Short Term HAB forecasting in a Changing Environment

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Marine Institute
Ireland

Short Term HAB forecasting:

OBSERVATIONS

UNDERSTANDING

PREDICTIVE

Key elements of HABs monitoring and observations

Developing approaches for minimising their negative impacts

Monitoring Programmes

- Phytoplankton
- Toxin Analysis

Satellites

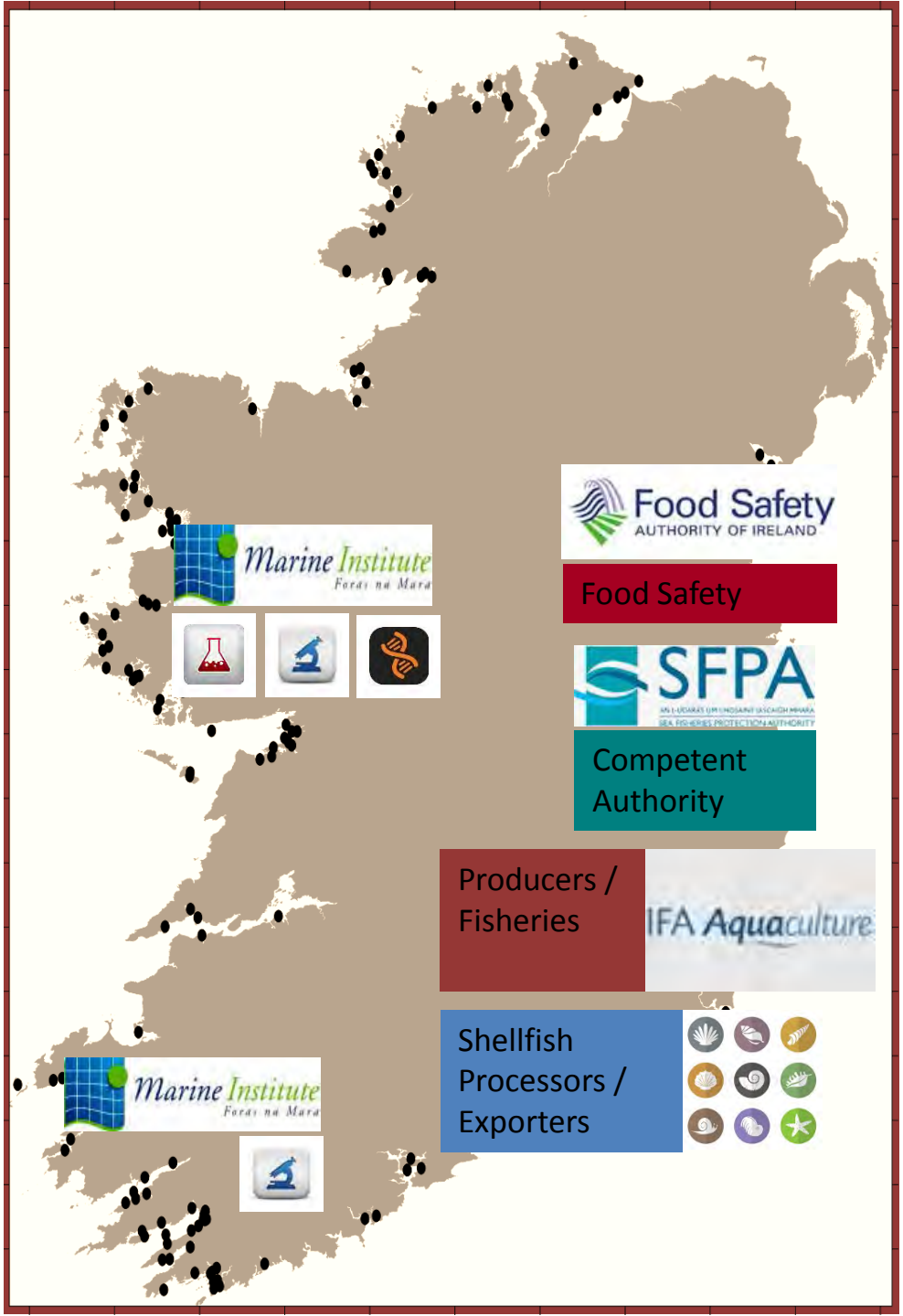
- SST
- Ocean Colour

Models

- Particle Tracking
- Biological behaviour

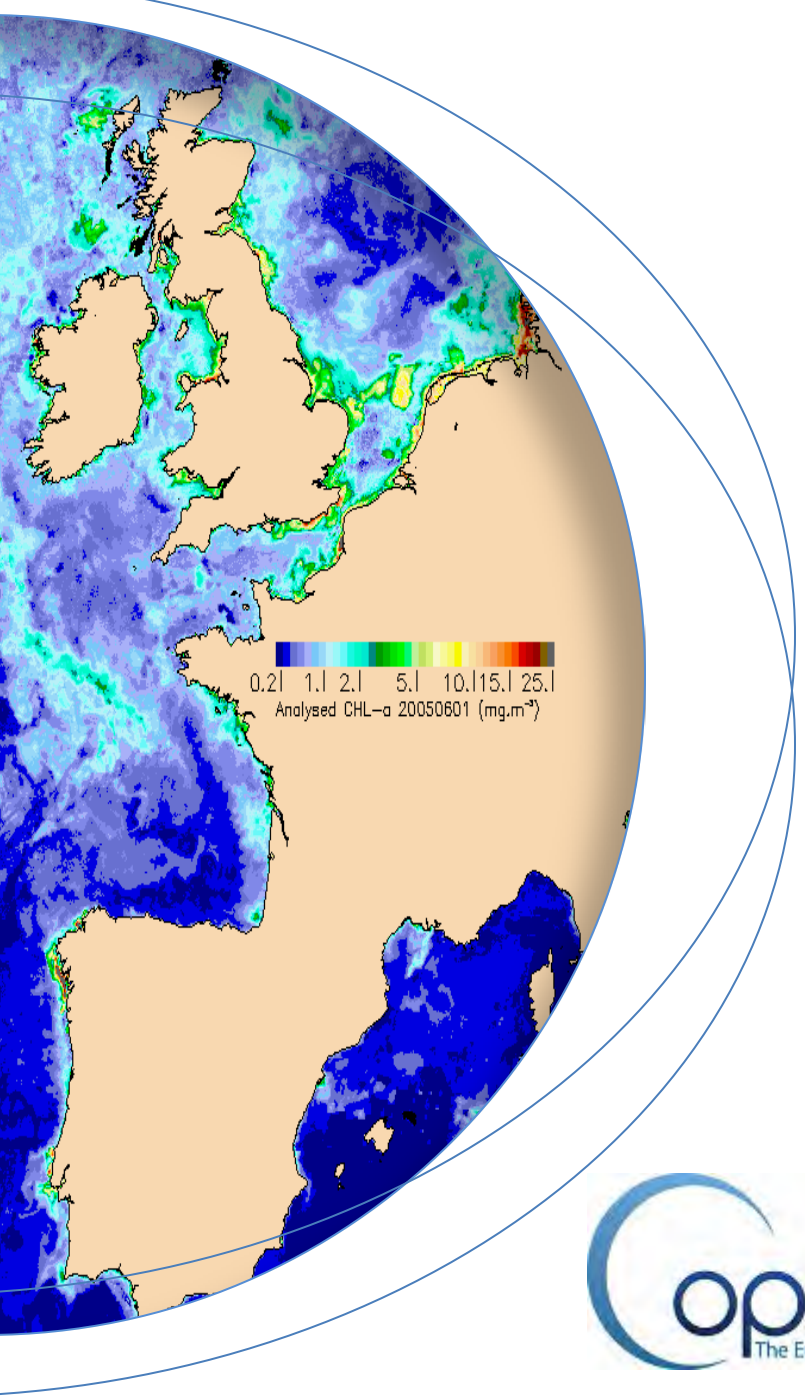
History

- Bay Profiles
- Previous patterns



Monitoring Network

- >90 Sample Locations
- 2 Phytoplankton labs
  1LCMS/HPLC Toxin Lab
  1 Molecular Lab
- Central Database located in MI Galway
- Report of these results compiled at MI
- Toxins / Phyto reports issued by E-Mail Website & SMS
- ~95% results reported within 3 working days



OBJECTIVE

A Copernicus downstream service to the European Aquaculture Industry

The delivery of a 3-4 day Harmful Algal Bloom forecast for the aquaculture industry situated along Europe's Atlantic margin

Copernicus
The European Earth Observation Programme

Copernicus masters
the European Earth Monitoring Competition

Why develop a HAB alert system?

