



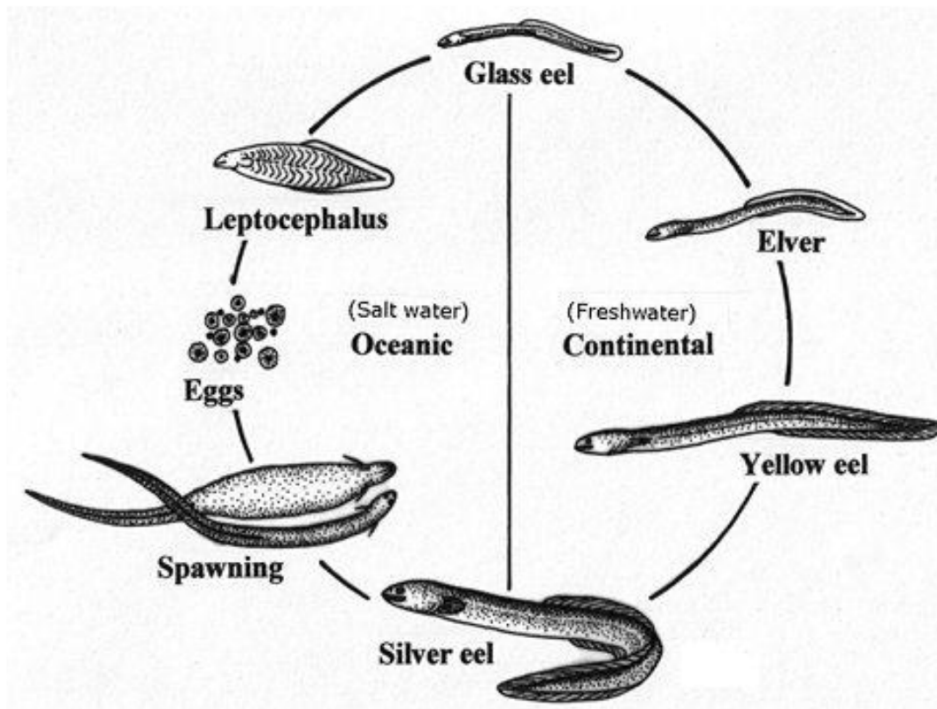
University of  
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Amherst

## **Session C5: Downstream Migration of Silver Eel (*Anguilla Anguilla*) in the River Meuse in the Netherlands 2008 – 2012**

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Rijkswaterstaat  
Ministry of Infrastructure and the  
Environment



## Downstream migration of silver eel (*Anguilla anguilla*) in the river Meuse in the Netherlands 2008 – 2012

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Commissioned by Rijkswaterstaat:  
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## Aim of the study

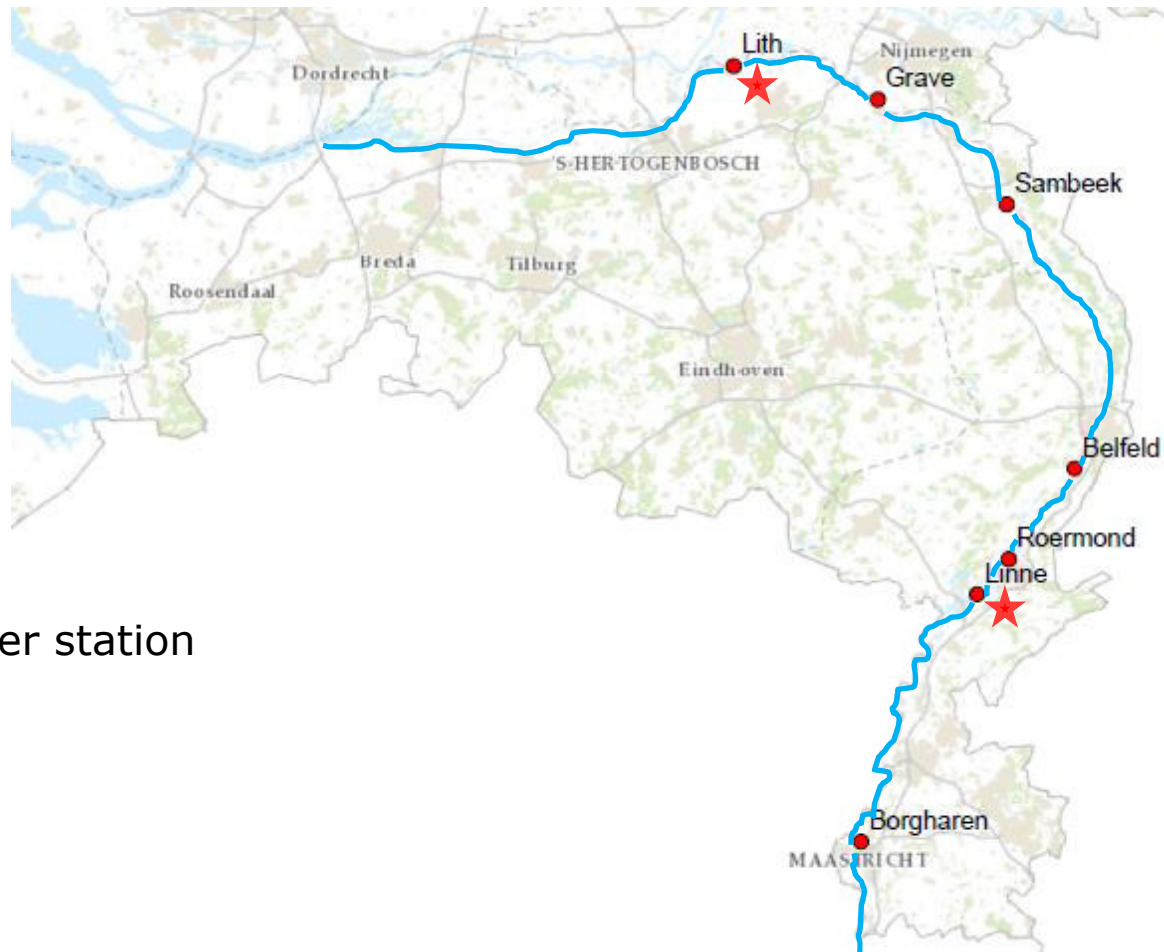
- To gain insight in silver eel migration in the river Meuse, to determine timing of migration, choice of route and migration speed of individual fishes in relation to river discharge and other factors;
- To obtain a reliable estimation of the average mortality of silver eel during downstream migration in the Dutch part of the river Meuse;
- To quantify direct en delayed mortality of silver eel passing hydropower stations and weirs in the river Meuse.

