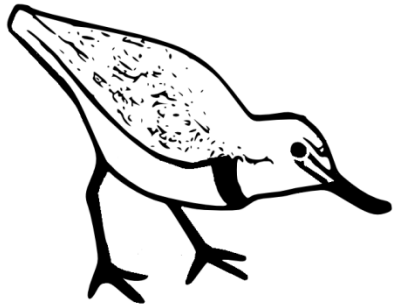
Introducing PLOVER 2*k*: Planning openings and values for Ellesmere's resilience



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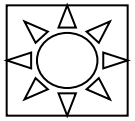
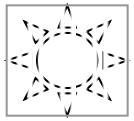
Thanks to the many people who helped with this complicated project,
Ken Hughey & Ken Taylor (2*k*), Ian Whitehouse,
Graeme Horrell, Don Jellyman, Zach Hill, & Ed Hearnshaw

Line art by John F. Raffensperger,
based on Walter Lawry Buller, *History of Birds of New Zealand*,
1888, image found on www.nzbirds.com/birds/wrybill.html

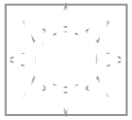
Different qualities in data



Strong. Causal relationships, good data.
Example: water flows are based on existing NIWA model.



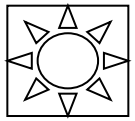
Okay. Correlative relationships, some data.
Example: salinity depends on water depth, based on ECan data.



Hazy. Anecdotal data or speculative relationships.
Example: blue-green algae calculated as a "threat" formula, based on a few reported events & general science.

When you consider scenarios, think about the strength of the data!
Points a direction, not necessarily degree.

Factors in PLOVER

Date. 

Simulate 38 years
of actual past hydrology,
5 Jan 1970 to 31 Dec 2007.

No attempt to predict the future.

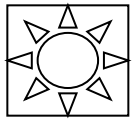
Hours sunlight from astronomical data.

Temperature from ECan data
& line of best fit.

2		Day of year	Hours sunlight	Water temperature, C
19	Date			
20	5-Jan-70	5-Jan	15:18	19.3
21	6-Jan-70	6-Jan	15:17	19.4
22	7-Jan-70	7-Jan	15:16	19.5
23	8-Jan-70	8-Jan	15:14	19.5
24	9-Jan-70	9-Jan	15:12	19.6
25	10-Jan-70	10-Jan	15:11	19.7
26	11-Jan-70	11-Jan	15:09	19.8
13887	24-Dec-07	24-Dec	15:25	18.3
13888	25-Dec-07	25-Dec	15:26	18.4
13889	26-Dec-07	26-Dec	15:25	18.5
13890	27-Dec-07	27-Dec	15:24	18.6
13891	28-Dec-07	28-Dec	15:24	18.7
13892	29-Dec-07	29-Dec	15:24	18.7
13893	30-Dec-07	30-Dec	15:23	18.8
13894	31-Dec-07	31-Dec	15:22	18.9

Key: opening inputs & resulting depths.

Lake depth from NIWA "TIDEDA" model.
Depends on **openings**.



	Scenario: status quo, baseline	Day of year	Hours sunlight	Water temperature, C	Lake depth, mm
3	Param a				**1-Apr**
4	Param b				1,130
5	Param c				**1-Aug**
6	Param d				1,050
7	Param e				**1-Sep**
8	Param f				1,050
9	Param g				FALSE
20	5-Jan-70	5-Jan	15:18	19.3	311
21	6-Jan-70	6-Jan	15:17	19.4	313
22	7-Jan-70	7-Jan	15:16	19.5	316
23	8-Jan-70	8-Jan	15:14	19.5	318
24	9-Jan-70	9-Jan	15:12	19.6	321
25	10-Jan-70	10-Jan	15:11	19.7	324
26	11-Jan-70	11-Jan	15:09	19.8	327

An "opening" is a 30-day *attempt* to lower the lake level. May fail due to roughness!

First day to attempt opening.

Trigger depth.