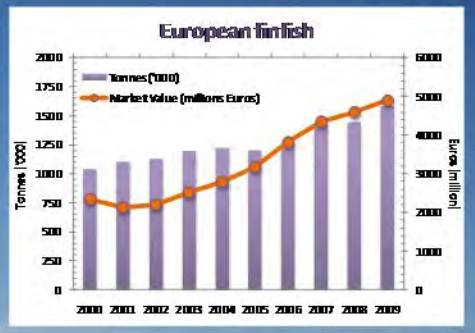
European Aquaculture Production

10 year period (2000 – 2009)

Finfish farming:

Production - increase with time

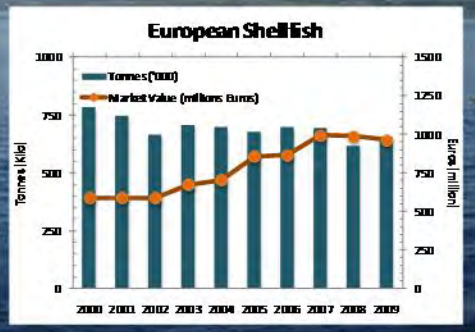
Market value - increased significantly



Shellfish farming:

Production - relatively stable

Market value - increased significantly

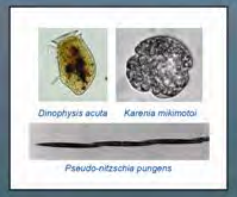


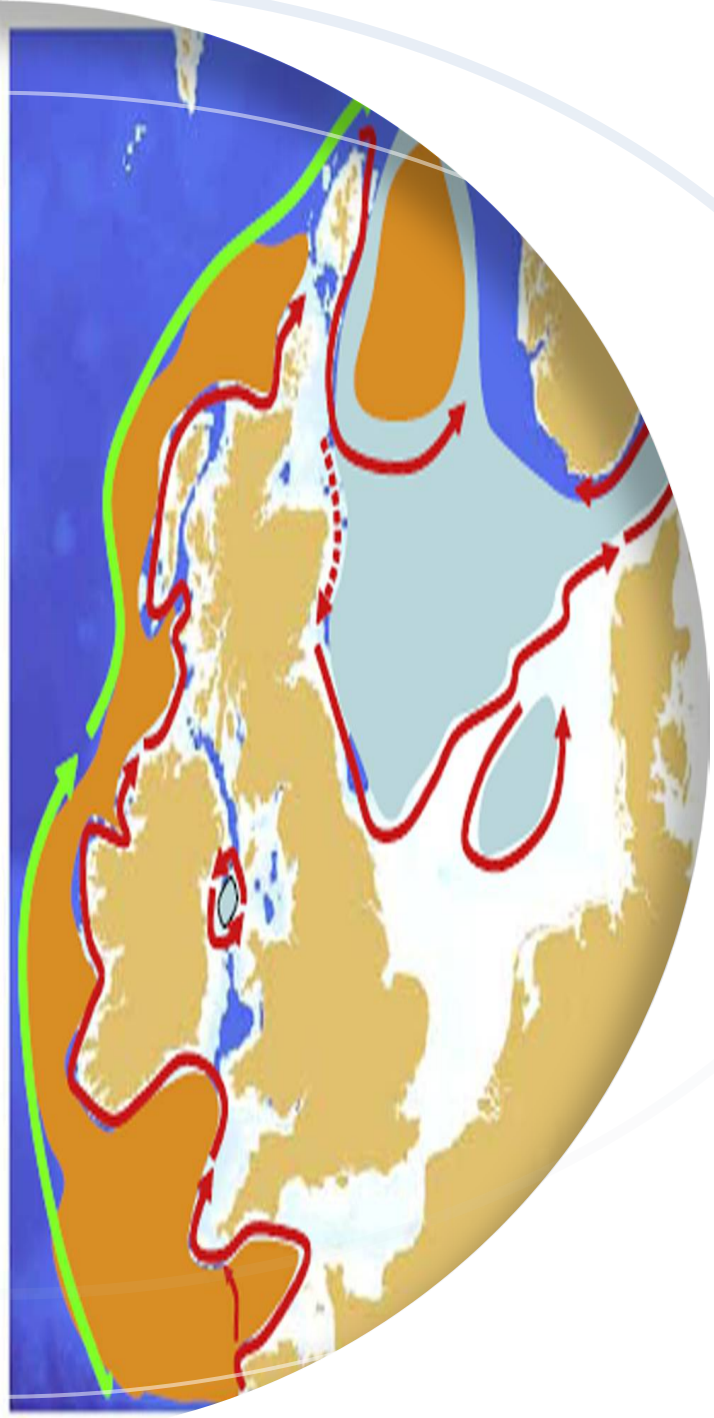
Data source: FishStat http://www.fao.org/fishery/statistics/software/fishstat/en
Food and Agriculture Organization of the United Nations

Why develop a HAB alert system?

Harmful and Toxic Algal Blooms

High biomass blooms	Low biomass blooms
1. Characteristics **sporadic**	1. Characteristics **unpredictable**
2. Impact **fish mortalities**	2. Impact **seriously disrupt production plans**
3. Consequences **waste disposal of fish**	3. Consequences **prolonged bay closures**



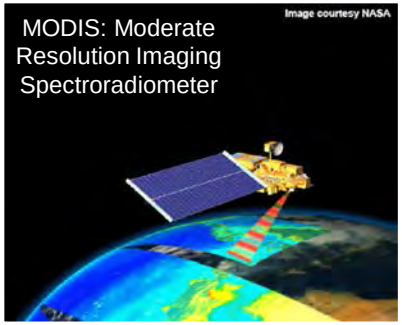


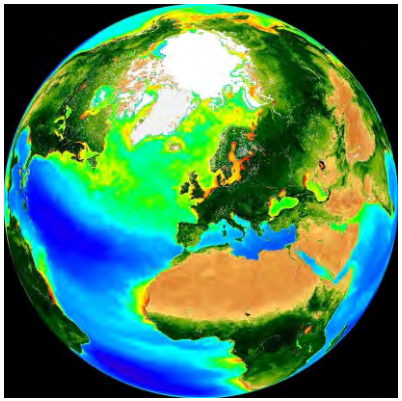
How?
An integrated approach

1. A HAB forecast system requires co-operation of **scientists in collaboration with policy makers and stakeholders**
2. Knowledge of regional physical processes and HAB dynamics (**OCEANOGRAPHERS**)
3. Select test sites where a good datasets of HABs has been established (**NMP**)
4. Select target HAB species to model (**BIOLOGISTS**)
5. Use all available existing resources e.g. NMP, satellite, observational and simulated data (**OBSERVATIONAL PROGRAMMES**)
6. Develop model(s) using historical data, validate and fine tune the model based on the outcome (**MODELLERS**)
7. When happy with results move on to nowcasting and forecasting (**EXPERT OPINION / COMMUNICATIONS**)

Tools used in the HAB alert system

Image of the real-time data buoy just deployed in a bay SW Ireland



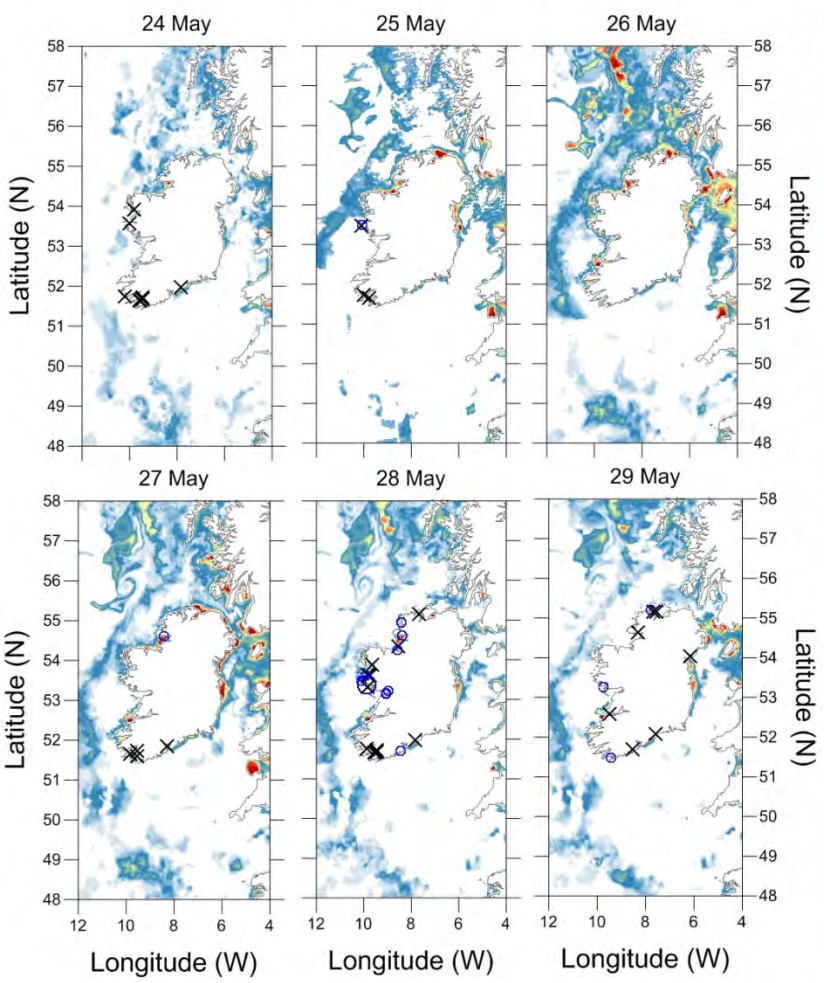


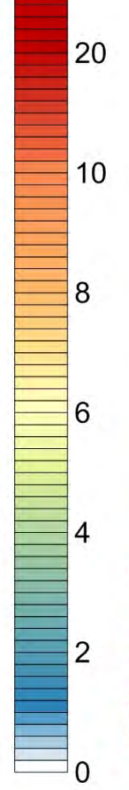
Nowcasting

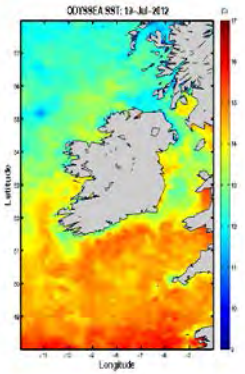
1. databuoys
2. satellite imagery

Tools used in the HAB alert system

Chlorophyll anaomaly tool







Karenia mikimotoi (cells/L)

