



Ancylus FjordEnv 4.0 – Manual

<http://www.ancylus.net>

Preface.

FjordEnv version 4.0 is a program that computes environmental effects of supplies of nutrients and organic matter due to fish farming and municipal and industrial wastewater on fjords and other inshore areas. It can also be used to estimate environmental effects of dredging and building road-banks in sea straits and changing runoff. In the surface layers, environmental changes are expressed as changes in sight (Secchi) depth. In deeper layers, environmental changes are expressed as changes in oxygen consumption and minimum oxygen concentrations, respectively.

The computations of environmental changes are based on computations of water exchange in different depth strata and the physical state of the actual fjord or inshore area. FjordEnv uses many published sub-models. It was created in 1990 under the name 'Fjordmiljø' and has since then been widely used in Norway by marine consultants, research institutes and in education.

The present version, FjordEnv 4.0, is run as a web application. It contains some significant improvements. One improvement concerns the loading imposed by aquaculture (fish farming in cages). The outlets (per produced ton of fish) of organic matter, by excess feed and faeces, and of dissolved nitrogen and phosphorus to the cages can now be changed. Another improvement concerns estuarine circulation where some important parameters that earlier had fixed values now can be changed. In addition, FjordEnv now provides two examples, the Ørsta Fjord and the Gullmar Fjord as built-in cases.

The primary geographical applicability of FjordEnv 4.0 is inshore waters along the Norwegian coast and the Baltic Sea and the intervening seas, Kattegat and Skagerrak. For these areas some parameters governed by the vertical stratification and its temporal variability and tides are given as default (but changeable) values. In FjordEnv these parameters control various modes of circulation. However, FjordEnv 4.0 can be applied to inshore waters in any inshore area of the World Ocean and large lakes if the values of the model parameters are known.

The manual is arranged as follows. Chapter 1 describes **how to handle the program technically**. In chapter 2, **Data Cards for input and results** (output) are described. The **scientific foundations for the computations** are described in reports and references given in chapter 3. In chapter 4 the subjects **error handling and support** are covered. Finally, **two default cases** are briefly described in chapter 5.

Contents.

- 1. How to use the FjordEnv program – A technical description**
 - 1.1 About case-handling in the program**
 - 1.2 About data input**
 - 1.3 About reports**
- 2. Description of Data Cards for input and results**
 - 2.1 Some applications of FjordEnv**
- 3. The scientific foundations for the computations in the FjordEnv program**
- 4. Support**
- 5. Default cases – the Ørsta Fjord and the Gullmar Fjord**



1. How to use the FjordEnv program – A technical description.

To do the computations in the FjordEnv program, data about the fjord or another inshore area are needed as input. Before the computations are done, one has to look after that all the information fields in data cards for input are filled.

Results from the computations are presented in data cards for output.

All data cards are discussed in chapter 2 below.

In the program, one may open old and new "cases" and store (file) data from different cases. One may also print out the report that is created during a model run on a printer. The report may be stored as text-file (.txt) for further processing in a word processor.

Read the report FjordEnv – can be downloaded from "Ancylus downloads" - "whitepapers in pdf-format" at www.ancylus.net

1.1 About Case handling in FjordEnv.

The user establishes different "Case" to simulate different Cases and localities. Each Case created will be stored in the database, accessible only for members of the organization creating the Case. All data input and output done in FjordEnv is linked to a specific Case, so that data can only be viewed or handled by a member from the owning organization that created the Case. Below is a description of how to handle the Case function.

Establish a new Case.

Choose "Cases" from the menu to the left of the main window (picture 1a). When the form to administrate Cases is opened to the right, press the button "Add New". Then input fields are shown in which a new Case may be established, type the name of the Case and possibly also a note describing the Case.

There is a possibility of base the new Case on the data from an existing Case that the user has access to. Select the field "Base the Case data on existing Case data", then the dropdown list will be filled with Cases that the user may access, select the Case you want to copy data from and press button "Save". Now the new created Case will be a copy of the existing Case selected.

A further possibility is to base the new Case upon a default-Case provided by Ancylus. To do this, select the field "Base the Case on default-Case data", then the dropdown list will be filled with default Cases provided by Ancylus, select the Case you want to copy data from and press button "Save". Now the new created Case will be a copy of the chosen default-Case.



Ancylus FjordEnv 4.0

Test Case Logged in as Thomas Smith

Cases

Name	Description	Created	Run Model	Delete Case
Gullmar Fjord	Fjord on the coast of Eastern Skagerrak	10/27/2012	Run Model	Delete Case
Test Case	A first attempt	02/25/2012	Run Model	Delete Case

Run Model

Reports

Options

Help & Support

Log Out

[Learn about Case-handling](#)

Picture 1a. Case handling



Delete Case.