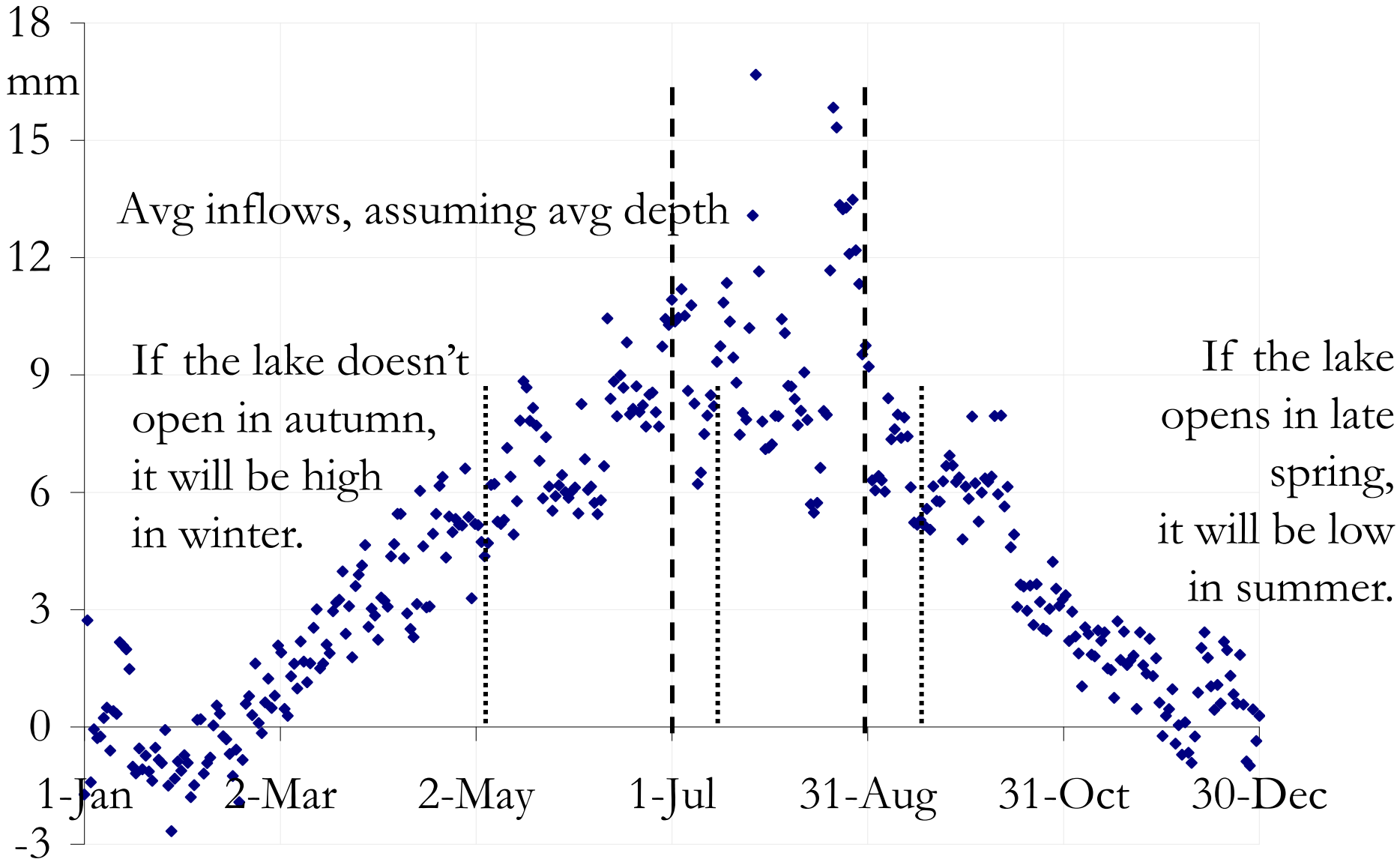
"On 1 Apr, if depth ≥ 1,130mm, try to open the lake."

FALSE: try for 30 days.
1,200mm "circuit breaker".

TRUE: keep trying to next date, with same depth trigger.

Half the water arrives in July & Aug.

1/3 the water comes 11 Sep to 3 May, 3 May to 16 July, 16 July to 11 Sep.