- × = 0
- >= 40 to < 5,000
- >= 5,000 to < 20,000
- >= 20,000 to < 100,000
- >= 100,000 to < 500,000
- >= 500,000 to < 1,000,000
- >= 1,000,000 to < 3,000,000
- >= 3,000,000 to < 10,000,000

Tools used in the HAB alert system

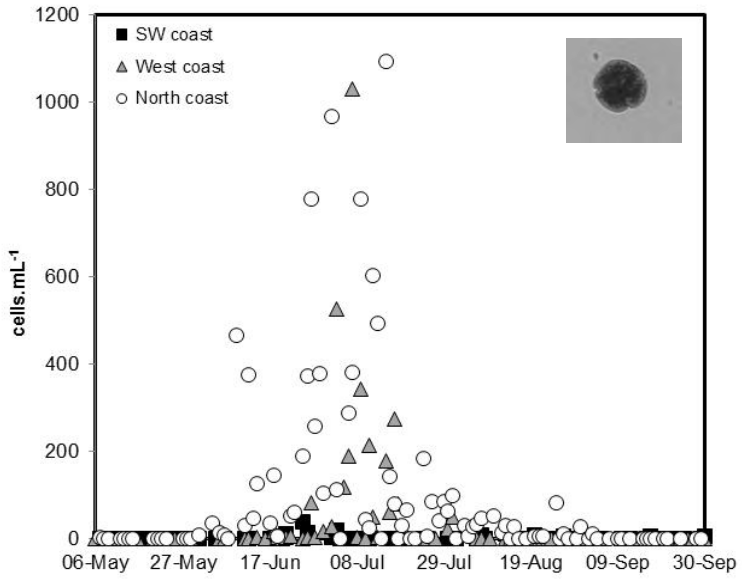
Nowcasting

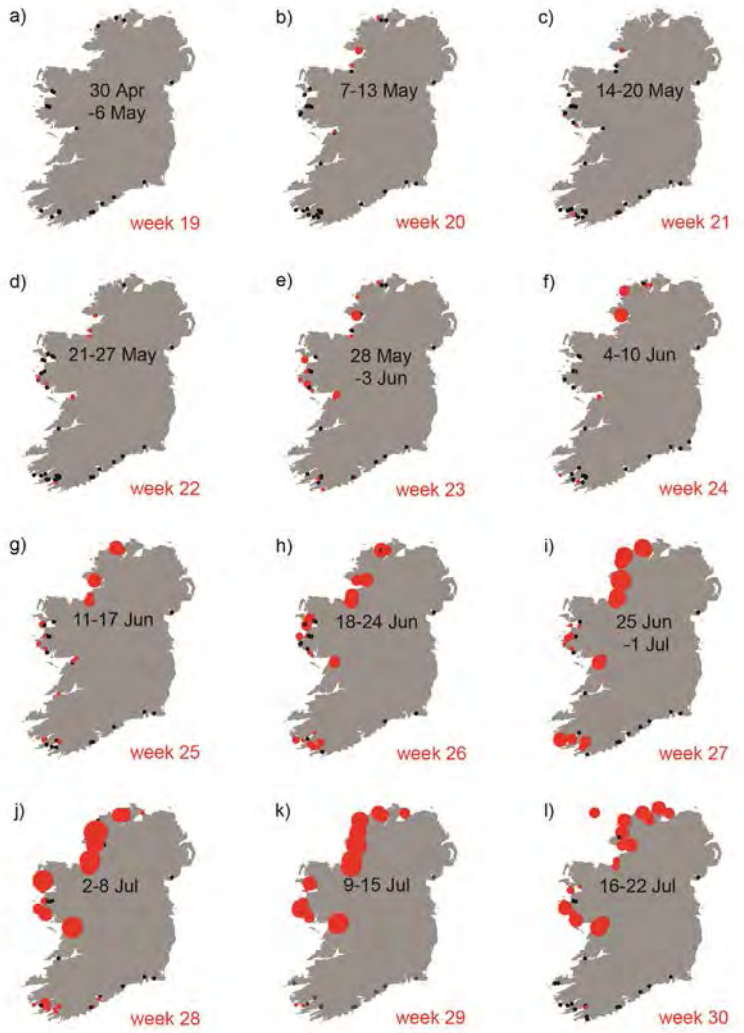
1. databuoys
2. satellite imagery
3. NMP data (HABs & biotoxins)

Tools used in the HAB alert system

Nowcasting: NMP HABs

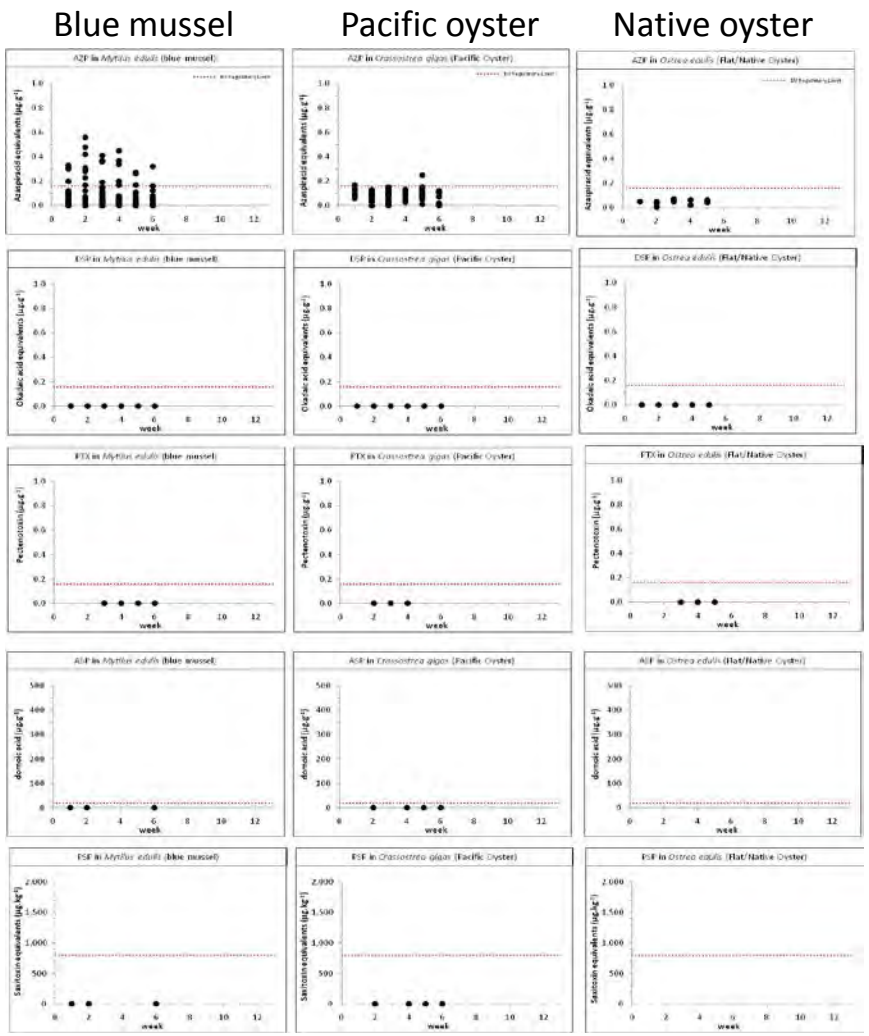
Karenia mikimotoi cell densities at Irish aquaculture sites.