If you delete a Case, all its input- and output data will be removed from the database.

To delete a Case, choose "Cases" from the toolbar to the left in the main window. When the form to administrate Case is opened (see Picture 1a), click "Delete Case". A question will be asked if you really want to delete the Case. To proceed, press "Yes" to delete the chosen Case. If you want to abort the deletion, press "No".

Edit Case.

To edit the name or description of a Case, choose "Cases" from the toolbar to the left in the main window (see Picture 1a). A form will open to the right of the browser window, showing available Cases, shown in Picture 1a. Click the name of the Case you want to edit in the leftmost column of the Case-list. An edit form will open below the list, where you can edit the name of the Case and the description of it. After editing the data, press button "Save" for changes to take effect.

1.2 About Reports

The report shows data input and results for the active case. Which case that is active can be seen in the name list at the top of the main window. The Report function can be reached from the menu at the left of the main window.

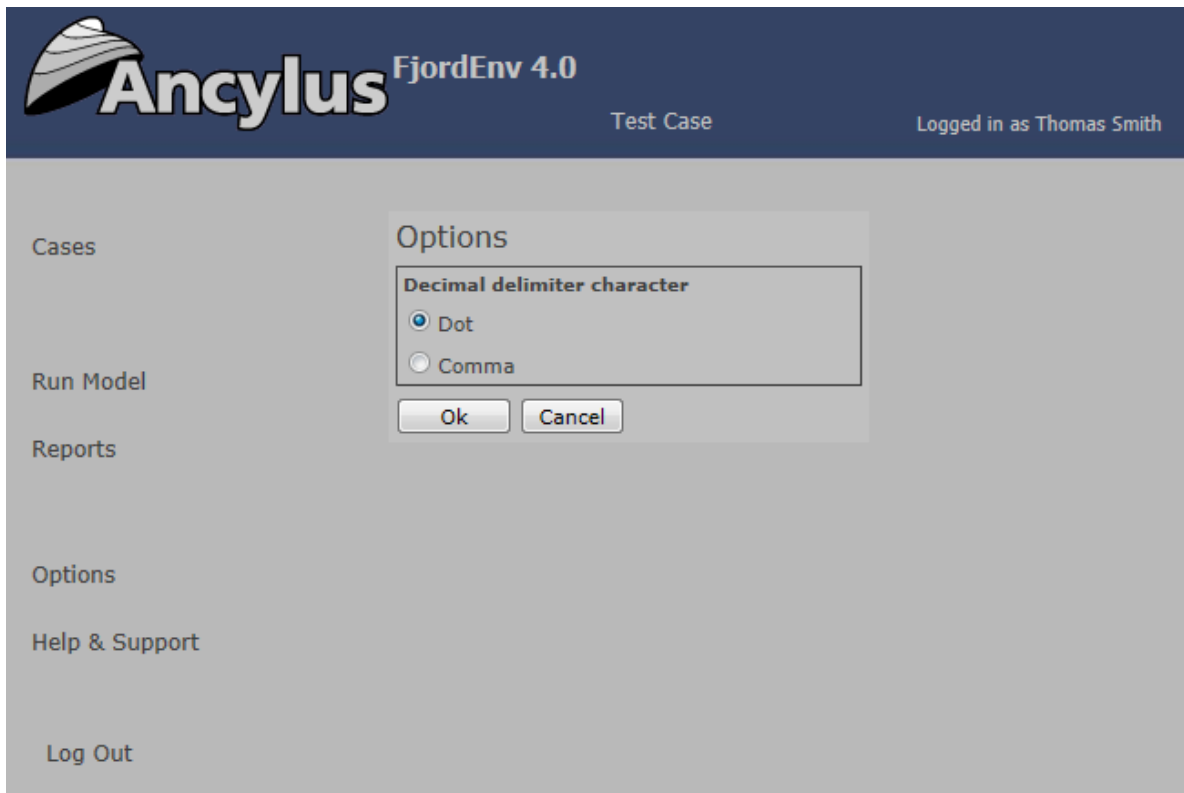
The report can be exported to Excel-format. This is done via the link Export to Excel at the top left of the report.



Picture 1b, the available reports of FjordEnv.

1.3 About Options

There is a possibility to use either dot or comma as decimal delimiter character in FjordEnv. FjordEnv uses dot as default. To change, click "Options" in the menu to the left of the main screen. A form will open where you are able change between dot and comma (see picture 1h). The change will take effect in all places of FjordEnv; input, output and reports.