Example of roughness

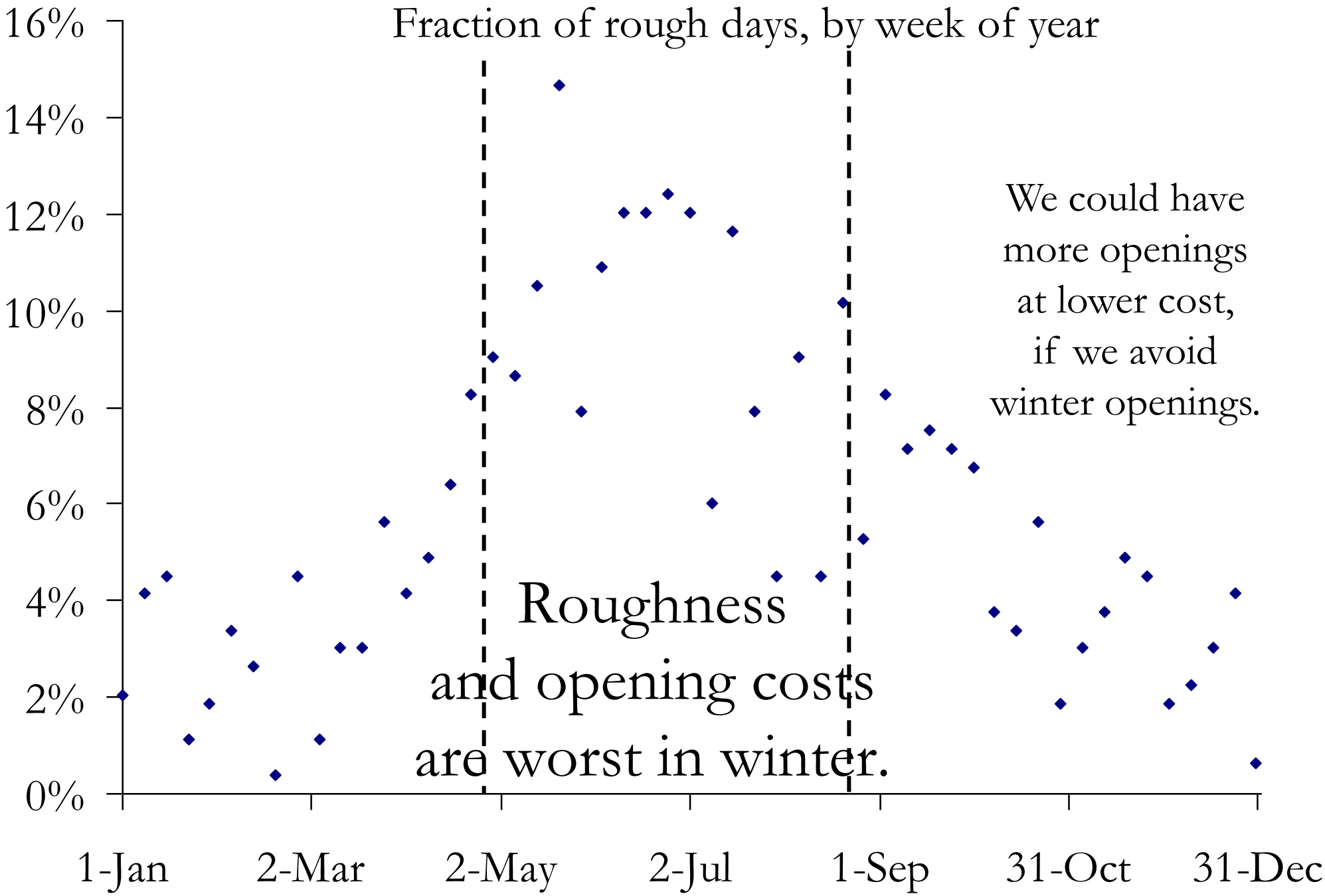
Aug '73 was a rough month!

Depth > 1,050,
but couldn't open.

Got it open,
but couldn't *keep* it open.

The NIWA hydrology model
does a good job
simulating the lake,
& its limitations
are understood.