This knowledge helps to formulate suitable measures to facilitate fish migration at barriers like hydropower stations and weirs, to protect fish in general and to support decision making in the process of licencing hydropower stations.



## Weirs and hydropower stations in the river Meuse

North Sea



- ★ = hydropower station
- = weir

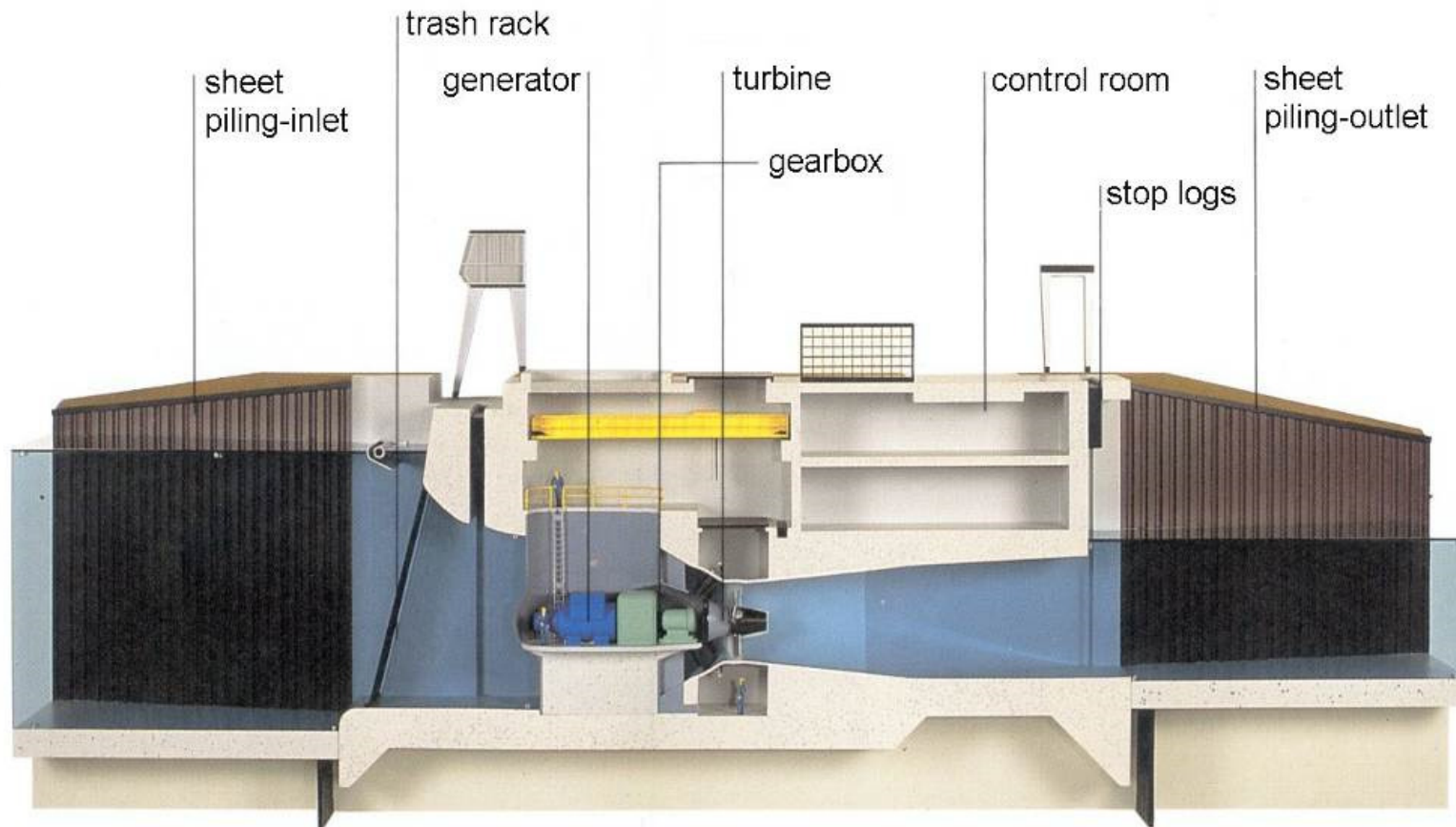


## Hydropower station Linne, weir and fish passage



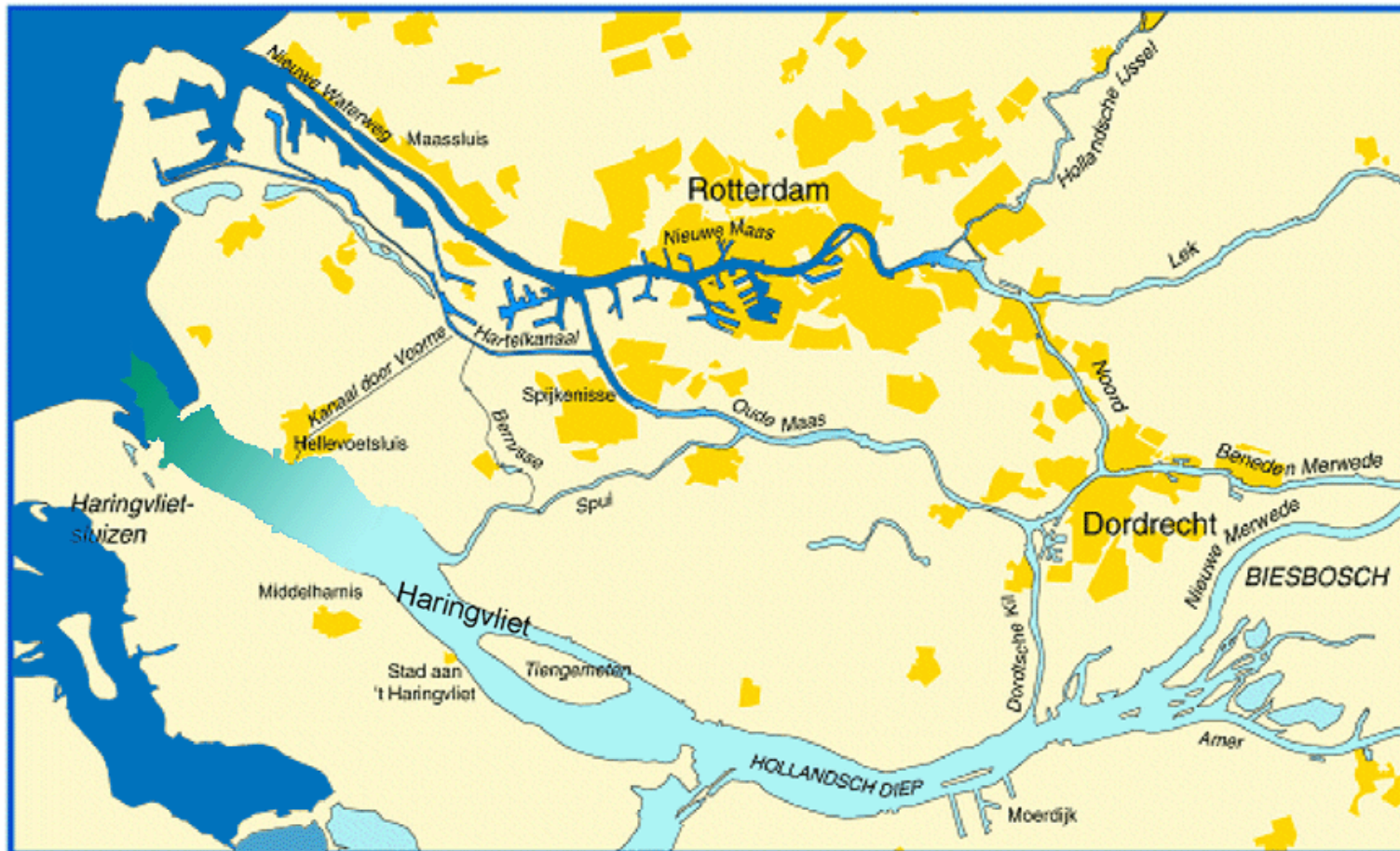


## Kaplan turbine in hydropower station Linne





## Delta area of the rivers Rhine and Meuse





## Most important barrier to fish migration: Haringvliet