New measurement technology, modelling and remote sensing in the lake Säkylä Pyhäjärvi area


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www.ymparisto.fi/syke/catchlake
Lake waters are heterogeneous and dynamic

“In Lake Belau wind from south west and the related current field were predicted to have the dominant impact. The spatial distribution of sediment types and of TOC are in very good agreement with the flow pattern under SW-winds and supported this prediction. There is strong evidence that the observed spatial differences in mollusca species composition, even in this small sheltered lake, are also directly and indirectly affected by current field.”

Spatial ecological structures in littoral zones and small lakes: Examples and future prospects of flow models as research tools. Gerald Schernewski, Victor Podsetchine, Meinolf Asshoff, Dieter Garbe-SchGnberg and Time Huttula.

Landscape outside lakes are also dynamic and even more heterogeneous.
We need data and tools to understand and assess...

- Processes in nature
- Causes and effects
- Human impacts
- Critical thresholds
To find out this you can..

- Go and see
- Take a sample and analyze it
- Make laboratory experiments
- Develop a model
- And even
  - Use automatic sensors
  - Use satellites
Technology has been developing

Fig. 2. The Finnish-built monitoring station consisting of microprocessor, in-situ type measuring probe and teleprinter.
CatchLake-project targets to

1. Coupling of integrated catchment and lake models, by utilizing both remote sensing technology and intensive measurement campaigns

2. Decreasing uncertainty in environmental modelling by using a more accurate input data

3. Better utilization of large scale remote sensing data sets

4. To benefit both public and private sector in this field
Participants

-SYKE and Technical University of Helsinki, Space Technology (2006-2009)

-Pyhäjärvi Institute, Lake Pyhäjärvi Protection Fund, SW Finland Regional Environment Centre and the University of Turku;

-in co-operation with the University of Reading (UK), EOMAP (Earth Observation & Mapping, Germany), and the National Environmental Research Institute of Denmark (NERI)

- corporate partners: SW Finland Water and Environmental Research, Ramboll, Luode Consulting, Numerola Ltd, Fish and Water Research Ltd, and Pöyry Environment Ltd
Lake Säkylän Pyhäjärvi (154 km²) and catchment (306 km²)

Volume 840 milj.m³
Mean depth 5.4 m
Maximum depth 26 m
Coastline 80 km

Water
Field
Forest + others

5 0 5 10 km

Southwest Finland Regional Environment Centre
National Land Survey of Finland Permission number 7/MYY/02
Why this pilot area?

-Pyhäjärvi is the most important lake in South-Western Finland
-agricultural land 22%, surface runoff and erosion are of importance
/ steep slopes at the fields along the river
-one of the most studied lakes in Finland, good time-series available
-active local regional work for lake protection; Lake Pyhäjärvi Protection Funds [http://www.pyhajarvensuojelu.net/]
-in total P at Yläneenjoki, no marked trends in 1968-2003
-increasing N concentrations, mild winters in 1990s?

Koivunen, S. (toim.)(2004) Yläneenjokiraportti

CatchLake; sub project 1

1. **Process based modelling in the catchment (SWAT, INCA-N)**

- application of two integrated models /testing and model comparisons
- satellite data of change in agriculture/forestry
- intensive measuring campaigns; utilisation of data in models
- model sensitivity analysis
CatchLake; sub project 2

Lake spatial water quality and lake modelling

- Spatial water quality (turbidity/suspended solids, chlorophyll-a) maps of will be constructed by interpretations of the time series of satellite images.
- High resolution spatial measurements from the lake; compared with remote sensing based data.
- LakeState and Coherens model applications; inputs from catchment models.
- Data-assimilation techniques.
# Data collection on watershed and lake

<table>
<thead>
<tr>
<th>Data</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
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</thead>
<tbody>
<tr>
<td>Lake meteorology</td>
<td>On small rock during open water</td>
<td>On small rock during open water</td>
<td>On float during autumn</td>
<td>On float during open water period</td>
</tr>
<tr>
<td>Spatial lake water distribution</td>
<td>Three campaigns during open water period</td>
<td>Two campaigns during open water period</td>
<td>Two campaigns during open water period</td>
<td>Three campaigns during open water period</td>
</tr>
<tr>
<td>On line river water quality</td>
<td>Two long campaigns in Yläneenjoki River, two sites</td>
<td>Two long campaigns in Yläneenjoki River, two sites</td>
<td>Oct-May campaigns in two main rivers</td>
<td>Will be decided soon</td>
</tr>
<tr>
<td>Reflection studies on lake</td>
<td>Three campaigns during open water period</td>
<td>Two campaigns during open water period</td>
<td>Three campaigns during open water period</td>
<td>Will be decided soon</td>
</tr>
<tr>
<td>Phenology of crops</td>
<td>Campaigns on several fields in one village</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
River Yläneenjoki automatic station