1319	27-Jul-73	27-Jul	1,249	Closed
1320	28-Jul-73	28-Jul	1,347	Closed
1321	29-Jul-73	29-Jul	1,427	Closed
1322	30-Jul-73	30-Jul	1,398	Open
1323	31-Jul-73	31-Jul	1,363	Open
1324	1-Aug-73	1-Aug	1,329	Open
1325	2-Aug-73	2-Aug	1,293	Open
1326	3-Aug-73	3-Aug	1,257	Open
1327	4-Aug-73	4-Aug	1,221	Open
1328	5-Aug-73	5-Aug	1,280	Open
1329	6-Aug-73	6-Aug	1,243	Open
1330	7-Aug-73	7-Aug	1,255	Closed
1331	8-Aug-73	8-Aug	1,267	Closed
1332	9-Aug-73	9-Aug	1,285	Closed
1333	10-Aug-73	10-Aug	1,301	Closed
1334	11-Aug-73	11-Aug	1,317	Closed
1335	12-Aug-73	12-Aug	1,287	Open
1336	13-Aug-73	13-Aug	1,255	Open
1337	14-Aug-73	14-Aug	1,224	Open
1338	15-Aug-73	15-Aug	1,191	Open
1339	16-Aug-73	16-Aug	1,159	Open
1340	17-Aug-73	17-Aug	1,125	Open
1341	18-Aug-73	18-Aug	1,092	Open
1342	19-Aug-73	19-Aug	1,058	Open
1343	20-Aug-73	20-Aug	1,025	Open
1344	21-Aug-73	21-Aug	1,043	Closed
1345	22-Aug-73	22-Aug	1,061	Closed
1346	23-Aug-73	23-Aug	1,077	Closed
1347	24-Aug-73	24-Aug	1,094	Closed


Fraction of rough days, by week of year
16%
14%
12%
10%
8%
6%
4%
2%
0%
1-Jan
2-Mar
2-May
2-Jul
1-Sep
31-Oct
31-Dec
We could have more openings at lower cost, if we avoid winter openings.
Roughness and opening costs are worst in winter.

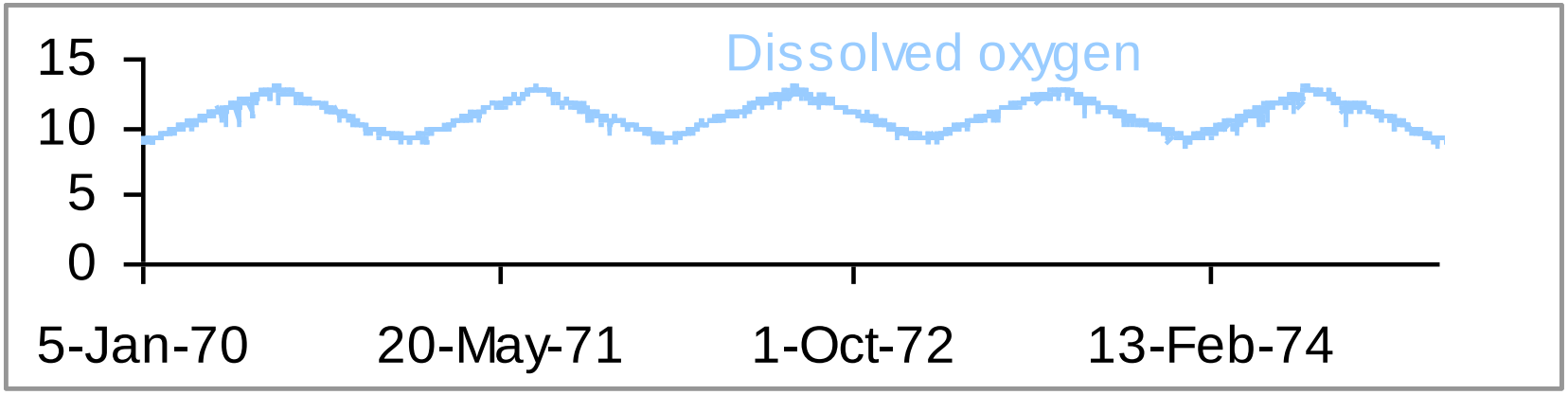
Area, volume, dissolved oxygen.