Picture 1c. Choose decimal delimiter character to use in FjordEnv.



2. Description of Data Cards for Input and Results.

There are eight cards. Some are used for input and some for output. The cards are described below.

In this manual, input data are denoted by In (unconditional) or Inopt (optional). Some input data are available as default values denoted Indef. Output data, computed by FjordEnv are denoted by X.

Most theories behind the different computations are explained in the report "FjordEnv – a water quality model for fjords and other inshore waters" by Anders Stigebrandt (2001). This report can be downloaded from www.ancylyus.net. However, if more recent theories are used this is mentioned in the text explaining the cards. Other important reports and papers that give detailed explanations of the mechanisms employed in the model are listed in Chapter 3.



Card 1: Topography (input)

Fjord area (km ²) for chosen depths		Mouth width (m) for chosen depths	
Depth (m)	Area (km ²)	Depth (m)	Width (m)
0	50	0	900
20	40	20	500
40	25	40	100
80	12	43	0
115	0		

Picture 2a. Input of topographic measures

Provide up to 10 depths and the horizontal surface area of the fjord (in km²) at the chosen depths. NB: the first depth should be 0, i.e. the sea surface, and the last depth should be the maximum depth of the basin.

The Table appears as follows

Fjord area (km ²) for chosen depths		
	Depth	Area
Min	In	In
	In	In
	In	In
Max	In	In

Maximum depth accepted by FjordEnv is 1000 m.

Provide up to 10 depths in the mouth and the width of the mouth (in metres) at these depths. NB: the first depth should be 0, i.e. the sea surface, and the last depth should be the maximum depth of the mouth, i.e. the so-called sill depth.

The Table appears as follows

Mouth width (m) for chosen depths		
	Depth	Width
Min	In	In
	In	In
	In	In
Max	In	In

Maximum sill depth accepted by FjordEnv is 350 m. Maximum sill depth should be at least 2 m less than Maximum depth.

When the tables in Topography are filled the operator should **press the button "Compute Topographic Conditions"**. The results of the computations are then shown in the table "Topographic conditions in the fjord and the mouth", Card 5, is then filled.

Card 2: Loading (Input)

Topogr	Loading	Location & Nat cond.	Env. change	Topogr.	Fjord diagn.	Flux org matter	Env changes
--------	----------------	----------------------	-------------	---------	--------------	-----------------	-------------

Annual Supplies of organic matter and nutrients

<p>From fish farming</p> <p>Production, shallow areas (tons/yr) Excess feed (%)</p> <p><input type="text" value="0"/> <input type="text" value="25"/></p> <p>Production, deep areas (tons/year)</p> <p><input type="text" value="0"/></p> <p>To cages per ton fish production</p> <p>Nitrogen (Kg) Phosphorus (kg)</p> <p><input type="text" value="7"/> <input type="text" value="1"/></p>	<p>From other sources</p> <p>Phosphorus, annual supply (tons)</p> <p><input type="text" value="0"/></p> <p>Nitrogen, annual supply (tons)</p> <p><input type="text" value="0"/></p>
---	--

Picture 2b. Input of loading from fish farming and from other sources.

Information on loading from surrounding land and fish farming should be given to the Table shown below.

Annual supplies from land and fish farming

Here the operator should give the annual supplies connected to the Secchi (sight) depth as given in Card 3 below. This is usually the present condition.

From fish farming

Fish production, over shallow ¹⁾ areas (tons/year) (fphs)	In, 0 – 500 000
Fish production, over deep areas (tons/year) (fpd)	In, 0 – 500 000
Excess feed (%) ²⁾	In, 0 - 400

To cages per ton fish production³⁾

Nitrogen (kg N per ton fish production)	In, 0 - 300
Phosphorus (kg P per ton fish production)	In, 0 - 30

From other sources⁴⁾

Phosphorus, supply (tons/year)	In, 0 – 1 000
Nitrogen, supply (tons/year)	In, 0 – 10 000

1) Shallow areas are defined as areas where the bottom depth equals the maximum depth of the mouth + 5 m. Deep areas, below shallow areas, are situated in the basin water.

2) Excess feed should be given in percent of the feed actually consumed by the fish. For instance, if the fish production equals A tons and the fish eats x·A tons while the fish has been given 1.2·A tons, the excess feed in percent of the eaten feed is $100(1.2-x)/x$. If, for instance, $x=0.9$, Excess feed=30%. x is the so-called feed coefficient and it depends on feed compositions and fish weight. x



can be computed by the MOM model (www.ancylus.net). NB! MOM also computes the feed factor for other species than salmon and other feed compositions.

