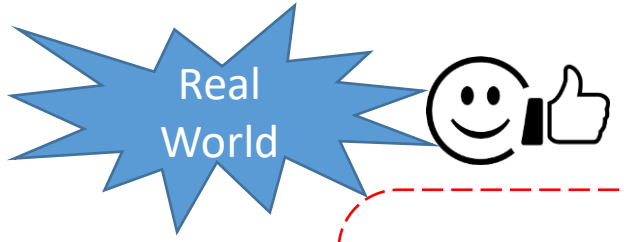
Accuracy is evaluated in terms of sensitivity (or True Positive Ratio – TPR) and specificity (or True Negative Ratio – TNR),

Actual Class \ Predicted Class	Positive	Negative	
Positive	True Positive (TP)	False Negative (FN) **Type II Error**	**Sensitivity** $\frac{TP}{(TP+FN)}$
Negative	False Positive (FP) **Type I Error**	True Negative (TN)	**Specificity** $\frac{TN}{(TN+FP)}$
	Precision $\frac{TP}{(TP+FP)}$	**Negative Predictive Value** $\frac{TN}{(TN+FN)}$	**Accuracy** $\frac{TP+TN}{(TP+TN+FP+FN)}$

THE VALUE OF WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

How certain decisions are based on forecasts?

Forecast solution 1
(ML trained with Landsat-8 and Sentinel-2 data)



Months with at least one HAB occurance (2009-2019)	Probability of at least one HAB incidence (based on historical data 2009 -2019)	Expected value of Action (1)	Expected value of Action (2) with PERFECT forecast	Value of Perfect Forecast	TPR	TRN	Expected value of Action (2) with IMPERFECT forecast	Value of "ONLY FORECASTS" (based on historical forecasts of 2015-2018
May	11%	- 39.650 €	- 9.900 €	29.750 €	99%	45%	- 108.048 €	- 68.398 €
June	77%	- 153.950 €	- 69.300 €	84.650 €	99%	45%	- 96.333 €	57.618 €
July	91%	- 172.850 €	- 81.900 €	90.950 €	99%	45%	- 93.848 €	79.003 €
August	94%	- 176.900 €	- 84.600 €	92.300 €	99%	45%	- 93.315 €	83.585 €
September	33%	- 89.400 €	- 29.700 €	59.700 €	99%	45%	- 104.143 €	- 14.743 €
				357.350 €				137.065 €

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THE VALUE OF WATER QUALITY FORECASTS FOR PHYTOPLANKTON BLOOM ALERTS

How certain decisions are based on forecasts?

Forecast solution 2
(ML trained with Sentinel-3 data)

Months with at least one HAB occurance (2009-2019)	Probability of at least one HAB incidence (based on historical data 2009 -2019)	Expected value of Action (1)	Expected value of Action (2) with PERFECT forecast	Value of Perfect Forecast	TPR	TRN	Expected value of Action (2) with IMPERFECT forecast	Value of "ONLY FORECASTS" (based on historical forecasts of 2015-2018
May	11%	- 39.650 €	- 9.900 €	29.750 €	67%	90%	- 35.868 €	3.783 €
June	77%	- 153.950 €	- 69.300 €	84.650 €	67%	90%	- 131.073 €	22.878 €
July	91%	- 172.850 €	- 81.900 €	90.950 €	67%	90%	- 151.268 €	21.583 €
August	94%	- 176.900 €	- 84.600 €	92.300 €	67%	90%	- 155.595 €	21.305 €
September	33%	- 89.400 €	- 29.700 €	59.700 €	67%	90%	- 67.603 €	21.798 €
				357.350 €				91.345 €

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Factors influencing the Value of Forecasting Information

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How certain decisions are based on forecasts?

- ❑ Even **a day ahead** Forecast-based EWS could **minimize the Exposure Window Down to 2 days** (min unavoidable exposure duration in a bloom - delay for closing lake after sampling)
- ❑ The adding value is a function of both **the probability of a HAB** and the **skills of the solution**. The adding value is high when HAB events have a high likelihood of occurrence and sensitivities are high. For less probable events models that have high specificity (less false alarms) could be more advantageous.

PrimeWater

Thank you for attending!

PrimeWater Team:

European Commission

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