Lake area, detailed GIS data: AgriBase & NIWA LIDAR data.
33 land types: Arable cropping, Beef cattle, Dairy cattle, …

Key: for each depth each day, PLOVER calculates
area and cost of each land type covered.

Volume of the lake, from GIS data.

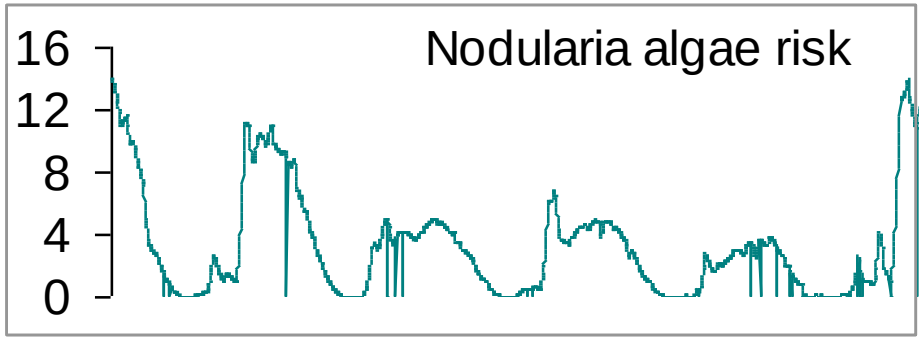
Dissolved oxygen, from ECan data.
Line of best fit, based on sunlight, wave height, lake level & temp.



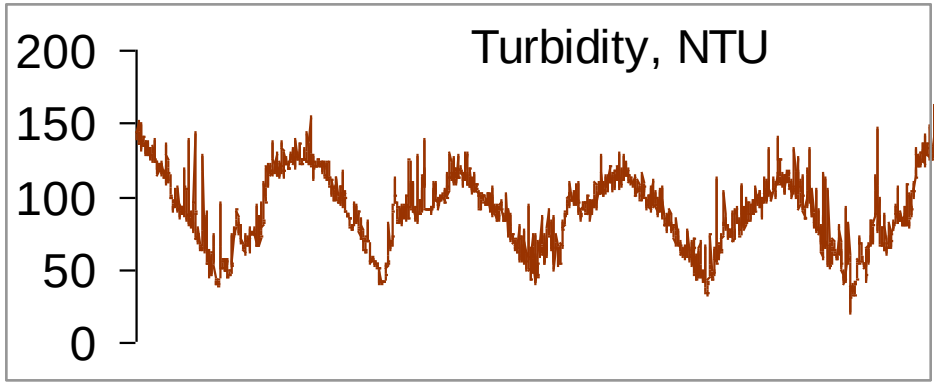
Salinity, algae, turbidity

Salinity, from line of best fit,
based on ECan data & lake volume.

Nodularia algae risk. Recreation.
Only anecdotal data!
Use "risk" formula
based on salinity & temp.



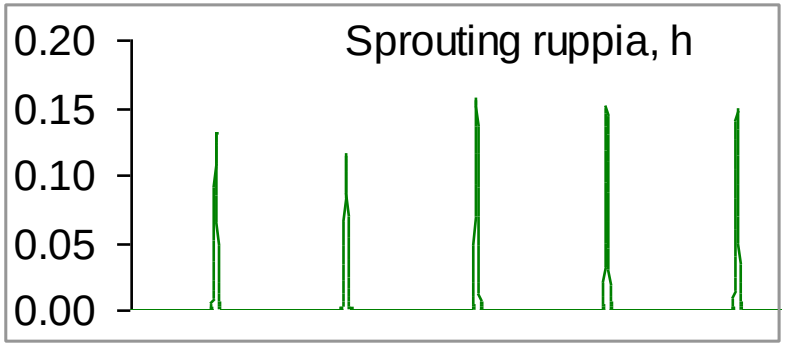
Turbidity, from line of best fit,
based on ECan data,
lake level, temp & wave height.



Ruppia, eel & flounder

Ruppia: sprouting only. No growth model.

Chance of sprouting is a bell curve centred on 29 Aug, with temp & salinity.



Eel: recruitment & migration only.