3) Outlets of dissolved N and P to the cages. In earlier versions of FjordEnv the outlets were set to 36 and 5 kg of N and P respectively (and could not be changed by the program operator). Modern salmon feed gives smaller outlets due to lower contents of protein and higher contents of fat. The outlets for a specified feed can be computed using the MOM model (www.ancylus.net). NB! MOM also computes nutrient outlets and excess feed for several other fish species for a given feed composition.

4) Supplies from other sources to the fjord (recipient), by runoff from land and by point source outlets of sewage and from industry.

NB: To calculate changes of the water quality due to changed supplies from land and/or fish farming the operator should later use Card4 "Env change". The results of changed loading may thereafter be seen in Card8 "Env changes".



Card 3: Location & natural conditions

Topogr	Loading	Location & Nat cond.	Env. change	Topogr.	Fjord diagn.	Flux org matter	Env changes
--------	---------	---------------------------------	-------------	---------	--------------	-----------------	-------------

Region	Location
Norway	Ostfold

Natural conditions

Secchi depth, typical summer value (m)	Background deepwater mixing (W/m^2)	Freshwater supply (annual mean) (m^3/s)
5	0.00002187	25
Oxygen conc. in "new" basin water ($ml\ O_2/l$)	Deltaro (kg/m^3)	Power supply from interior sills (kW)
6	2.94	0.00
Tidal amplitude - M_2+S_2 (m)	Sigmara (kg/m^3)	Flux of organic matter ($gC/m^2/month$)
0.15	0.82	4
Semidiurnal contribution (fi)	Int circulation forcing (kg/m^2)	<input type="button" value="Find Natural Conditions"/>
2	52.5	
S2	Efi	Wi
24	2	5

Picture 2c. Card for input of location and natural conditions

Location:
Norway
Eastern Skagerrak
Kattegat
Baltic Sea

Drop down lists:

- Norway:**
 Østfold
 Vestfold
 Telemark
 Aust-Agder
 Vest-Agder
 Rogaland
 Hordaland
 Sogn & Fjordane
 Møre and Romsdal
 Sør-Trøndelag
 Nord- Trøndelag
 Nordland
 Troms
 Finnmark
- Baltic Sea:**
 Baltic proper
 Bothnian Sea
 Bothnian Bay



NB! If you run FjordEnv for a region outside the pre-selected regions – chose one of the preselected regions and a location from the drop-down list with natural conditions most similar to those of your location.

When the region and location (above) and the topography (Card 1) have been selected, the operator may **press the button "Find Natural Conditions"** to obtain the default input values for the area. These are shown in the table "Natural conditions", below. The values may be changed if considered not representative for the actual water area. In particular the values of freshwater supply and power supply from interior sills must be checked.

Natural conditions

Secchi depth, typical summer value (m)	In, 1 - 30
Oxygen conc in "new" basin water (ml O ₂ /l)	In, 1 - 10
Tidal amplitude – M ₂ +S ₂ (m)	In, 0,01 - 6
Semidiurnal contribution ($0.3 < f_i \leq 1$) ¹⁾	In, 1 - 10
Background deepwater mixing (mW/m ²)	In, 0 - 0,1
Deltaro	In, 0,1 - 30
Sigmaro	In, 0,1 - 2
Interm circulation: forcing (kg/m ²)	In, 0 - 100
Freshwater supply (m ³ /s) ²⁾	In, 0 - 10000
Power supply from interior sills (kW) ³⁾	In 0 - 500
Flux of organic matter (gC/m ² /month) ⁴⁾	In, 0 – 500
S ₂ , salinity of intermediary layer ⁵⁾	In, 0 – 40
Efi, parameter (default 2,0) ⁵⁾	In, 1,7 - 3
Wi, mean wind speed (m/s) ⁵⁾	In, 1 – 25

1) Semidiurnal contribution coming out on "Location and Nat. Cond" is in fact $1/f_i$, see e.g. Stigebrandt (2001) (see list of references in Ch. 3.)