Tools used in the HAB alert system

Nowcasting: biotoxins



AZP

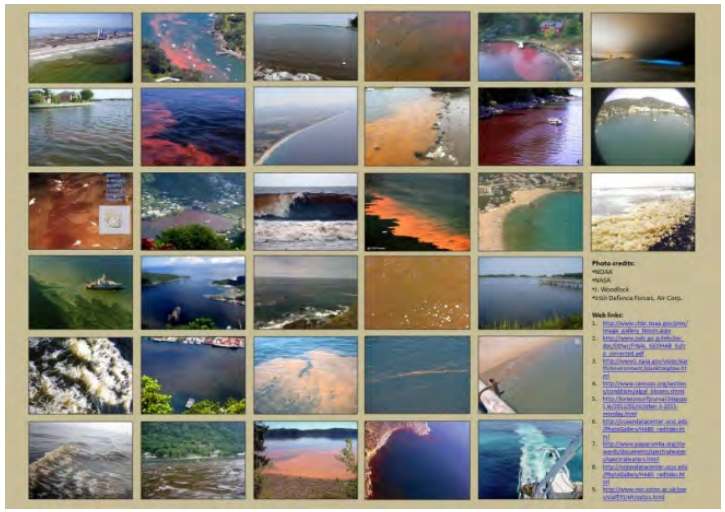
DSP

PTX

ASP

PSP

Tools used in the HAB alert system



Nowcasting

1. databuoys
2. satellite imagery
3. NMP data (HABs & biotoxins)
4. surveillance on the ground
   - Irish Coast Guard: samples, images, video
   - Navy: samples
   - Air corp.: images

Tools used in the HAB alert system

Phytoplankton sampler

Irish Coast Guard

Coast Guard Units

[54 are crewed by 950 volunteers]

Collaboration with 5 key located bases

- 1 x south: OLD HD. KINSALE, Co. Cork
- 2 x southwest: GOLEEN and TOE HEAD, Co. Cork
- 1 x west: CLEGGAN, Co. Galway
- 1 x north: MULROY, Co. Donegal

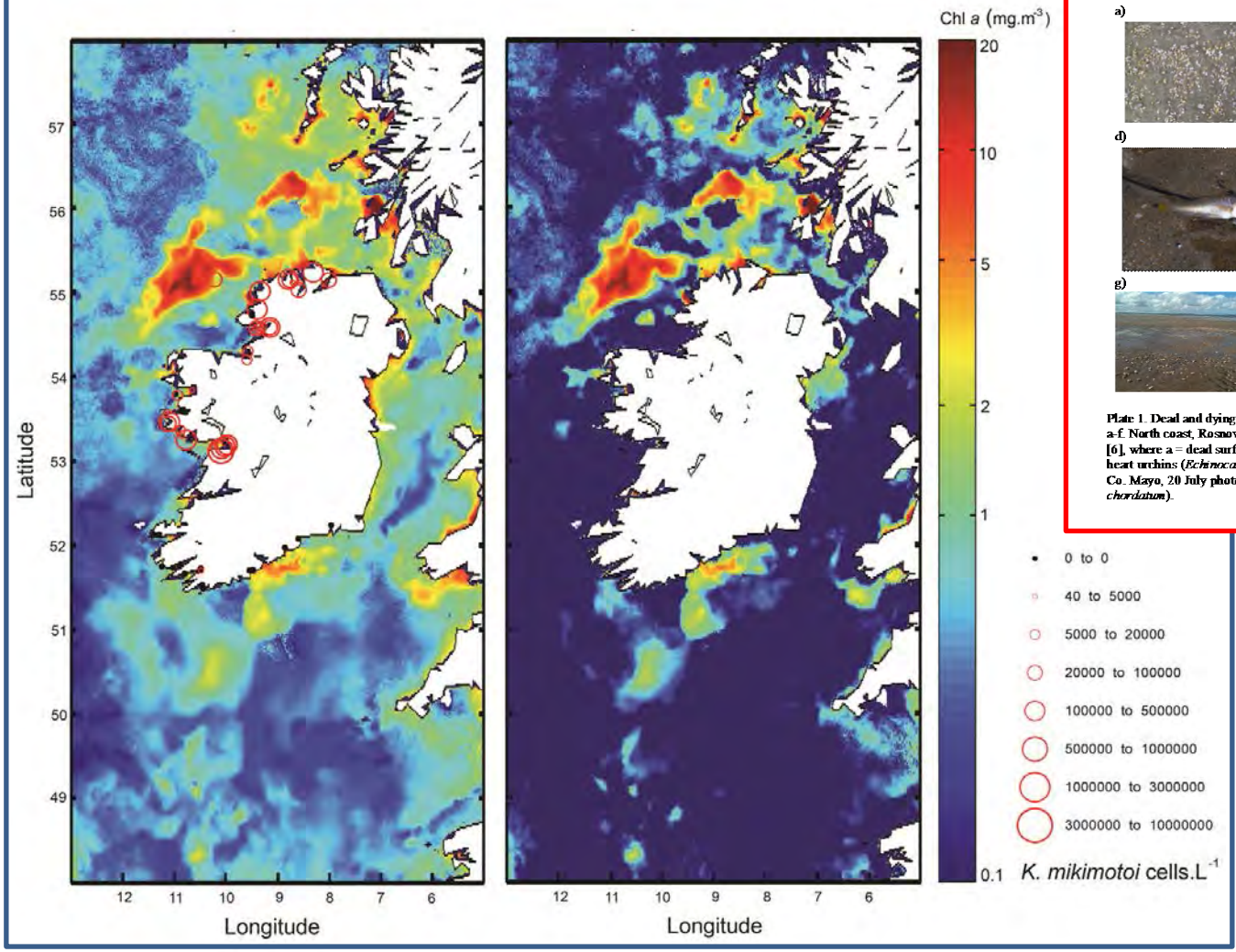
4 x Helicopters on contract from C.H.C. Ireland Ltd.

- 4 aircraft (Sligo, Shannon, Dublin and Waterford airports); two types of Sikorsky helicopters

Irish Coast Guard
GARDA CÓSTA na hÉIREANN

Nowcasting

Example of the importance of the Coast Guard collaboration 2012 high biomass bloom of *Karenia mikimotoi* …



Impact of bloom onshore

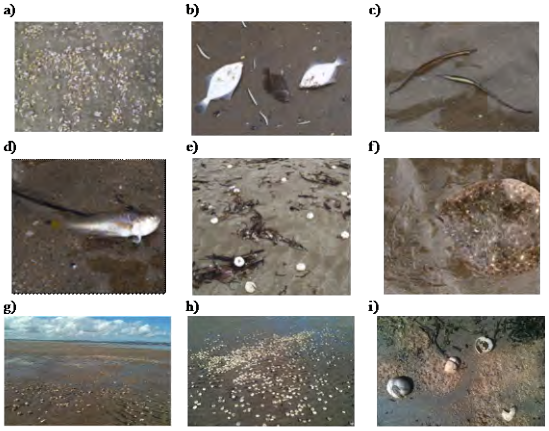
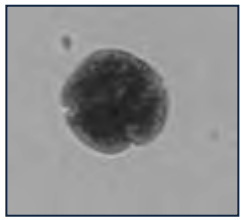


Plate 1. Dead and dying marine life, Atlantic coastline 2012.
a-f. North coast, Rosnowlagh beach, Co. Donegal photos courtesy of johnwest, Sea-Angling-Ireland [6], where a = dead surf clams; b = Sea-sticklebacks; c = Small-weever; d = dying turbot; e = dead heart urchins (*Echinocardium cordatum*) and f = dying flounder. g-i. West coast, Enniscrone beach, Co. Mayo, 20 July photos courtesy of B. Kennedy (EPA). g-i = dead heart urchins (*Echinocardium cordatum*).



Distribution of daily surface chlorophyll *a* and *Karenia mikimotoi* cell concentrations in waters around Ireland, 19 July 2012. An IRCG surface sample confirmed predominance of *Karenia mikimotoi* at the periphery of the high chlorophyll signature off NW coast.

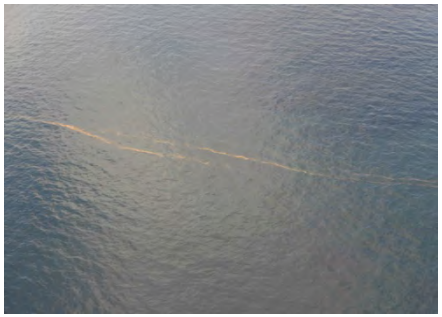
Tools used in the HAB alert system

CASA CN235

Irish Defence Forces

Naval Service:
- 8 ships

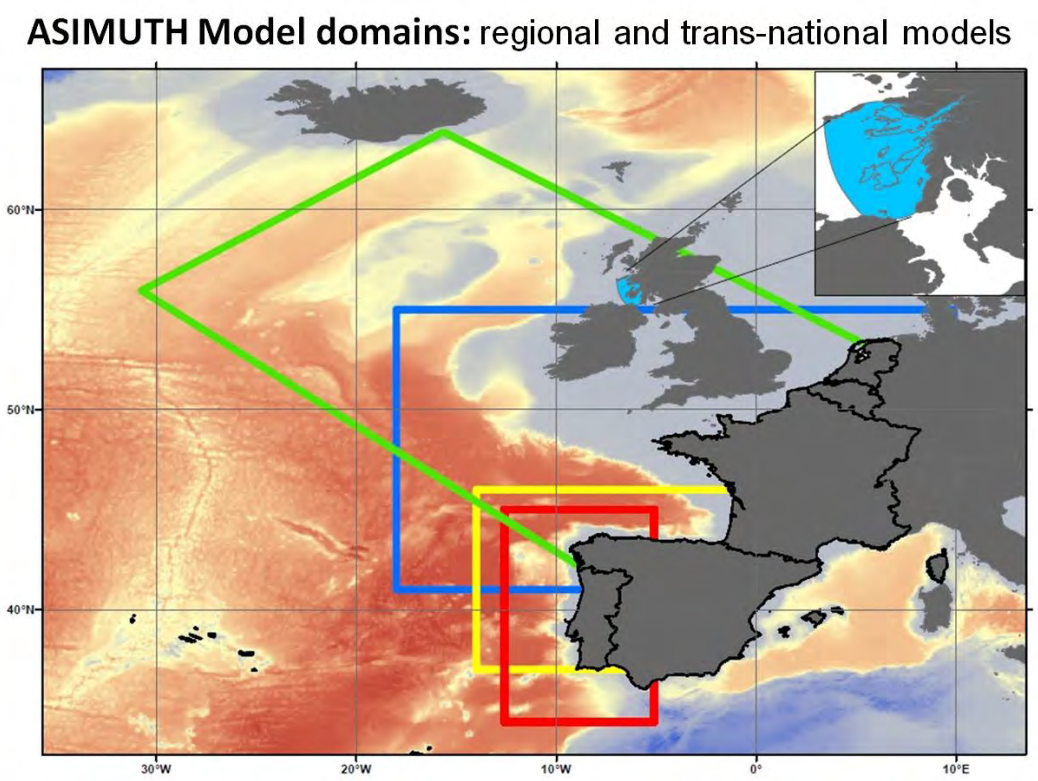
Air Corp
- 6 helicopters
- 17 other aircraft



Images taken by Air Corp off NW coast in July 2012
No sample: looks like *Noctilluca scintillans* ?