dam







# Sluices in the Haringvliet dam





# Implantation of a transponder in silver eel



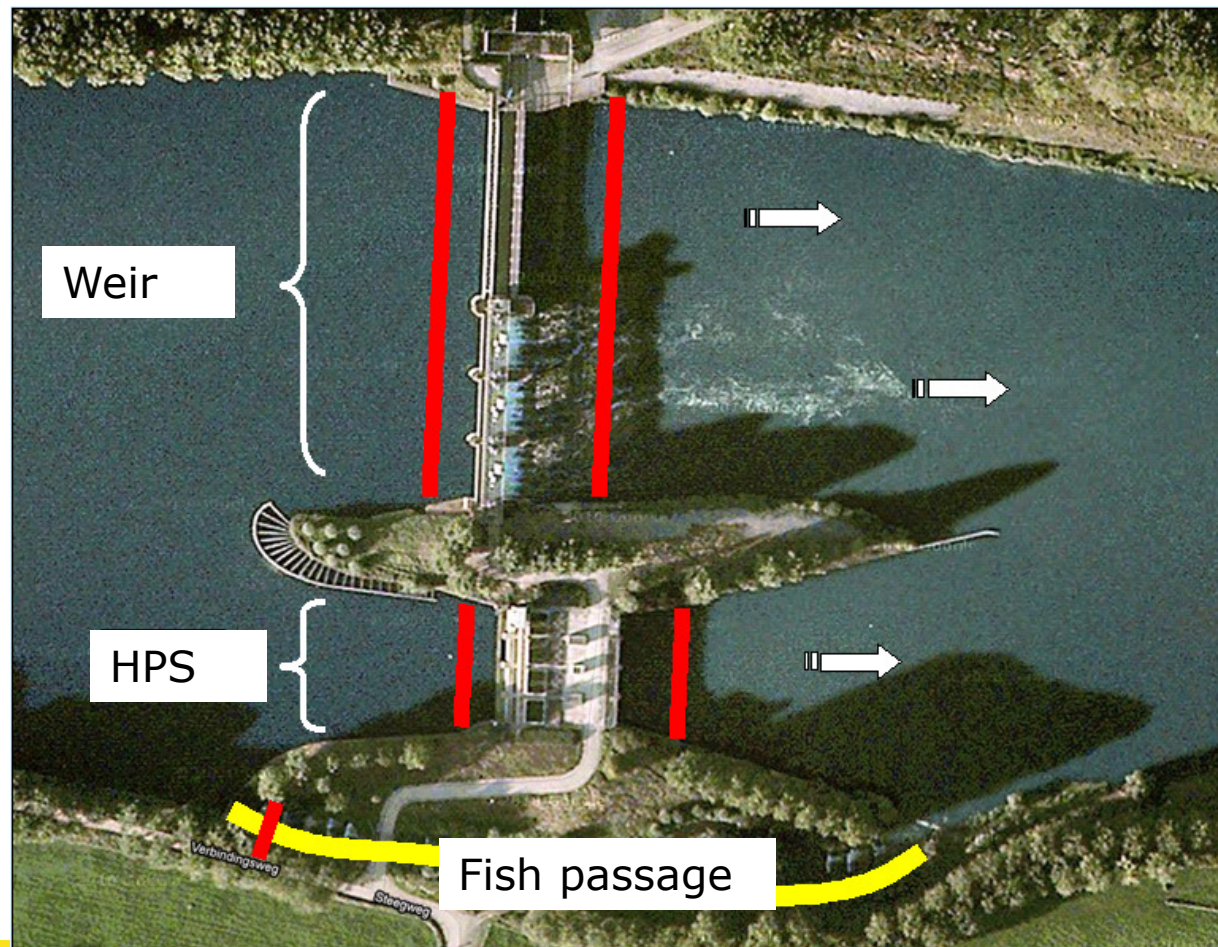


## NEDAP Trail system®: detection stations





## Detection stations at hydropower station and weir Linne





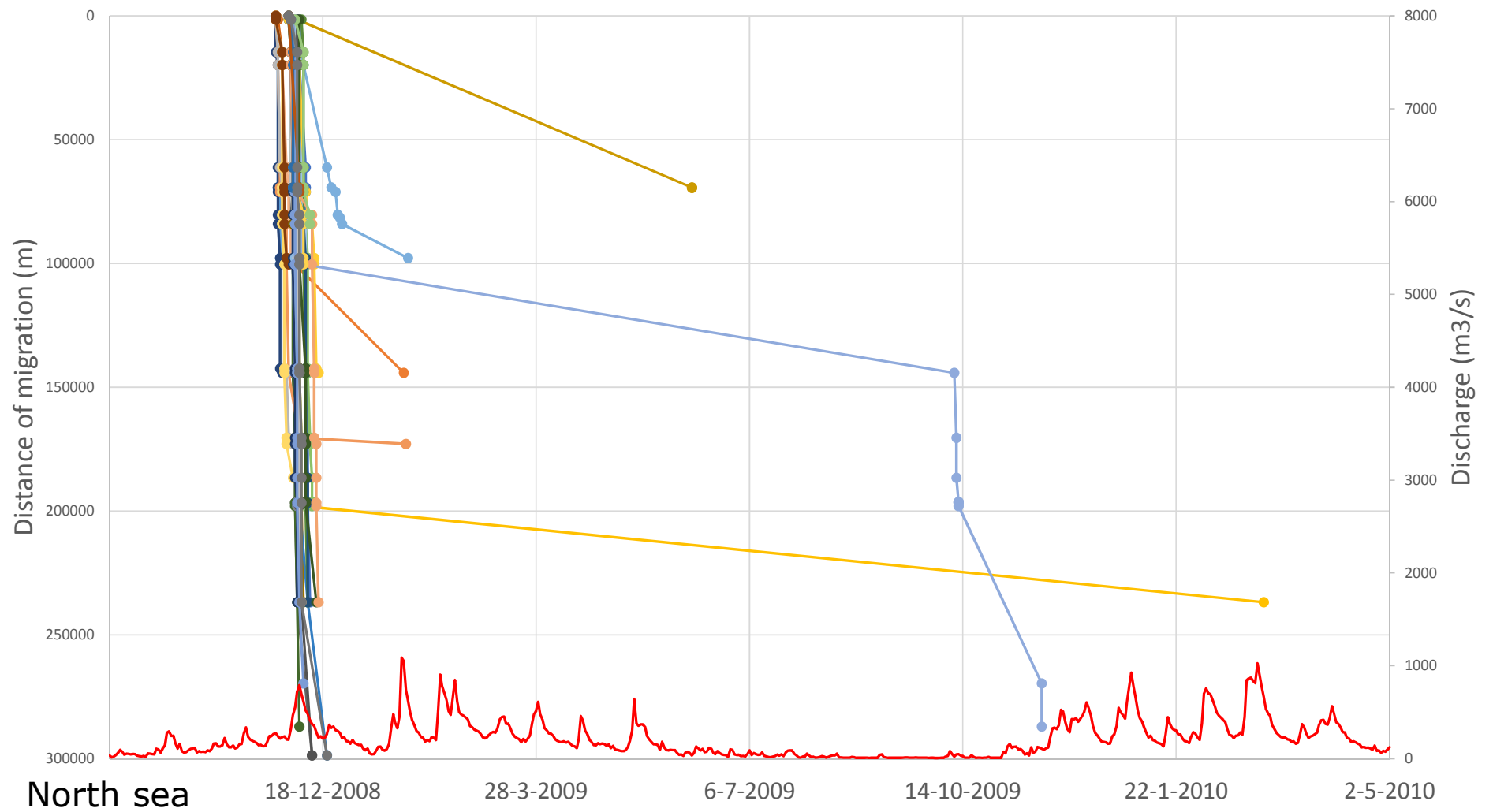
## Results silver eel migration 2008 - 2012

- In total 840 silver eels were released in late autumn (100 – 200 fish per year), on two different locations (near Belgian border and 56 km further downstream);
- 75% was detected (630 silver eels);
- At location Linne, 138 silver eels migrated through the hydropower station and 229 silver eels passed over the weir;
- In the river stretch downstream location Linne (126 km), 50% of the eel which passed through the hydropower station was lost compared to 28% of the eel which passed over the weir;
- Mortality of 'hydropower eel' was roughly twice as high compared to 'weir eel';
- Mortality of 'hydropower eel' is 0,43% per km, mortality of 'weir eel' is 0,22% per km;
- Silver eel start their downstream migration with increasing discharge on the river Meuse;
- Migration patterns of silver eel are very individual. Some eels reach the North sea (approximately 300 km) in three days. Others take months or years to migrate over this distance.