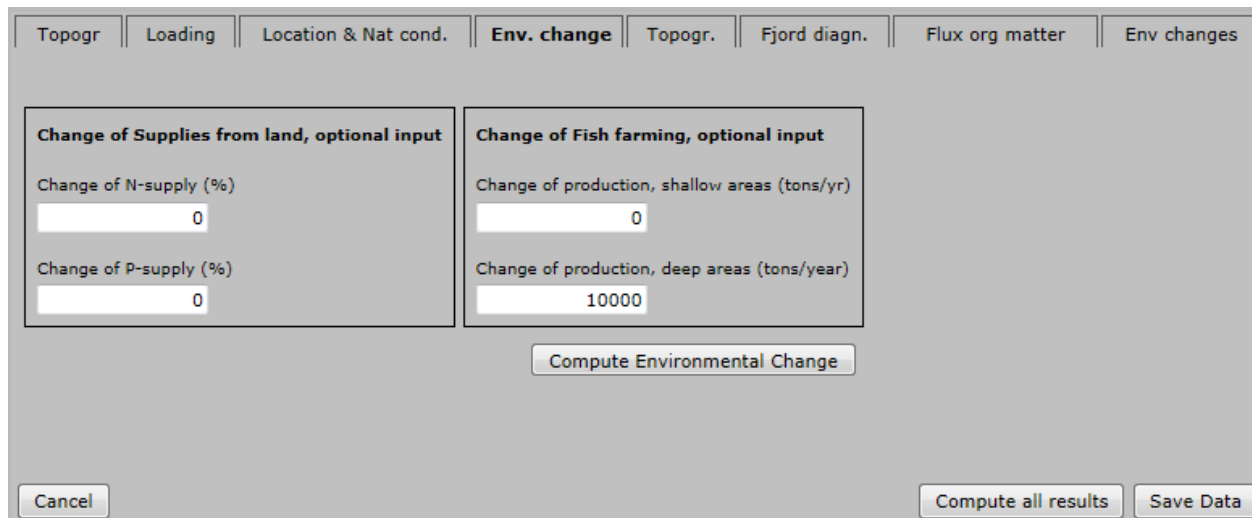
2) Use typical value for the production season (spring-summer -autumn)

3) Use value from previous run for interior, coupled fjord basin, see Card 6 "Power supply to exterior basin (kW)"

4) Default values: Norway, 5.5, except for the Skagerrak coast where 8 is used. Eastern Skagerrak 8, Kattegat and Baltic proper 6, Bothnian Sea 4 and Bothnian Bay 1.

5) Needed for computations of estuarine circulation, see Stigebrandt (2001).

Card 4: Environmental change (input)



Picture 1d. Environmental change.

This card should be used to estimate water quality changes due to changed supplies of nutrients from land (changes in % compared to figures given in Card 2). Changes in fish production should be given in tons/year.

Change of Supplies from land, optional input

Change of N-supply (%)	In (-100 - not limited)
Change of P-supply (%)	In (-100 – not limited)

Change of Fish farming, optional input

Change of production, shallow areas (tons/yr)	In, (-f _{psh} *) – (500 000-f _{psh})
Change of production, deep areas (tons/year)	In, (-f _{pd} *) – (500 000-f _{pd})

*) Here f_{psh} equals the fish production over shallow areas and f_{pd} equals fish production over deep areas, both given in Card 2 (Loading)

After having filled the Tables “Change of Supplies from land” and “Change of Fish farming, optional input”, the operator should **press the button “Compute Environmental Change”**. Values for the environmental changes are then shown in Card 8 below.

Card 5: Topographic conditions in the fjord and the mouth (output)

Topogr	Loading	Location & Nat cond.	Env. change	Topogr.	Fjord diagn.	Flux org matter	Env changes
Topographic conditions in the fjord and the mouth							
Maximal depth of the basin (m)	115.00	Area at the sea surface (km2)			50.00		
Sill depth (m)	43.00	Area at sill level (km2)			24.03		
Mean depth of the sill basin (m)	36.48	Vertical cross-sectional area of the mouth (m2)			20150.00		
Volume of the fjord (km3)	2.50000	Depth of half of the mouth area (m)			13.10		
Volume above sill depth (km3)	1.62354	Fjord area/Mouth area			2481.39		
Volume of the sill basin (km3)	0.87646						

Picture 1e. Computed topographic conditions in the fjord and the mouth

This card shows various computed topographic measures of the basin based on the input given in Card 1.

Maximal depth of the basin (m) ¹⁾	X
Mean depth of the sill basin (m) ²⁾	X
Volume of the fjord (km3)	X
Volume above sill depth (km3)	X
Volume of the sill basin (km3)	X
Area at the sea surface (km2) ¹⁾	X
Area at sill level (km2)	X
Width of the mouth at the sea surface (m) ¹⁾	X
Vertical cross-sectional area of the mouth (m2)	X
Depth of half of the mouth area (m) ³⁾	X
Fjord area/Mouth area	X

¹⁾ Given in Card 1

²⁾ Equals average thickness of the water layer beneath the sill depth=Volume of the sill basin/Area at sill level.

