Note: This is presentation material only

Bath treatment modelling

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SEPA SCOTTISH ENVIRONMENT PROTECTION AGENCY

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Overview

- require a uniform method that produces site-specific indicative values for quantities of controlled chemicals unlikely to be of risk to the environment
    - bath treatments
    - chemical characteristics
    - EQS and AZE
    - appropriate modelling tools
    - short-term model
    - long-term model
    - ‘tricky bits’
    - reporting of results

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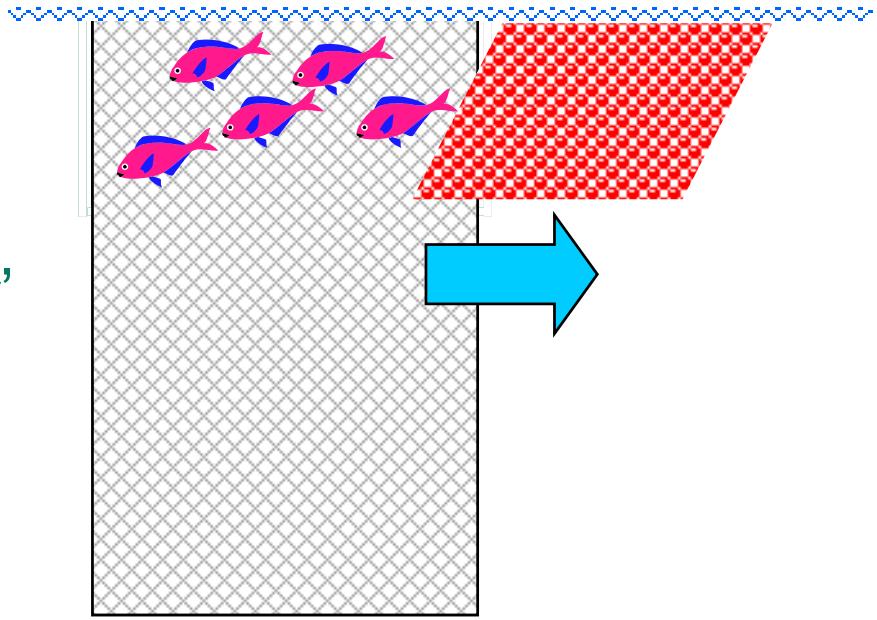
Bath Treatments

- topical application of anti-parasitic chemical
- shallow cage and enclose with tarpaulin
- dose with chemical
- ‘leave to cook for 1 hour’
- remove tarpaulin and return nets to full depth
- chemical released and dispersed



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Chemical Characteristics

- cypermethrin
  - synthetic pyrethroid - CNS disruptor
  - binds to solid particles readily
  - removed from water column by sedimentation
- azamethiphos
  - organophosphate - cholinesterase inhibitor, interferes with signal transmission across synapses
  - remains in aqueous phase until decay
  - decay half-life of 8.9 days; $\propto$ pH, T, light

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EQS and AZE

- Environmental Quality Standards derived from ecotoxicological studies
  - typically LC_{50} of most susceptible species / safety factor (10-100)
- Allowable Zone of Effect
  - concentration may exceed EQS up to MAC
  - for aza. lower of: 0.5km^2 or 2% of loch area

cypermethrin		
timescale	**value**	**standard**
(hours)	**ngl^{-1}**	
3	16	EQS

azamethiphos		
timescale	**value**	**standard**
(hours)	**ngl^{-1}**	
3	250	EQS
72	40	EQS
72	100	MAC

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Modelling Strategy

- choose/devise tools appropriate to:
  - chemical longevity
  - complexity of processes involved
  - balance of effort vs “accuracy”

- simple, short-term method - for < ebb or flood period
  - for 3-hr EQS
- complex, long-term method - for > tidal ebb/flood cycle
  - for 72-hr EQS/MAC

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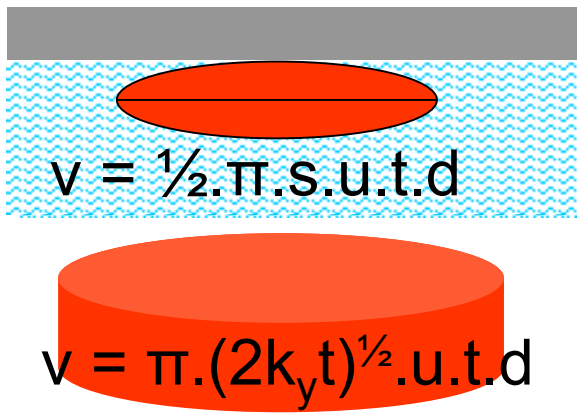
Short-term Model I