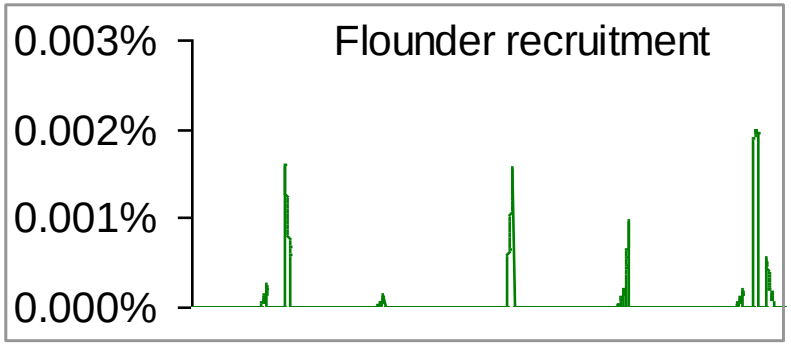
No growth or habitat.

Chance of recruitment & migration are bell curves centred on 1 Nov & 1 May, and only if open.

Flounder: recruitment only.

No growth or habitat.

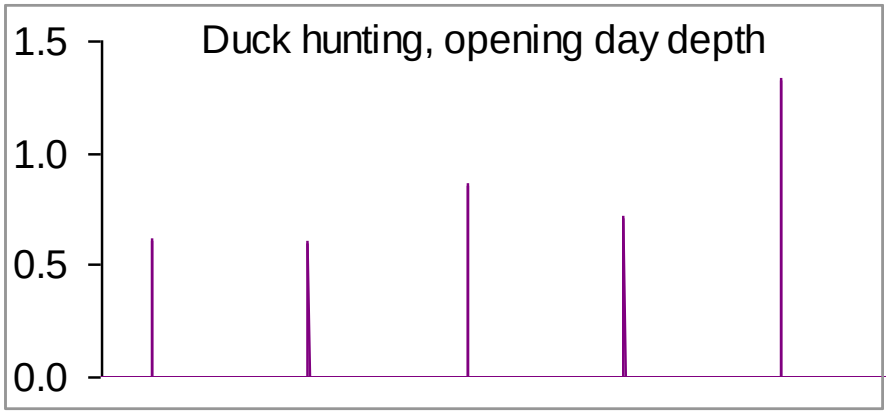
Chance of recruitment is a bell curve centred at 1 Oct, and only if open.



Duck hunting, wader habitat & population

Duck hunting:

lake depth on 1st Saturday in May.



Wader habitat:

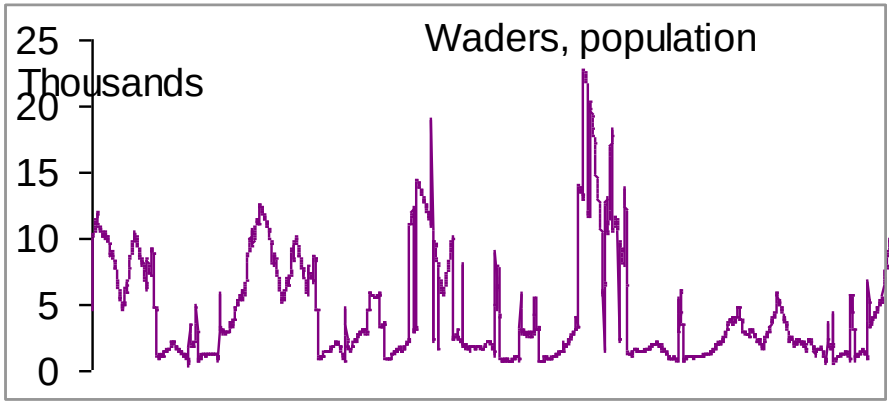
habitat quality adjusted hectares.

Expert assessment of GIS land types.