Nowcasting

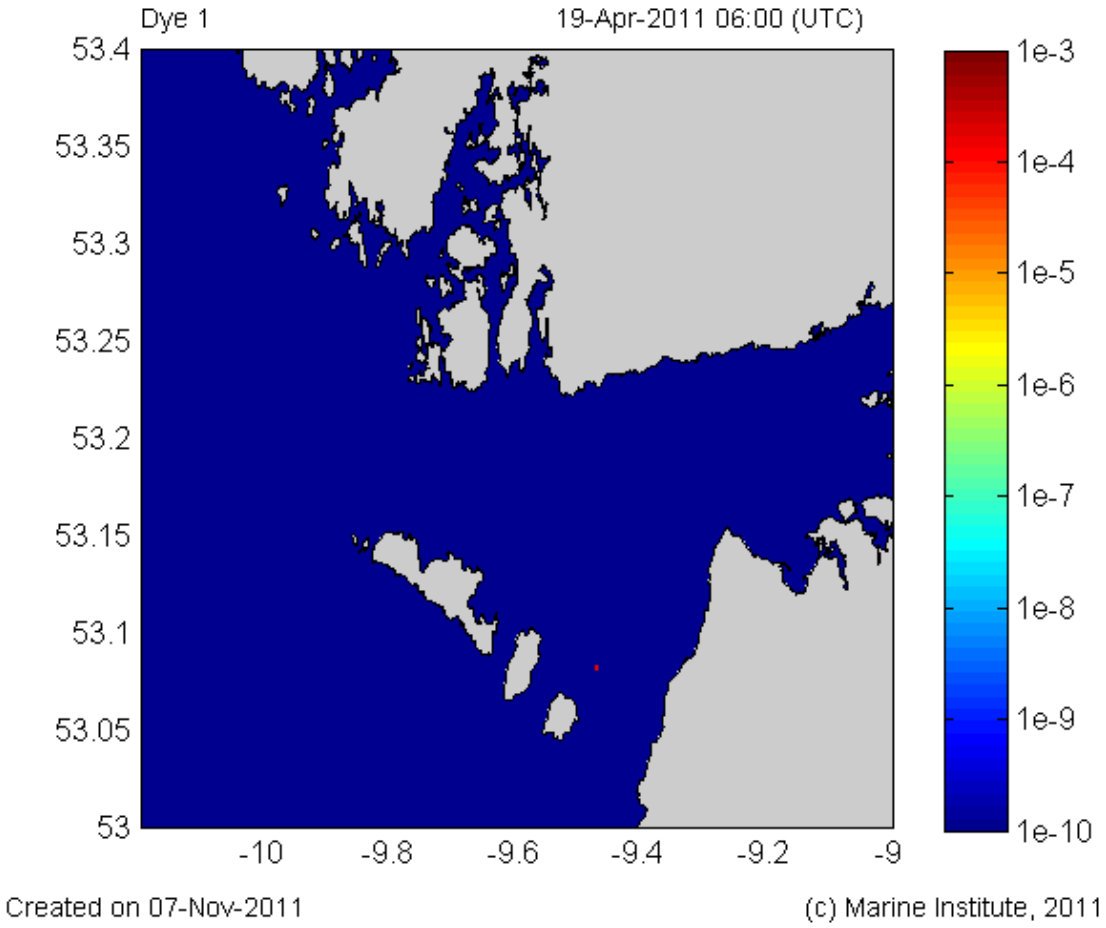
Tools used in the HAB alert system



Forecasting

1. Langrangian models
2. Eularian models
3. IBM

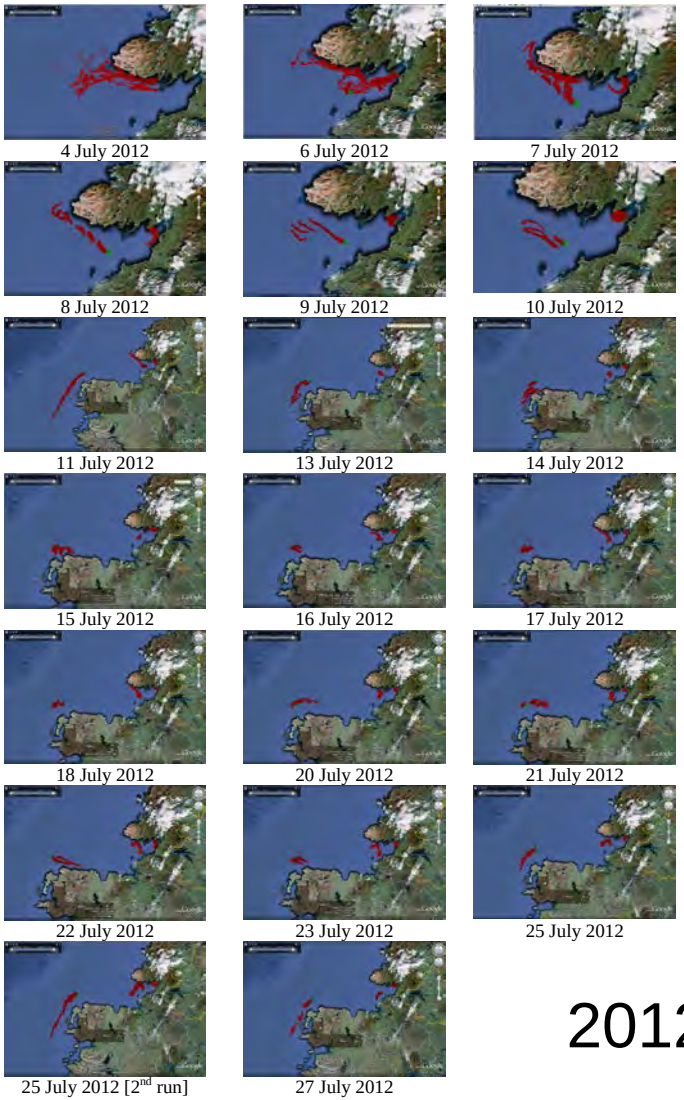
Tools used in the HAB alert system



Forecasting

MI example: langrangian model

Tools used in the HAB alert system

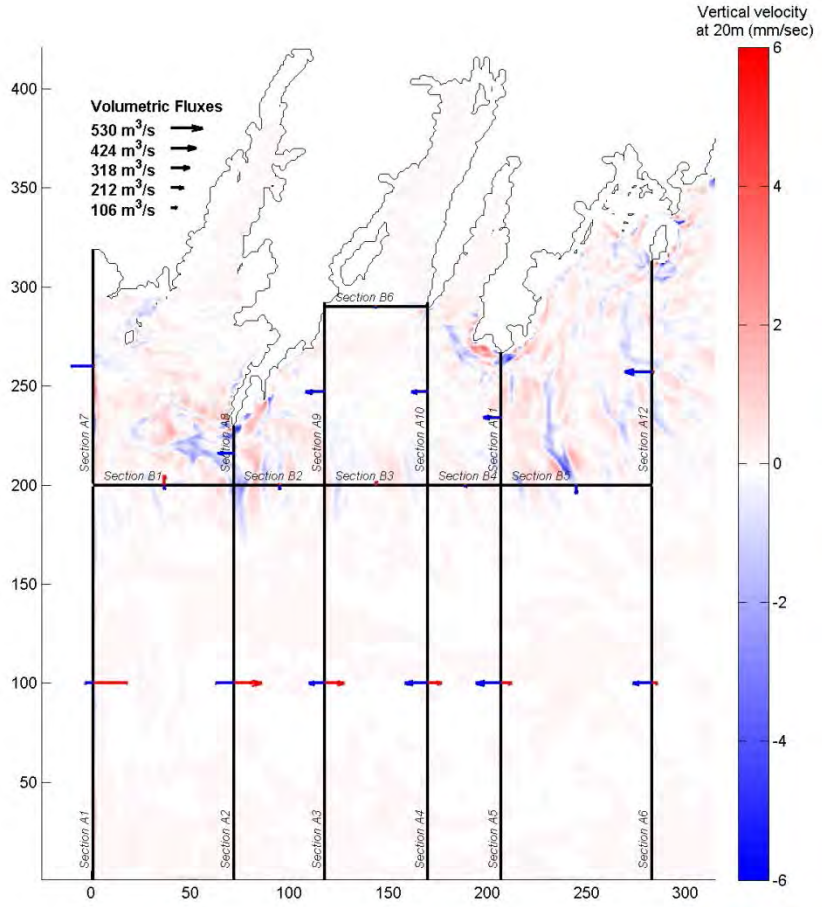


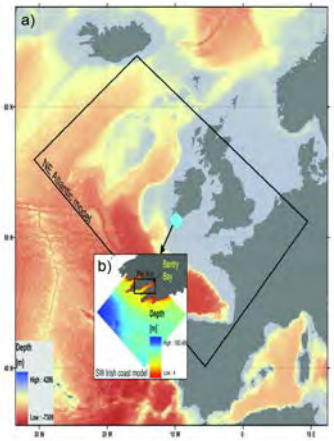
Langrangian model used during 2012 *Karenia* bloom

Three day forecast trajectories of ROMS virtual particles displayed on Google Earth, July 2012. Green filled circle denote the starting point, red filled circles the physically forced particle dispersion from the point of origin over a 3-day period. Date below each forecast represent the start date.