- elliptical patch spread by:
  - longitudinal advection - mean u × t (3 hours)
  - lateral dispersion - $4(2k_yt)^{½}$; $k_y = 0.1m^2s^{-1}$
- constrained by:
  - mixing depth (d) - lower of: ½ depth or 10m
  - shore (s)



- consent mass = volume (v) × EQS concentration

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Short-term Model II

Site Name:	Assessment Of Use Of *Azamethiphos* For Use In Marine Cage Fish Farms									
Lilliput										
Model Input / Output Parameters FILL IN YELLOW BOX GREEN BOXES CONTAIN DERIVED INFORMATION	Mean Current Speed At Cage Site (m/s)	Distance From Cage To Shore (m)	Diffusion Coefficient (m^2/s)	3hr Mixing Zone Ellipse Length (m)	3 hr Mixing Zone Ellipse Width (m)	3 hr Mixing Zone Ellipse Volume (m^3)	3 hr Treatment Volume (m^3) (Note 1)	Number Of Cages That Can Be Treated In Any 3 hr Period (Note2)	Concentration Of Azamethiphos In The 3hr Mixing Ellipse After A Single Treament (ng/l)	Mass Of Azamethiphos Permitted To Be Added In Any 3 Hour Period (kg)
Fill In Yellow Boxes Only	0.24	100.00	0.10	2602.88	186	4.55E+06	11365.23	5.510	45.37	1.1365
Current Speed Increased By 20%	0.29	100	0.10	3123.46	186	5.46E+06	13638.28	6.612	37.81	1.3638
Current Speed Decreased By 20%	0.19	100	0.10	2082.31	186	3.64E+06	9092.19	4.408	56.71	0.9092
Shoreline Concs Allowed To Breach The EQS:	0.24	100	0.10	2602.88	186	4.55E+06	11365.23	5.510	45.37	1.1365
Does Gaussian Plume Width Impact ShoreLine:	NO									
Current Speed Increased By 20%	0.29	100	0.10	3123.46	186	5.46E+06	13638.28	6.612	37.81	1.3638
Current Speed Decreased By 20%	0.19	100	0.10	2082.31	186	3.64E+06	9092.19	4.408	56.71	0.9092

Additional Required Input Parameters					
Mixing Zone Depth =	10	m	EQS Concentration =	250	ng/l
Cage Volume =	2063	m^3	After	3	hours
Cage Width/Diameter=	28.65	m	Cage Type (Round Or Square):		Round
Treatment Conc. =	100,000	ng/l	N.B. ng/l = nanograms per litre.		
Treatment Mass =	0.206264806	kg			

Note 1: This is the volume within the 3 hr Mixing Ellipse which will contain Azamethiphos in a concentration that will meet the three hour EQS standard.

Note 2: To obtain the number of Cages that can be treated we divide the 3 hr Treatment Volume (Rounded Down) by the volume of the cage(s) to be treated.

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Long-term Model I

- modification of model by Turrell & Gillibrand (FRS#2/99)
- whole site treated with multiple releases
- each patch advected and dispersed
  - advection by sinusoidally oscillating tidal flow
  - advection by residual flow
  - dispersion (2D) by Fickian diffusion; $k_y=0.1m^2s^{-1}$
- 'closed' boundaries constrain dispersion
  - uses method of 'virtual sources'
- finite mixing depth - 10m
- logarhithmic decay of chemical
- grid resolution: 300m (long.), 100m (lat.)

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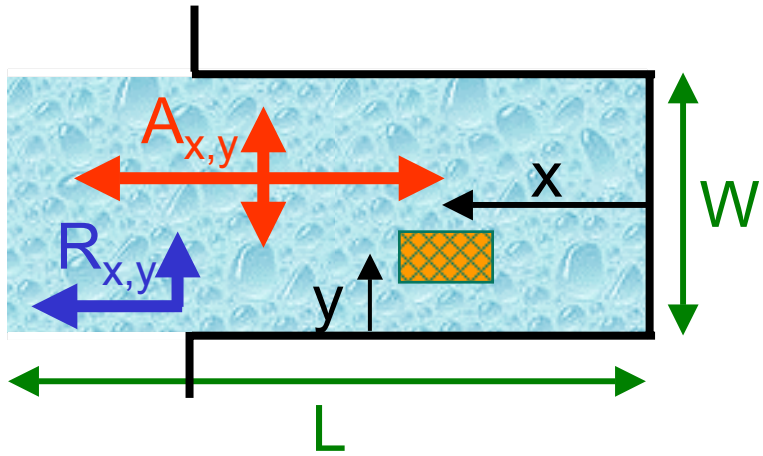
Long-term Model II

- 3 topographies
  - Open (or coastal water)
  - Strait
  - Loch (or voe)