YSI Environmental sensor
- water level
- temperature
- conductivity
- turbidity

www.luode.net
Turbidity and water level meters in River Yläneenjoki and Pyhäjoki 2008-2009

www.a-lab.fi
Flood and loading peak in January; River Ylääneenjoki
18.12-16.1.2007

Vedenkorkeus (cm)

Pinnankorkeus [cm]
Sameus [NTU]

Pyhäjärven suojelurahasto
Mittaukset: Luode Oy
Spring 2008, Yläneenjoki

[Graph showing data on turbidity (FTU), water depth (cm), NO3-N, and DOC (mg/l) from 28.2 to 1.5.]

- DOC [mg/l]
- Sameus [FTU]
- Nitraattityppi [mg/l]
- Pinnankorkeus [cm]

Turbidity (FTU), W (cm)

NO3-N, DOC (mg/l)
Lake Pyhäjärvi automatic station

Variables

- Current direction and speed in surface waters
- Weather
  - Air humidity
  - Wind direction
  - Wind speed
  - Air temperature
  - Air pressure
  - Precipitation
- Water oxygen content and temperature
  - Depths 5, 10, 15 ja 20m
- Water quality in surface waters
  - Blue-green algae
  - A-chlorofyl
  - Turbidity
  - Temperature
  - Nitrate nitrogen

The station was set up on 19.8.2008 on the basin of Lake Pyhäjärvi
The site of the station

The station is in the middle of the northern end of the basin
Results from the lake station: Currents

Current direction and speed 25.9. - 2.10.08 (Thursday - Thursday)

High current speeds to north/ north east on Sunday evening
Results from the lake station: Wind

Wind direction and speed 25.9.-2.10.08

On Sunday strong wind
• more than 10 m/s
• from south west / south
In situ data vs. laboratory data

O₂ surface laboratory [mg/l]  O₂ 5m [mg/l]  O₂ 10m [mg/l]  O₂ 15m [mg/l]  O₂ 20m [mg/l]

17.8. 27.8. 6.9. 16.9. 26.9. 6.10. 16.10. 26.10.
In situ data vs. laboratory data

Graphs showing comparisons between in situ and laboratory data for various parameters such as chlorophyll, turbidity, and blue greens.
Data quality control development

Measuring station

Corrected data → Raw data

A-lab server

Data corrections/SYKE_JKL

Quality Control/SYKE_JKL

Station maintenance/MTT(&SYKE)

Reseacher/MTT

Reseacher/IL

Reseacher/SYKE

Reseacher/…

SYKE_HYD-station

IL meteorogical stations

MTT automatic stations

HKI_TESTBED-stations

Water quality stations related to regional and local hot spots
## Catchlake 9.5.2006

<table>
<thead>
<tr>
<th>Station</th>
<th>Distance (m)</th>
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<tr>
<td>S1</td>
<td>520</td>
</tr>
<tr>
<td>S2</td>
<td>340</td>
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<tr>
<td>S3</td>
<td>460</td>
</tr>
<tr>
<td>S4</td>
<td>2500</td>
</tr>
<tr>
<td>S5</td>
<td>430</td>
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<td>S6</td>
<td>720</td>
</tr>
<tr>
<td>S7</td>
<td>90</td>
</tr>
<tr>
<td>S8</td>
<td>530</td>
</tr>
<tr>
<td>S9</td>
<td>1150</td>
</tr>
</tbody>
</table>
SWAT “Soil Water Assessment Tool”

HRU
- soil
- vegetation
- slope
SWAT; soils in Yläneenjoki catchment
SWAT (Soil Water Assessment Tool)

29 subbasins
139 HRU’s

Continuation of the first calibration in the EU project BMW

”Benchmarking models for Water Framework Directive purposes”
Calibrating and testing the SWAT model

Suspended sediment concentration at Vanhakartano [mg l\(^{-1}\)]

=> Sparse data allows testing of the simulated concentration level but does not necessary capture peak events

=> Automated measurements of variables which can be related to suspended sediment concentration
Correlation turbidity vs. suspended sediments

**P2: Vanhakartano, main stream**

**S11: Peräsuonoja, tributary**

**Time series:** 1995-2006, spring 2006 (INT1) & autumn 2006 (INT2)
Concentrations calculated from the measurement period spring 2006 and from the long term monitoring compared with the monitoring results from spring 2006.
INCA-N – application; aims