³⁾ Half of the vertical cross-sectional area of the mouth is above (below) this depth.



Card 6: Fjord diagnostics (output)

Topogr	Loading	Location & Nat cond.	Env. change	Topogr.	Fjord diagn.	Flux org matter	Env changes
--------	---------	----------------------	-------------	---------	---------------------	-----------------	-------------

General fjord diagnosis			
Choking coefficient	1.00	Estuarine circulation (m3/s)	154.52
Tidal speed in the mouth (m/s)	0.05	Residence time for water above sill level (days)	12.28
Speed of internal waves in the fjord (m/s)	0.75	Settling time for particular organic matter (days)	28.67
Intermediary circulation (m3/s)	1208.99	The function f1	0.00
Tidally forced circulation (m3/s)	167.11	The function f2	0.00

Conditions in the basin water			
The fjord is a wave fjord	$c_i/u_{s0} = 14.3014$	Work against the buoyancy forces (mW/m ²)	0.07
Filling time for basin water (days)	6.63	Background(mW/m ²)	0.02
Re-value of the sill basin	0.82	Tidally forced (mW/m ²)	0.05
Density reduction (kg/m ³ /month)	0.03	From interior sills (mW/m ²)	0.00
Oxygen consumption (ml/l/month)	0.09	Oxygen minimum in the basin water (ml/l)	3.38
Time-scale for water exchange (months)	29.61	The Function f3	0.00
Time-scale for oxygen consumption (months)	67.72	Power supply to exterior basin (kW)	1.15

Cancel Compute all results Save Data

Picture 1f. Fjord diagnostics – computed physical quantities

General fjord diagnosis

- Choking coefficient X
- Tidal speed in the mouth u_{s0} (m/s) X
- Speed of internal waves in the fjord c_i (m/s) X
- Intermediary circulation (m3/s) X
- Tidally forced circulation (m3/s) X
- Estuarine circulation (m3/s) X
- Residence time for water above sill level (days) X
- Settling time for particular organic matter (days) X
- The Function f1*) X
- The Function f2*) X



Conditions in the basin water

If $c_i > u_s 0$ then	
The fjord is a wave fjord, $c_i / u_s 0 =$	X
If $c_i < u_s 0$ then	
The fjord is a jet fjord, $c_i / u_s 0 =$	X
Filling time for basin water (days)	X
Re-value of the sill basin	X
Density reduction ($\text{kg/m}^3/\text{month}$)	X
Oxygen consumption (ml/l/month)	X
Time-scale for water exchange (months) ¹⁾	X
Time-scale for oxygen consumption (months)	X
Oxygen minimum in the basin water (ml/l)	X
The Function f_3^*)	X
Work against the buoyancy forces (mW/m^{-2})	X
Background (mW/m^{-2})	X
Tidally forced (mW/m^{-2})	X
From interior sills (mW/m^{-2})	X
Power supply to exterior basin (kW)#)	X

¹⁾ For weaker mixing the time scale for water exchange equals one year or multiples of one year, see Stigebrandt (2012) (references are given in Chapter 3).

*) These functions are in the range 0-1. Usually they are equal to 0, see Stigebrandt (1992) or (2001).

#) For fjords in series, this value should be inserted in Card 3 when running FjordEnv for an outer neighbour.

Card 7: Fluxes of organic matter into the sill basin (output) and field data (optional input)

Topogr	Loading	Location & Nat cond.	Env. change	Topogr.	Fjord diagn.	Flux org matter	Env changes
<p>Fluxes of organic matter into the sill basin</p> <p>Carbon, natural (tons/year) 383.49</p> <p>Nitrogen, natural (tons/year) 67.53</p> <p>Phosphorus, natural (tons/year) 9.35</p> <p>UOD, natural (tons/year) 1342.21</p> <p>From fish farming</p> <p>Carbon from excess food and faeces (tons/year) 0.00</p> <p>Nitrogen from excess food and faeces (tons/year) 0.00</p> <p>Phosphorus from excess food and faeces (tons/year) 0.00</p> <p>UOD from excess food and faeces (tons/year) 0.00</p>		<p>Field data, optional input</p> <p>Oxygen consumption in the basin water (ml O₂/l/month)</p> <p><input type="text" value="-99"/></p> <p>Oxygen minimum (ml O₂/l)</p> <p><input type="text" value="-99"/></p> <p><input type="button" value="Rerun Fjord Physics"/></p>					
<p><input type="button" value="Cancel"/></p>		<p><input type="button" value="Compute all results"/></p> <p><input type="button" value="Save Data"/></p>					