# Release location

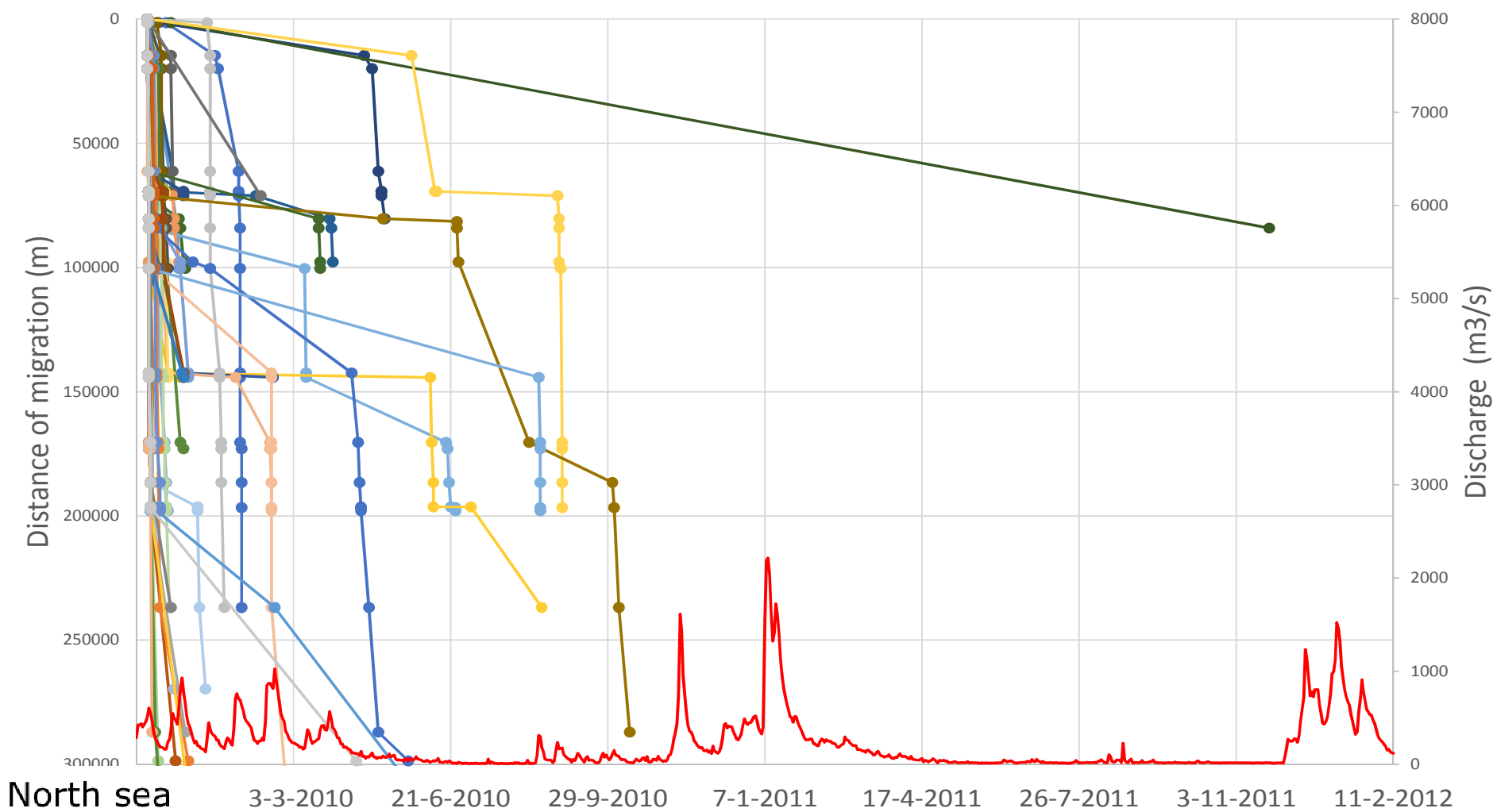
# Silver eel migration in 2008





# Release location

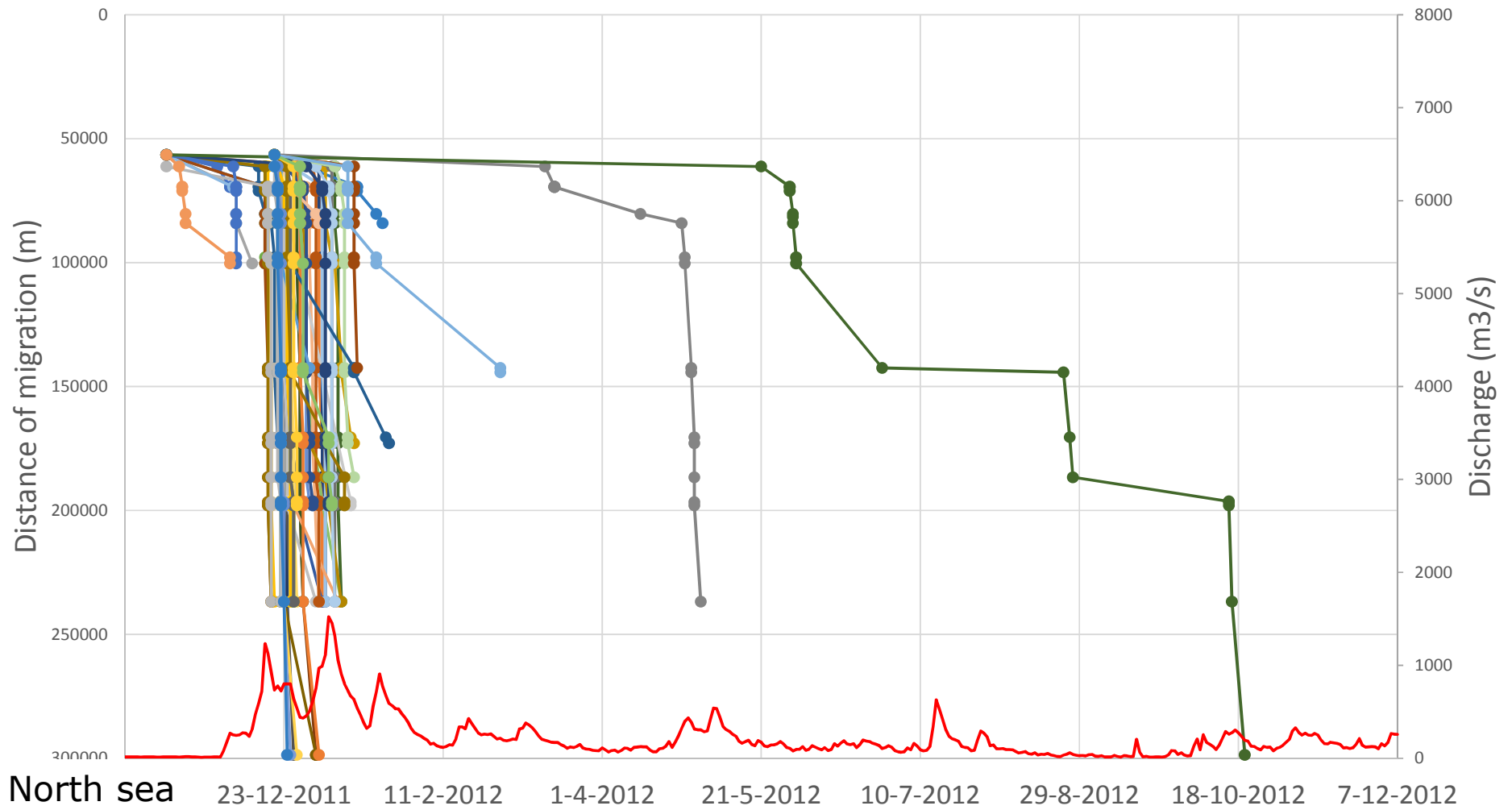
## Silver eel migration in 2009





# Release location

# Silver eel migration in 2011

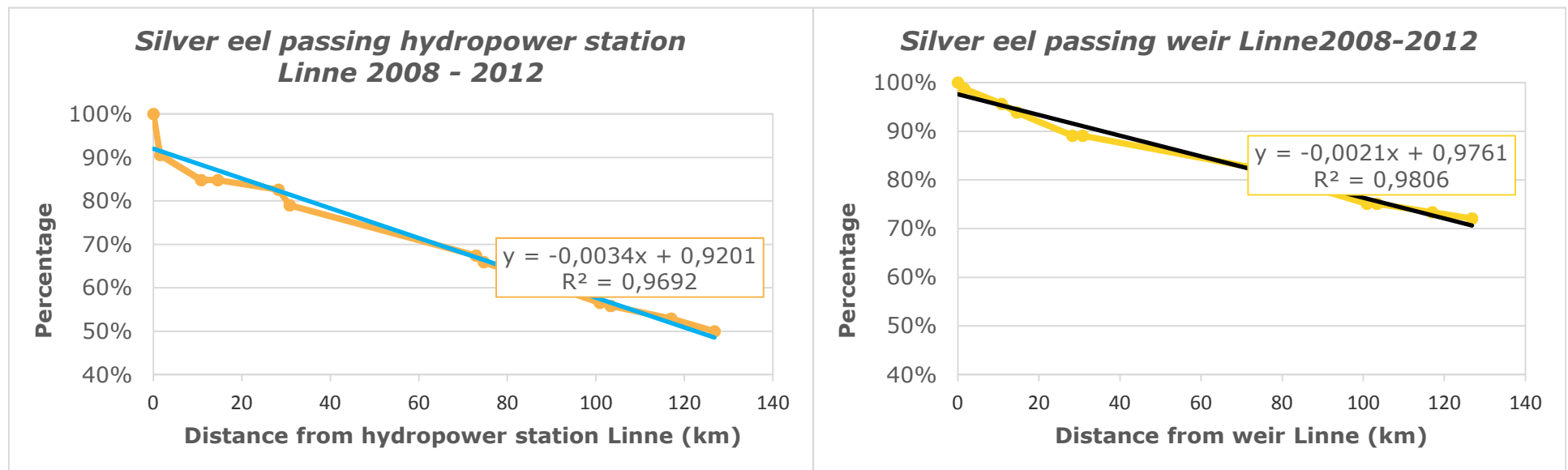