2012 Irish ASIMUTH field campaign

Tools used in the HAB alert system



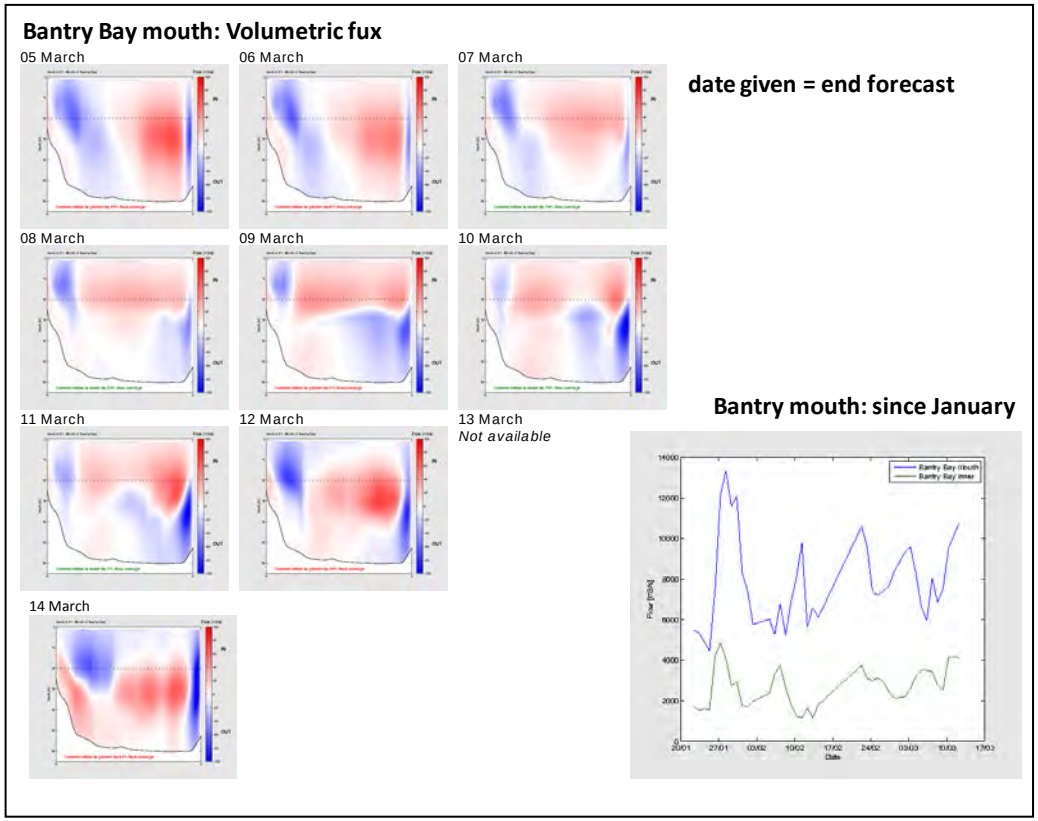


Volumetric fluxes through various sections of BANTRY_ROMS model domain.
red = upwelling, blue = downwelling events.

Forecasting

1. Volumetric Fluxes

Tools used in the HAB alert system

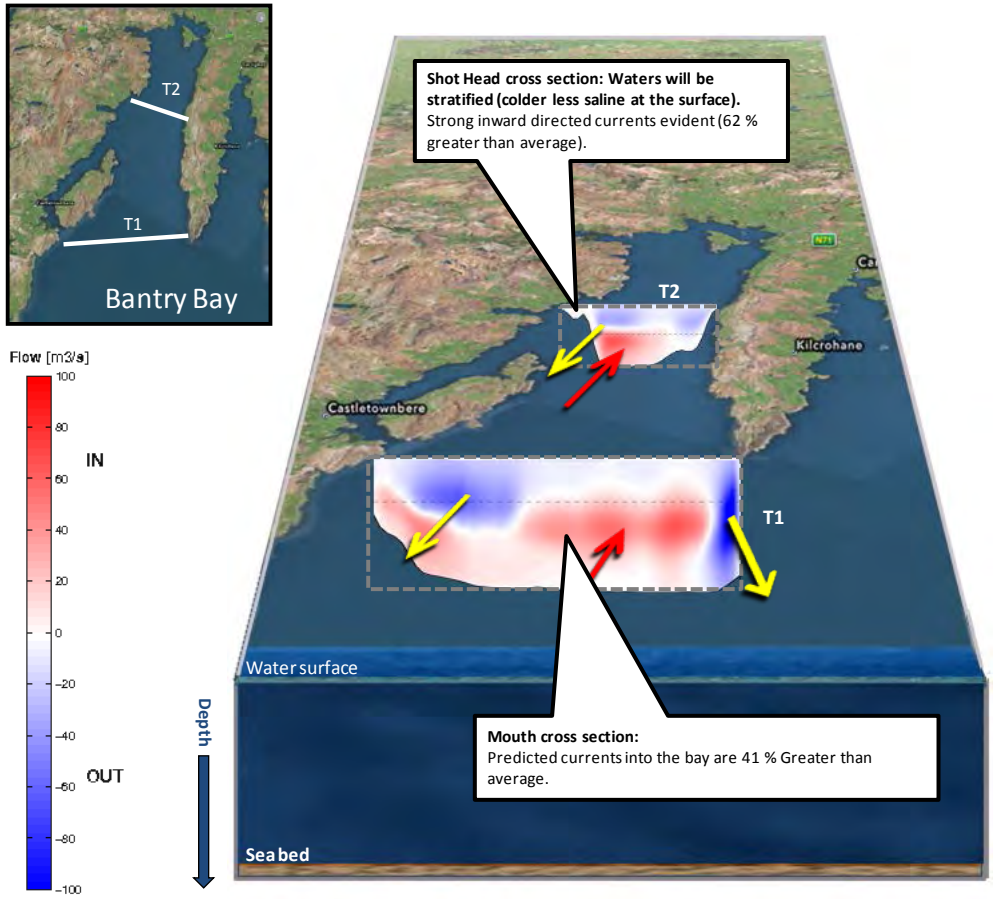


Vertical sections through a transect at the entrance to Bantry showing tidally-averaged volumetric fluxes. Currents entering the bay are shown in red, outward currents are blue

Forecasting

1. Volumetric Fluxes

Model output tools developed



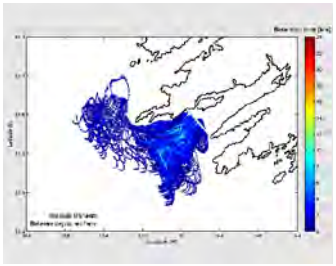
Week 10: 5 March – 11 March, 2013

Forecasting

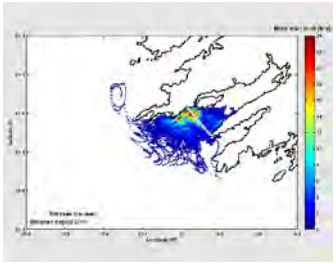
1. Volumetric Fluxes

Model output tools developed

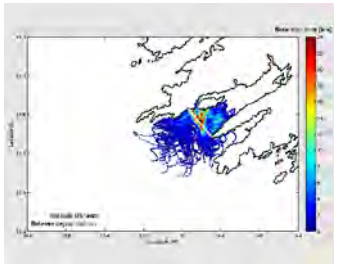
Bantry mouth: end forecast at 14_03_2013-0000hrs



Surface

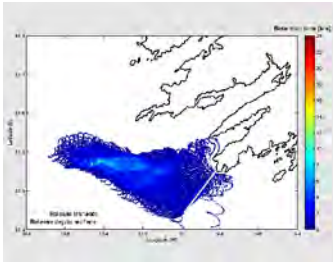


20 metres

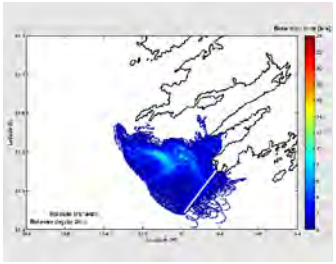


Bottom

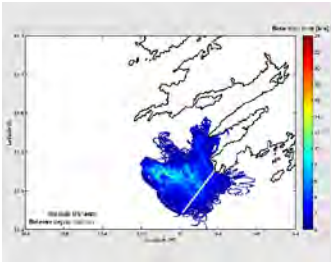
Mizen Head: end forecast at 14_03_2013-0000hrs