Wader population:

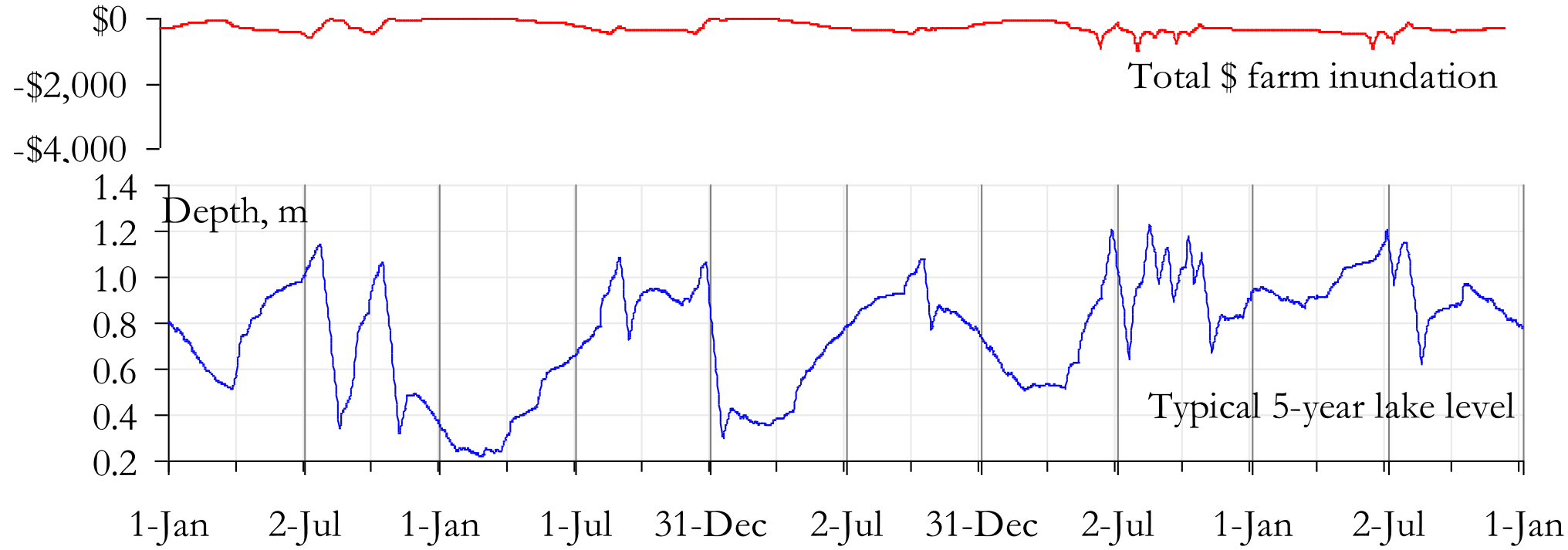
used 1 year of population data,

scaled by habitat area to baseline area.