## Silver eel migration 2008 - 2012

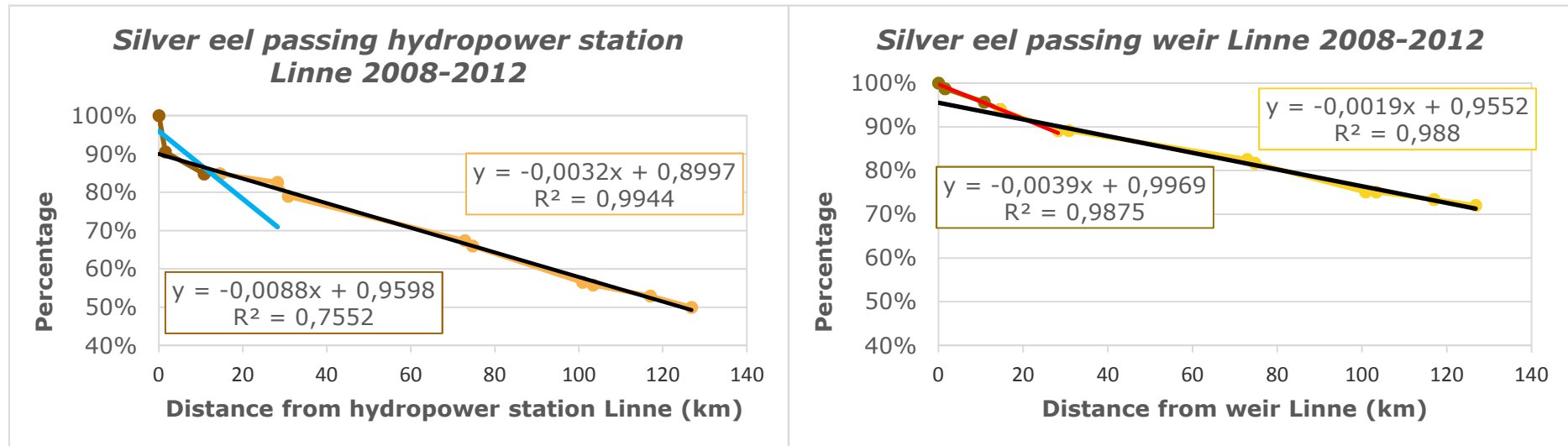
Linear regression shows significant difference in mortality rate of eels passing the hydropower station and eels passing over the weir.