• a dynamic (1 day time step), process-based catchment model, taking into account sources of nutrients and hydrology
• simulating transformation processes, water flow and inorganic N concentrations and fluxes in selected spots along a river channel (denitrification and nitrification are included)
• application to Yläneenjoki catchment
• use of GIS data of the land use changes /remote sensing
• retention of N in the catchment system and in the lake
INCA-N modeling framework

SYKE Hydrological watershed model, semi-distributed

DAIQUIRI N deposition model

Satellite based land use classification

INCA
- soil hydrological submodel
- catchment N submodel
  - major N transformation processes
  - temperature and soil moisture dependent
  - six land-use classes
- river N submodel
  - dilution
  - in-river transformations
INCA-application

Level 3: Cell Model

Level 2: Sub-catchment comprising 1 to 6 land use types

Level 1: River catchment

Link between land and in-stream components

INPUT

OUTPUT

store

Metsä Pelloit yht. Kevätviljat Syysviljat Nurmi Kesanto Muut

Maanlakymo %

YLäne 1
YLäne 2
YLäne 3
YLäne 4
YLäne 5

KG/SYKE
INCA-N nitrogen model: soil processes

Nitrate fertiliser + deposition

Ammonium fertiliser + deposition

Nitrogen Fixation

Urban waste to River

Nitrate Addition

Plant uptake

Ammonium Addition

Plant uptake

denitrification

nitrification

Net mineralisation

Organic N

Soil Reactive Zone

Leaching to river

Leaching to river

Leaching to river

Leaching to river

Groundwater

EU/Euro-limpacs/
Reading University
Livestock
N fertilizing/ Yläneenjoki

![Bar chart showing N fertilizing for different crops over years](image)
Rainfall, temperature and soil moisture deficit; 1995-2006
INCA-N preliminary simulation 1995-2006, Yläneenjoki
Sensor data helps in calibration of the model: NO$_3$-N simulation results, Vanhakartano 2007

Calibration ok in spring

Model under estimates concentration in autumn

Model results  Sensor results  Manual samples
COHERENS model application

- 3D model
- Originated from MUMM (Management Unit for the Management of Mathematical Models for the North Sea), close development with NERI
- Physical (water level, currents, temperature, salinity), chemical (N by origin and P in SYKE) as well as biological (chlorophyl-a by origin and blue greens + other algae in SYKE)
- A recent comparison study on Baltic good results
- Säkylän Pyhäjärvi
- 500m grid size
- 10 layers in vertical direction (0.05m-2.0m)
Surface and near bottom currents in steady state
Suspended solids load from Yläneenjoki to the lake

COHERENS-simulation from 6.5.06 0:00:

Initial values for SS
- Lake: 5 mg/l
- Yläneenjoki: 31 mg/l

Color scale:
0 (blue) -30 (red) mg/l.

Sigma layers:
Surface (Pinta): uppermost 1/10 over depth,
Bottom (Pohja): lowest 1/10 over depth.
Phosphorous load from Yläneenjoki to the lake

COHERENS-simulation from 6.5.06 0:00:

Initial values for ToTP:
•Lakei: 15 ug/l
•Yläneenjoki: 82 ug/l

Color scale:
0 (blue)
-100 (red) ug/l.

Sigma layers:
•Surface (Pinta): uppermost 1/10 over depth,
•Bottom (Pohja): lowest 1/10 over depth.
ULAPPA database system

- Remote sensing of water quality
- Combination of different sources of water quality information
- Water areas, which are monitorable with EO data have been mapped
- 15758 separate areas (lakes and coastal sea)
- Integrating monitoring methods to be used with modeling software

Areas for different resolutions, according to monitoring purposes
ULAPPA areas

- Medium/low resolution satellite data can be gathered according to these predefined areas.
- Mean values etc can be calculated for these areas (lakes; other types of areas?)
- Different sources of information are to be linked within the database (areas and in situ results, areas and model input parameters etc.)
- Can contain model input data for modeling the lakes, optical properties to be used etc using XML data formats
- Running on SQL server, Matlab interface for modelers available
- Complex system with new technology, large scale operational use delayed
- System still under implementation & testing
Project continues

- Calibration of INCA-N model
- SWAT applications
  - improving River Yläneenjoki application with new data
  - River Pyhäjoki sub basin application (different as River Yläänjoki sub basin)
- HRU and sub catchment scale
- sensitivity analysis
- COHERENS-application
  - tuning suspended solids model (wave calculation, resuspension)
  - testing more episodes
  - satellite data assimilation (surface temp and turbidity)
- Linking catchment and lake model
Related publications

Further information:
www.ymparisto.fi/syke/catchlake