- domain length (L) from: run duration, tidal amplitude, residual current and distance from head of loch
- domain width (W) from:
  - Open: 5km
  - Strait: user input (<5km)
  - Loch: area/length

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Long-term Model III

- site information:
  - distance from shore and head of loch
  - cage area & treatment depth
  - number of cages
- treatment information:
  - chemical concentration
    - derive total quantity for site and per cage
  - total number of treatments
    - derive cages per treatment; = short-term result
  - number of treatments per day
  - interval between treatments; ≥ 3 hours

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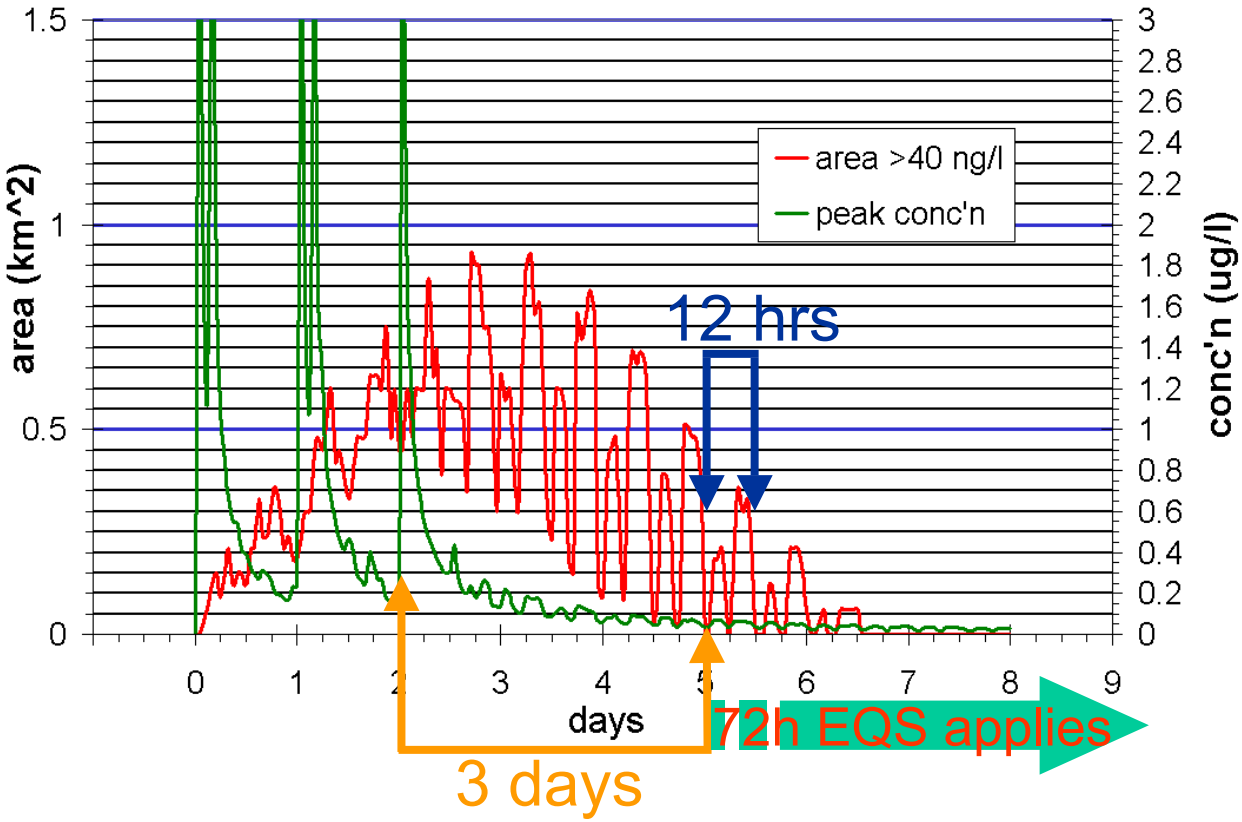
Long-term Model IV

- test parameters
  - EQS value that forms boundary of AZE (0.04 $\mu g l^{-1}$)
  - EQS period (72h); (+12 hours to catch relict peaks)



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Long-term Model V

- function:
  - release quantity of chemical from source at specified intervals until all cages treated
  - track patches; advect, disperse and decay
  - continue until specified period after final release

- output:
  - display: area >EQS and peak concentration
  - files:
    - time-series of area >EQS and peak concentration
    - set-up parameters, final patch positions & “display”

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Long-term Model VI

- assessment procedure:
  - define domain, flow field, site info. & EQS parameters
  - set initial treatment parameters = 3hr model result
  - RUN model
  - assess results against EQS/MAC/AZE tests
    - FAIL? : redefine treatment parameters:
      - ⇓ # treatments/day
      - ⇑ interval between treatments
      - ⇑ # treatments; i.e. ⇓ # cages/treatment
      - ⇓ depth
    - re-RUN with new treatment configuration
  - PASS? : report maximum chemical in 24 hours