## Silver eel migration 2008 - 2012

Segmented linear regression shows significant difference in mortality rates over the first stretch after passing hydropower station and weir, compared to the latter part of the route to sea.





## Silver eel migration 2008 – 2012

### Mortality per km of eel passing through hydropower station

River section				Mortality silver eel per kilometer (hydropower station)					
Nr	Start	End	distance (km)	2008-2012	2008	2009	2010	2011	2012
1	Maas_Linne_boven	Maas_Linne_beneden	0,2	<b>0,0%</b>	0,0%	0,0%	0,0%	0,0%	0,0%
2	Maas_Linne_beneden	Maas_Linne_dorp	1,5	<b>6,1%</b>	2,3%	5,0%	0,0%	21,5%	24,6%
3	Maas_Linne_dorp	Maas_Roermond_bov	9,3	<b>0,7%</b>	0,0%	0,0%	1,1%	0,0%	1,7%
4	Maas_Roermond_bov	Maas_Buggenum	3,7	<b>0,0%</b>	0,0%	0,0%	0,0%	0,0%	0,0%
5	Maas_Buggenum	Maas_Belfeld_bov	13,7	<b>0,2%</b>	0,0%	0,3%	0,1%	1,8%	0,0%
6	Maas_Belfeld_bov	Maas_Steyl	2,5	<b>1,7%</b>	0,0%	3,5%	1,6%	0,0%	3,6%
7	Maas_Steyl	Maas_Afferden	42,1	<b>0,3%</b>	0,4%	0,5%	0,2%	0,8%	0,2%
8	Maas_Afferden	Maas_Sambeek_ben_stu	1,8	<b>1,2%</b>	0,0%	0,0%	2,6%	0,0%	0,0%
9	Maas_Sambeek_ben_stu	Maas_Grave_bov	26,2	<b>0,5%</b>	0,7%	0,9%	0,5%	0,0%	0,0%
10	Maas_Grave_bov	Maas_Balgoij	2,5	<b>0,5%</b>	0,0%	3,1%	0,0%	0,0%	0,0%
11	Maas_Balgoij	Maas_Megen	13,6	<b>0,4%</b>	0,8%	0,6%	0,2%	0,0%	0,0%
12	Maas_Megen	Maas_Lith_boven	9,8	<b>0,6%</b>	0,6%	0,0%	0,6%	0,0%	1,1%
13	Maas_Lith_boven	Maas_Lith_beneden	0,3	<b>5,4%</b>	0,0%	0,0%	11,2%	0,0%	0,0%
14	Maas_Lith_beneden	Maas_Lith_dorp	1,3	<b>7,6%</b>	0,0%	20,2%	9,3%	0,0%	0,0%
15	Maas_Lith_dorp	Bergsche Maas_Capelse Veer	38,9	<b>0,4%</b>	0,2%	1,0%	0,3%	0,0%	1,0%
Totaal aantal vissen (n)				<b>138</b>	28	26	57	6	21
shaded yellow: weir present									