Picture 1g Fluxes of organic matter into the sill and Field data, optional input

Carbon, natural (tons/year)	X
Nitrogen, natural (tons/year)	X
Phosphorus, natural (tons/year)	X
UOD, natural (tons/year)	X

From fish farming:

Carbon from excess food and faeces (tons/year)	X
Nitrogen from excess food and faeces (tons/year)	X
Phosphorus from excess food and faeces (tons/year)	X
UOD from excess food and faeces (tons/year)	X

NB! The fluxes from excess food and faeces are computed assuming equilibrium, i.e. the supply and release are equally large so there is no accumulation of particulate organic matter on the bottom (according to MOM requirements)

Field data, optional input

If additional fjord data are available, the computations may be re-done using this information. This should give safer estimates of both the time-scale of water exchange and the Re-value of the sill basin. The table "Field data, optional input" below should be filled with -99 (meaning not available) as long as the operator of FjordEnv does not use this option.

Oxygen consumption in the basin water (ml O ₂ /l/month)*)	In, 0,01 - 25
Oxygen minimum (ml O ₂ /l)*)	In, 0 - 10

*) Use -99 when additional data are not used

When this table is filled press the button **"Rerun fjord physics"**.



Card 8: Environmental changes (output)

Topogr	Loading	Location & Nat cond.	Env. change	Topogr.	Fjord diagn.	Flux org matter	Env changes
Environmental changes							
Secchi depth, per cent of earlier value(%)			96.46				
Oxygen consumption, change (%)			325.96				
New Oxygen minimum in the basin water (ml/l)			-2.59				
<input type="button" value="Cancel"/>			<input type="button" value="Compute all results"/>		<input type="button" value="Save Data"/>		

Picture 1h. Environmental changes

Secchi depth, per cent of earlier value (%) ¹⁾	X
Oxygen consumption, change (%)	X
New Oxygen minimum in the basin water (ml/l)	X

These computations are based on the changes of the loading given in Card 4 "Environmental change"

¹⁾ <100 means a decrease; > 100 means an increase



2.1 Some applications of FjordEnv

Some typical applications of FjordEnv are briefly described below.

Card 1 must be filled for all computations.

To just compute volumes and areas at different depths in a basin and the area of the mouth, it is sufficient to use only Card 1. The computational results are given on Card 5.

If Card 1,2 and 3 are filled, diagnostic results are computed and presented on Card 6 and 7. These show the likely state of the inshore area based on the given values of the input.

An improvement of the diagnostic results for the basin water in Card 6 and 7 may be achieved if the Table "Field data, optional input" (on Card 7) is filled and the program thereafter is rerun. NB! This computation is optional, i.e. may be done only if data on oxygen conditions in the basin water are available and if oxygen consumption has been computed.

To compute changes of the water quality due to changes in fish farming and/or changes in supply of nutrients from other sources, the changes should be given in Card 4. However, first the computations described above must be undertaken. Thereafter Card 4, environmental change, is filled and the program is rerun. The changes in water quality variables are presented on Card 8.

In the case of coupled basins, start with computations for the innermost basin. The computed value of "Power supply to exterior basin (kW)" in Card 6 is then used as input, in Card 3 "Power supply from interior sills (kW)", when running the next basin.

One default case (example fjord) is provided with the program. Run this fjord to become acquainted with the model. Data for the example fjord together with some comments are given in Section 5.



3. The scientific foundations for the computations in the FjordEnv program

A comprehensive description in English of the ideas behind and computations executed in FjordEnv is now available (Stigebrandt, 2001). This report can be downloaded from www.ancylus.net.

A comprehensive description of FjordEnv was given in Stigebrandt (1992). This booklet may still be used by users familiar with Norwegian.

List of References

Reports describing FjordEnv:

Stigebrandt, A., 2001: FjordEnv – a water quality model for fjords and other inshore areas. Göteborg University, Earth Sciences Centre, Report C40, 41 pp. Can be downloaded from www.ancylus.net

Stigebrandt, A., 1992: Beregning av miljøeffekter fra menneskelige aktiviteter. Lærebok for brukere av vannkvalitetsmodellen Fjordmiljø. Statens Forurensningstilsyn og Ancylus, 58 pp.

Scientific reports resulting from the Møre project where decisive components of the FjordEnv model were developed.

Aure, J. and Stigebrandt, A., 1989: On the influence of topographic factors upon the oxygen consumption rate in sill basins of fjords. *Estuarine, coastal and Shelf Science*, 28, 59-69.