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Long-term Model VII

Lilliput	site		**Scenario**							
10	mixing depth		**Site:**	**Lilliput**						
0.1	dispersion	**# runs:**	**Run #:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
L	topog type	8	Cages per treatment:	1	1	1	2	1	1	1	1
3.1	Loch length		# of treatments:	8	8	8	4	8	8	8	8
7.1	Loch area		# treatments per day:	2	2	1	1	1	1	1	1
1	flushing time		Treatment interval (hrs):	3	3	24	24	24	24	24	24
0.013	resid u		Shallowing depth (m):	3.0	2.0	3.0	3.0	4.0	3.5	3.4	3.3
0.005	resid v		**Results**								
0.062	amp u	**Std.**									
0.036	amp v	**0.1**	Peak conc'n in patch >40ng/l after 72h (ug/l):	0.097	0.065	0.052	0.104	0.069	0.06	0.059	**0.057**
0	phase	**0.142**	Area > std. (km^2):	0.66	0.24	0.09	0.81	0.27	0.15	0.15	**0.12**
8	# cages	**0.1**	Peak conc'n (ug/l):	4.818	3.212	4.818	9.636	6.424	5.621	5.461	**5.3**
1363.4	tonnage	**0.142**	Peak area >std. (km^2):	1.17	0.66	0.6	1.26	0.87	0.72	0.69	**0.66**
5832	cage area		Time to treat (days):	4d	4d	8d	4d	8d	8d	8d	**8d**
1.2	distance to head		Mass of medicine per treatment (g):	218.7	145.8	218.7	437.4	291.6	255.2	247.9	**240.6**
0.18	distance to shore		Pass/Fail:	F	F	P	F	F	F	F	**P**
3	shallowing depth		(Modelled by):	js	js	js	js	js	js	js	**js**
Azamethiphos	chemical										
100	treatment conc		Total medicine used (kg):	1.75	1.166	1.75	1.75	2.333	2.041	1.983	**1.925**
8.9	decay half-life		Max medicine per 24h (g):	437.4	291.6	218.7	437.4	291.6	255.2	247.9	**240.6**
8	# treatments										
2	# treatments/day										
3	interval										
0.04	EQS										
0.04	contour										
84	duration										

- Excel s/s tool that automates iteration: input file set-up and calls model code (BathAuto)

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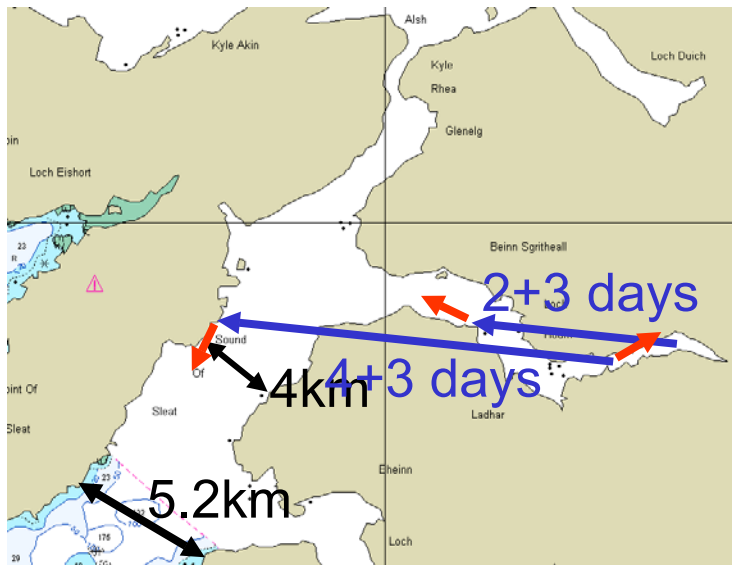
Tricky Bits I

- choosing topography - loch, strait or open?
  - determine maximum patch displacement (D)
    - residual current × run time (days to treat + 3)
    - amplitude of tidal oscillation
  - examine map/chart of site
  - where does D in residual direction put patch?



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Tricky Bits II

- how far away is the ‘head of the loch’?
  - defines distance to closed boundary
  - ‘upstream’ significant impediment to dispersion

- receiving water is littered with islands
  - may enhance dispersion due to increased shear
  - reduces available mixing area in loch/strait
  - reduce loch area or strait width $\propto$ area of islands within domain

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Reporting Results

- short-term model (3h assessment of aza. & cyp.)
  - mass of chemical
  - print-out to include: mean u, shore distance, cage vol
- long-term model (72h assessment of aza.)
  - mass of chemical
  - ‘input.dat’ file
  - area within EQS contour
  - peak concentration

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