Surface



20 metres



Bottom

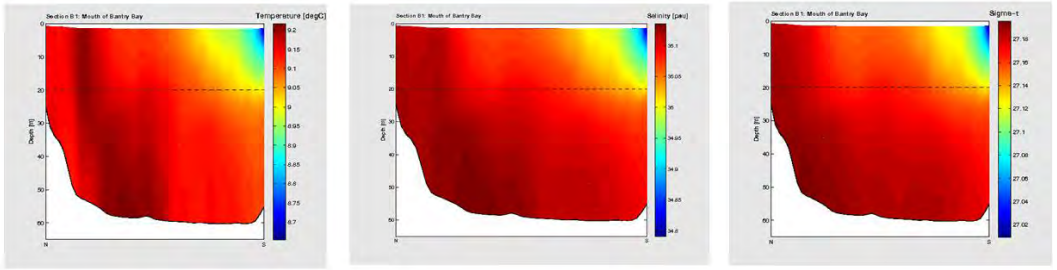
Spatial distribution of particle-hours following the release at the water surface, 20 m and bottom along the transect at the entrance to Bantry Bay and off Mizen Head.

Forecasting

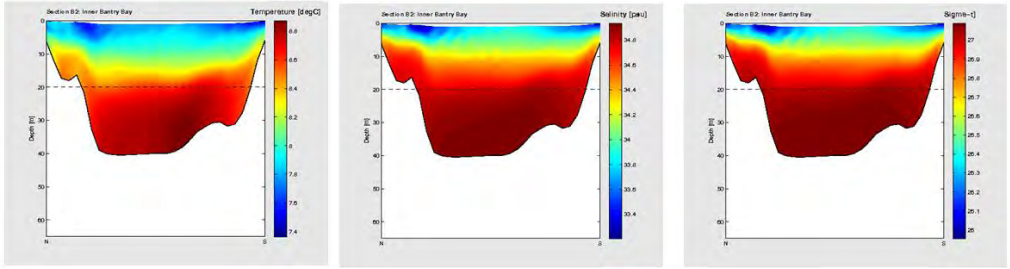
1. Volumetric Fluxes
2. Particle Transport

Model output tools developed

Bantry mouth: end forecast at 15-02-2013-0000hrs



Shot Head: end forecast at 15-02-2013-0000hrs

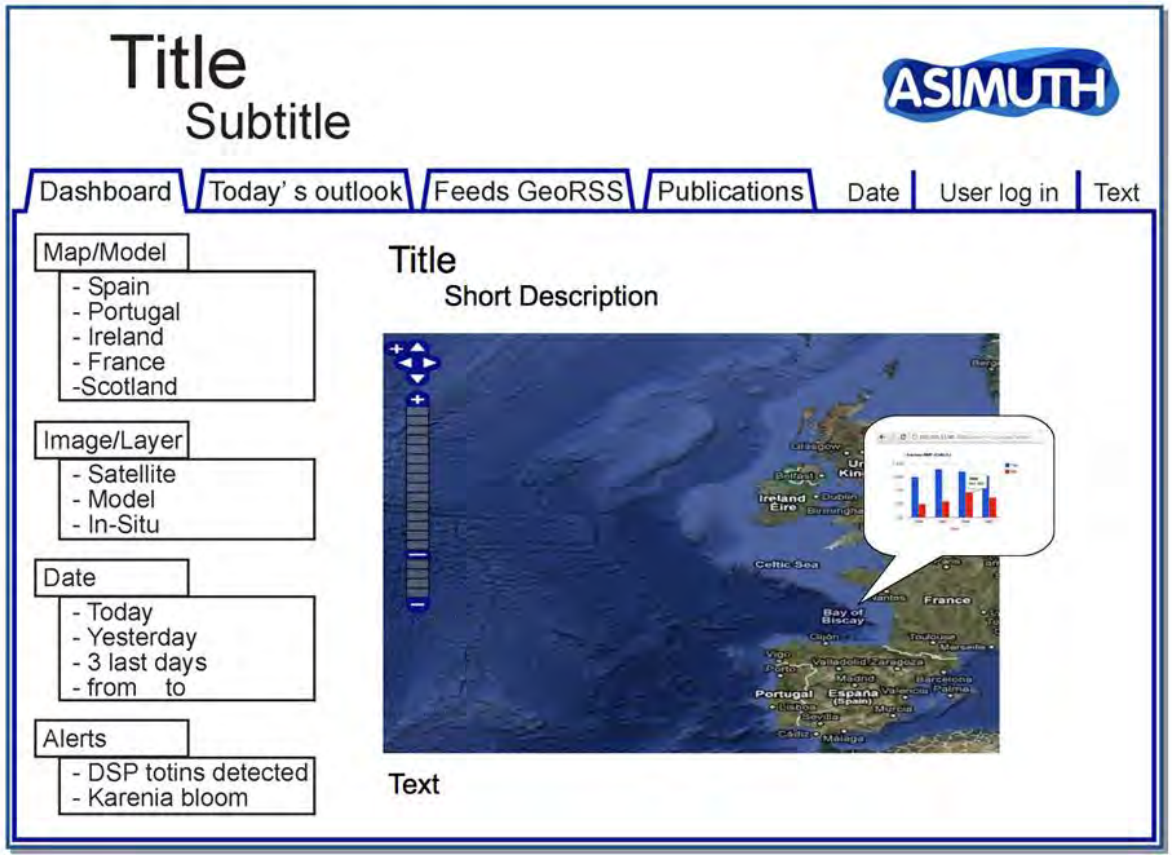


Forecasting

1. Volumetric Fluxes
2. Particle Transport
3. T, S & Rho profiles

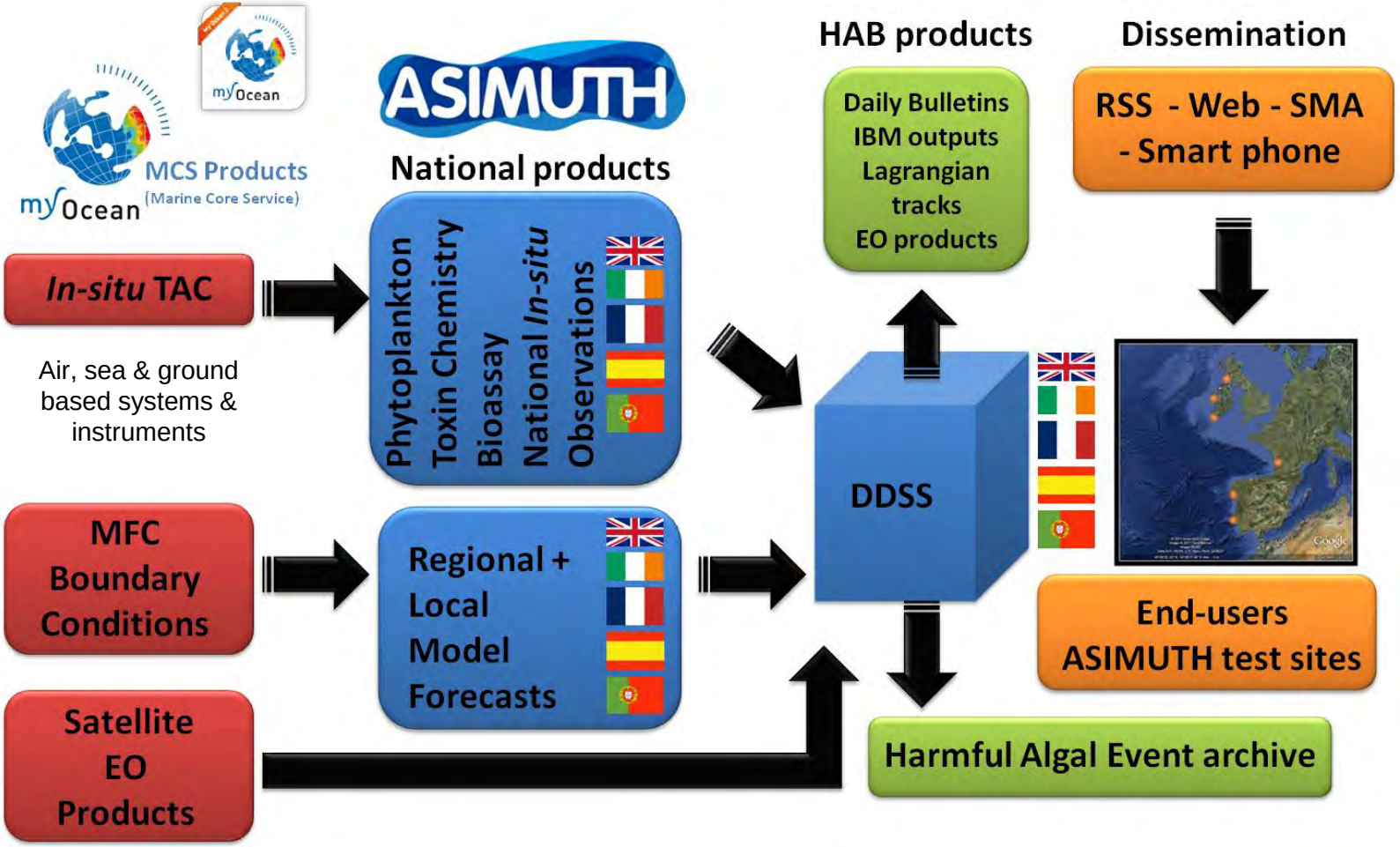
Delivery system

ASIMUTH HAB-DDSS



Developed by Starlab, Barcelona

Bringing it all together



My Ocean = FP7 project, the GMES « Marine Fast Track » project

Ireland: **Current Conditions**

Shellfish biotoxin report (last week)