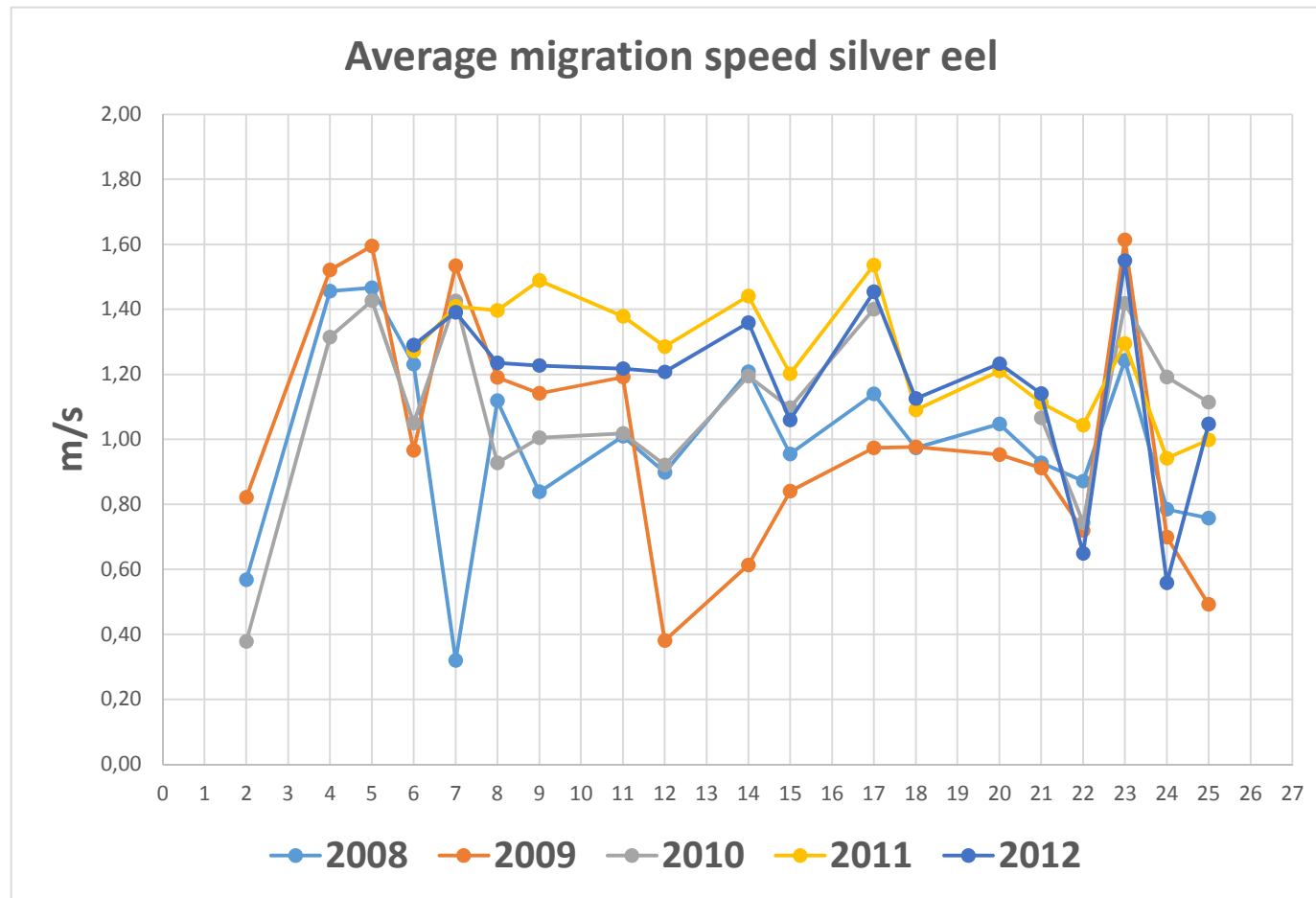
# Silver eel migration 2008 – 2012

## Mortality per km of eel passing over weir

River section				Mortality silver eel per kilometer (weir)					
Nr	Start	End	distance (km)	2008-2012	2008	2009	2010	2011	2012
1	Maas_Linne_boven	Maas_Linne_beneden	0,2	<b>0,0%</b>	0,0%	0,0%	0,0%	0,0%	0,0%
2	Maas_Linne_beneden	Maas_Linne_dorp	1,5	<b>0,8%</b>	0,0%	0,0%	1,6%	1,0%	1,0%
3	Maas_Linne_dorp	Maas_Roermond_bov	9,3	<b>0,3%</b>	0,8%	0,7%	0,3%	0,0%	0,3%
4	Maas_Roermond_bov	Maas_Buggenum	3,7	<b>0,5%</b>	0,0%	0,0%	1,4%	0,0%	0,8%
5	Maas_Buggenum	Maas_Belfeld_bov	13,7	<b>0,4%</b>	0,6%	0,5%	0,0%	0,6%	0,2%
6	Maas_Belfeld_bov	Maas_Steyl	2,5	<b>0,0%</b>	0,0%	0,0%	0,0%	0,0%	0,0%
7	Maas_Steyl	Maas_Afferden	42,1	<b>0,2%</b>	0,2%	0,3%	0,1%	0,2%	0,1%
8	Maas_Afferden	Maas_Sambeek_ben_stu	1,8	<b>0,6%</b>	0,0%	0,0%	1,6%	1,1%	0,0%
9	Maas_Sambeek_ben_stu	Maas_Grave_bov	26,2	<b>0,3%</b>	0,4%	0,4%	0,0%	0,2%	0,5%
10	Maas_Grave_bov	Maas_Balgoij	2,5	<b>0,0%</b>	0,0%	0,0%	0,0%	0,0%	0,0%
11	Maas_Balgoij	Maas_Megen	13,6	<b>0,2%</b>	0,0%	0,0%	0,0%	0,3%	0,3%
12	Maas_Megen	Maas_Lith_boven	9,8	<b>0,2%</b>	0,0%	0,3%	0,3%	0,2%	0,0%
13	Maas_Lith_boven	Maas_Lith_beneden	0,3	<b>4,5%</b>	0,0%	11,9%	0,0%	0,0%	7,9%
14	Maas_Lith_beneden	Maas_Lith_dorp	1,3	<b>5,5%</b>	0,0%	22,2%	4,5%	1,6%	0,0%
15	Maas_Lith_dorp	Bergsche Maas_Capelse Veer	38,9	<b>0,4%</b>	0,3%	1,0%	0,3%	0,3%	0,3%
Totaal aantal vissen (n)				<b>229</b>	13	48	40	62	66
shaded yellow: weir present									



## Silver eel migration 2008 – 2012





## Silver eel migration 2008 – 2012, migration speed

- Large individual differences, seaward migration (more than 300 km) in 3 days versus step wise migration over a period of 2 years;
- But, when averaging migration speed over the whole group per year, the results are astonishingly similar:

2008: 0,99 m/s;

2009: 1,00 m/s;

2010: 0,98 m/s;


2011: 1,06 m/s;

2012: 0,99 m/s.

- Maximum ground speed over longer distance: 2,5 m/s;
- No relation between swimming speed and distance travelled;
- No difference in migration activity during day or night by number of detections (day average 49%, night average 51% detections);
- Very slight preference for migration during early daytime and night time hours.



## Silver eel migration 2008 – 2012, other conclusions

- Escapement to sea is very low: 2008: 4%;  
2009: 4%;  
2010: 3%;  
2011: 1%;  
2012: 7%.
- Eel fishing ban (since 2010) does not lead to increase of escapement;
- Most eels choose Haringvliet as a route to sea, not Nieuwe Waterweg (discharge related);
- Near hydropower stations and weirs migration speed decreases  delay;
- Mortality after passage of hydropower station is twice as high;
- Onset of migration is related to sharp increase of discharge;
- Migration speed is significantly related to river discharge, predictive value is low;
- No (significant) relation between migration speed/distance and
  - 1) fish length, 2) fish weight 3) condition 4) stage of maturation
  - 5) water temperature and 6) oxygen content.



Thanks for your attention!