Aure, J. and Stigebrandt, A., 1990: Quantitative estimates of eutrophication effects on fjords of fish farming. *Aquaculture*, 90, 135-156.

Stigebrandt, A., 1990: On the response of the horizontal mean vertical density distribution in fjords to low-frequency density fluctuations in the coastal water. *Tellus*, 42A, 605-614.

Stigebrandt, A. and Aure, J., 1988: Observations of plant nutrients in some Norwegian fjords. *Sarsia*, 73, 303-307.

Stigebrandt, A. and Aure, J., 1989: Vertical mixing in the basin waters of fjords. *J. Physical Oceanography*, 19, 917-926.

Later scientific papers:

Aure, J., Molvær, J. and Stigebrandt, A., 1997: Observations of inshore water exchange forced by a fluctuating offshore density field. *Marine Pollution Bulletin*, 33, 112-119.

Green, J.A.M., Molvaer, J. and Stigebrandt, A., 2004: Hydrographic response of Holandsfjord to changed freshwater runoff. *J. Geophys. Res.*, 109, C07021, doi:10.1029/2004JC002295

Stigebrandt, A., 1999: Resistance to barotropic tidal flow in straits by baroclinic wave drag. *J. Phys. Oceanogr.*, 29, 191-197.

Stigebrandt, A., 2012: Hydrodynamics and circulation of fjords. In *Encyclopedia of Lakes and Reservoirs*, (eds. L. Bengtsson, Herschy, R.W. and Fairbridge, R.W.). DOI 10.1007/978-1-4020-4410-6, @Springer Science+Business Media B.V.



4. Support

Contact Ancyclus for technical support. Please send an email with a description of the problem to support@ancyclus.net. Normally, you will be answered within a few days, and always within one week.



5. Default cases in FjordEnv 4.0

To provide examples, FjordEnv has the Ørsta Fjord and the Gullmar Fjord as two built-in cases.

5.1 The Ørsta Fjord

The fjord is situated in Møre and Romsdal, Norway. It has a main basin with greatest depth 172 m. The sill level is 24 m. The area of the fjord is 15.5 km² and the total volume equals 1.30 km³. The annual mean freshwater supply by runoff is about 16 m³ s⁻¹. The annual supplies of phosphorus and nitrogen are 2 and 150 tons, respectively (Aure and Stigebrandt, 1989). In 1989 there was no fish production by aquaculture in the fjord.

With the standard setting of "Natural conditions" for Møre and Romsdal in Card 3, FjordEnv predicts for the basin water an oxygen consumption of 0.09 mL/L/month and an oxygen minimum of 2.62 mL/L. If the oxygen consumption is set to 0.12 mL/L/month under "optional input" in Card 7, the oxygen minimum changes to 1.39 mL/L. In Aure & Stigebrandt (1989) the oxygen consumption was set to 0.12 mL/L/month and oxygen minimum was calculated to -0.6 mL/L. NB, this estimate was made before the first version of the original Fjordmiljø had been finished.

5.2 The Gullmar Fjord

This fjord is situated in the Eastern Skagerrak on the west coast of Sweden. The town Lysekil is situated at the northern shore, close to the mouth. The fjord is well investigated since long which means that lots of observational data have been obtained in the fjord, see e.g. Erlandsson et al (2006).

Often the time-scale of water exchange becomes wrong because the Re-method is not accurate enough for fjord basins with residence times longer than a couple of month. This is explained in Stigebrandt (2012), see the reference list in Section 3 above. However, one may override the computations by using field data from the fjord basin. In the case of Gullmar fjord, the oxygen minimum is about 2 ml/l and the rate of oxygen consumption is about 0.4 ml/l/month. If these figures are inserted under "Field data, optional input" in Card "Flux of organic matter" the time-scale for water exchange becomes about 13 months (which is close to the correct mean value 12 months) and Re-value of the sill basin becomes about 0,37. In a future version of FjordEnv, a more correct method to compute the residence time in fjord basins will be implemented (along the lines described in Stigebrandt, 2012).

References

- Aure, J. and Stigebrandt, A., 1989: Havbruksplan Møre og Romsdal. Delrapport 3. II "Terselfjordrapporten" – Fjordrapportar. Møre og Romsdal Fylkeskommune, Mars 1989.
- Erlandsson, C.P., Stigebrandt, A., Arneborg, L., 2006: The sensitivity of minimum oxygen concentrations in a fjord to changes in biotic and abiotic external forcing. *Limnology and Oceanography*, 51, 631-638.