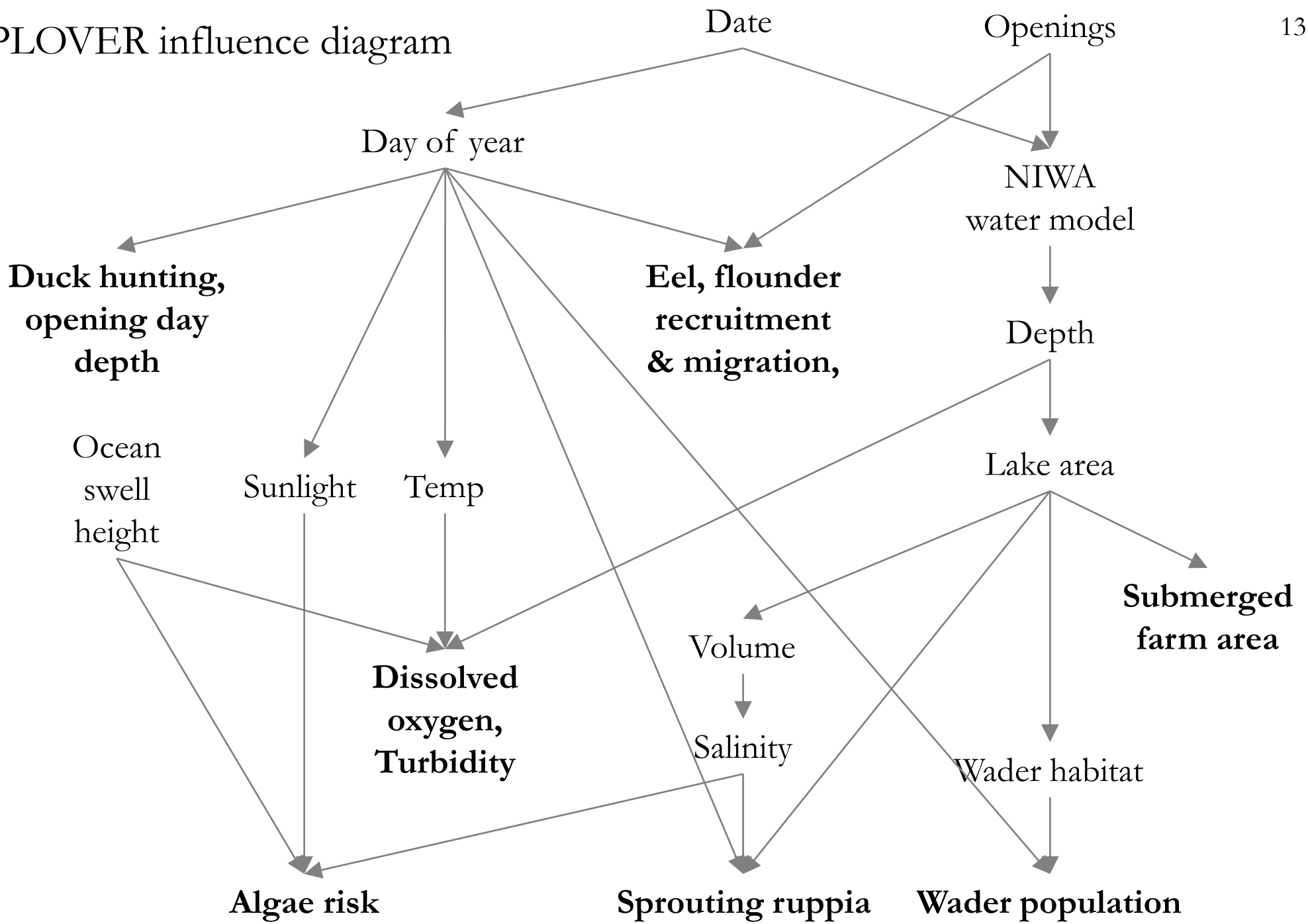


Farm area covered.

Used the detailed GIS database.
Used approximate $/hectare/day, for each land type.
Calculated total $/hectare/day, for all land types.
High-quality data, missing only wind lash.



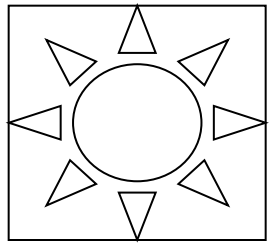
PLOVER influence diagram



Strengths & weaknesses of PLOVER 2*k*

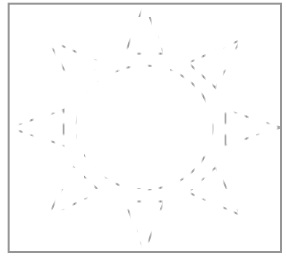
Strengths

- Good hydrology model.
- Good GIS & land use data.
- Wader habitat is probably good.
  Could be used for other flora & fauna.



Weaknesses

- Hydrology model is deterministic.
- Lacks population & habitat for eel.
- Lacks growth & predation for ruppia.
- Lacks population component for all birds, except waders which is weak.
- Many factors are exogenous, e.g., inflows & nutrients.



If these were fixed, we could *better* estimate opening regime effects for eel, flounder, ruppia re-planting & birds.

Suggestions for improved models

1. PLOVER 3. Add growth & habitat for eel.

2. PLOVER 3. Add more details for ruppia. *See Estrada et al.*

3. PLOVER 4. Use stochastic reservoir mgmt techniques.
   Create *conditional* rules, "If depth is lower than X on date Y, don't open."
   Add weather forecasts.

4. PLOVER 5. Model the catchment.
   Ground & surface water, nutrient run-off, impervious cover.
   We have the technology to do this now, and much of the data.
   A big job, but helpful for other purposes, too.