ASP — Week 19

All areas: 22 sites

north	west	east	southwest	south
4	8	0	10	0

Not toxic (100%)
Toxic (0%)

AZP — Week 19

All areas: 31 sites

north	west	east	southwest	south
8	10	1	12	0

Not toxic (100%)
Toxic (0%)

DSP — Week 19

All areas: 31 sites

north	west	east	southwest	south
8	10	1	12	0

Not toxic (100%)
Toxic (0%)

PSP — Week 19

All areas: 0 sites

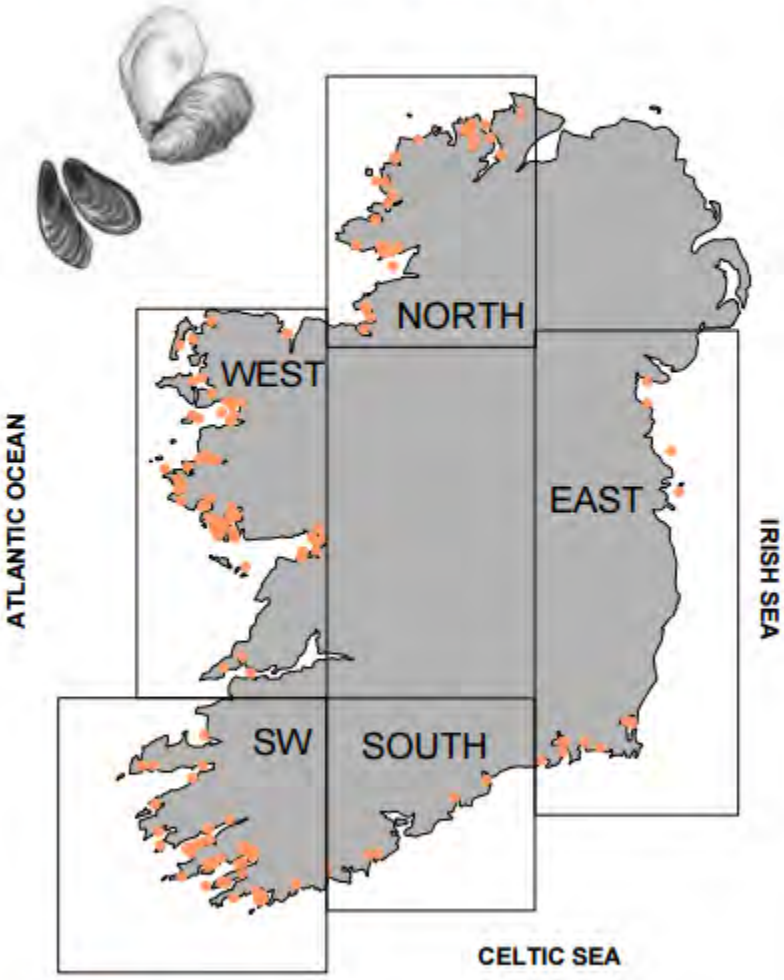
north	west	east	southwest	south
0	0	0	0	0

Not toxic (NaN%)
Toxic (NaN%)

EU Regulatory Limit:
ASP 20 µg/g; AZP 0.16 µg/g; DSP 0.16 µg/g; PSP 800 µg/kg

Toxin groups
ASP = **A**mnesic **S**hellfish **P**oisoning; AZP = **AZ**aspiracid **P**oisoning;
DSP = **D**iarrhetic **S**hellfish **P**oisoning; PSP = **P**aralytic **S**hellfish **P**oisoning

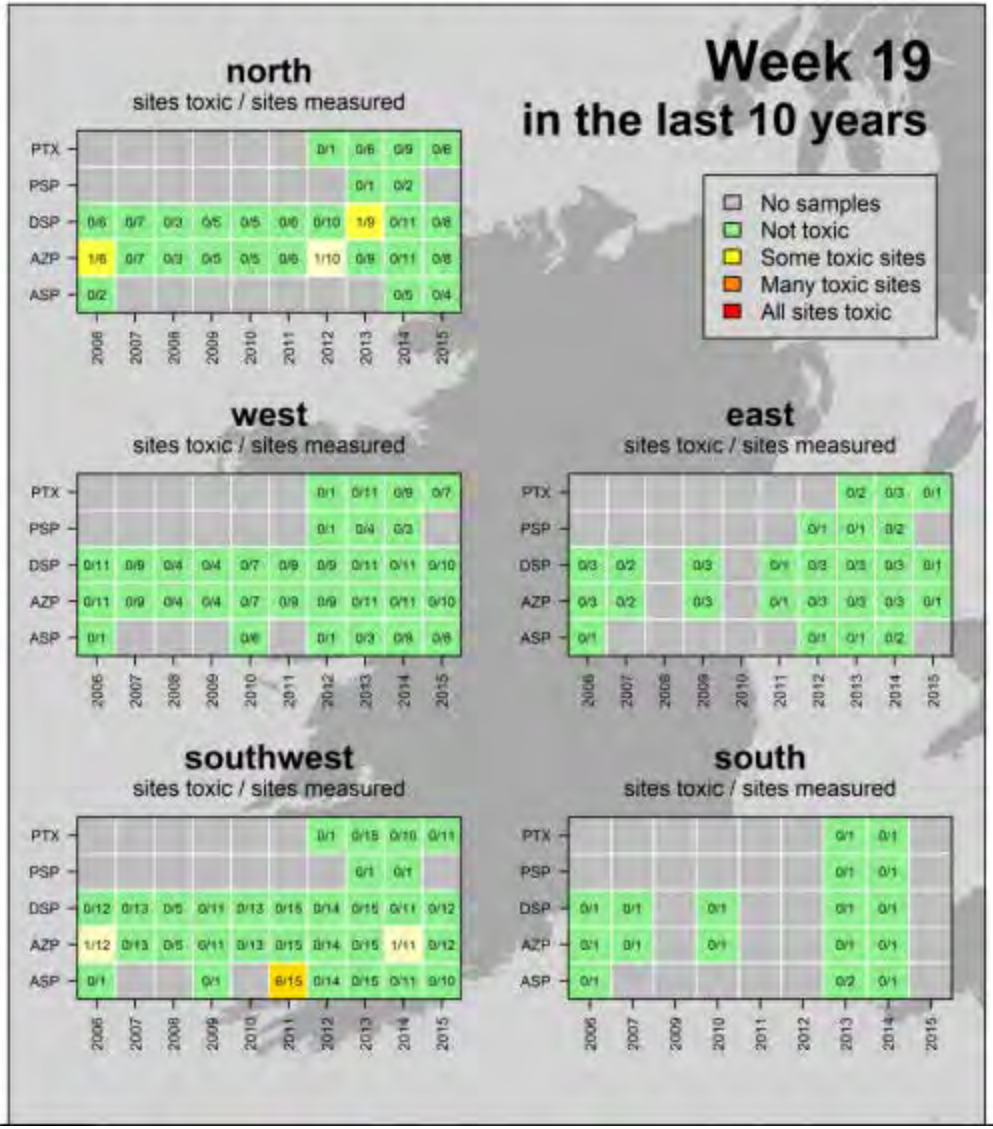
National Monitoring Programme
Designated Sampling Sites



● = aquaculture site

Ireland: **Historic Conditions**

A look back at how last weeks biotoxin results compares to other years



Ireland HISTORIC TRENDS

Likely times for Shellfish Toxicity: does not include winter carry over of biotoxins

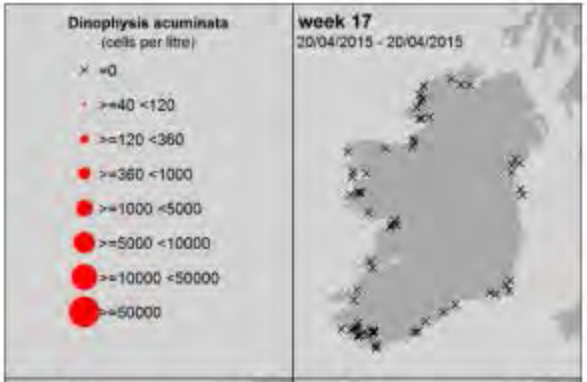
ASP events: mid-March to early May
AZP events: April to December
DSP events: May to December
PSP events: June to mid-July and end September; only in Cork Harbour

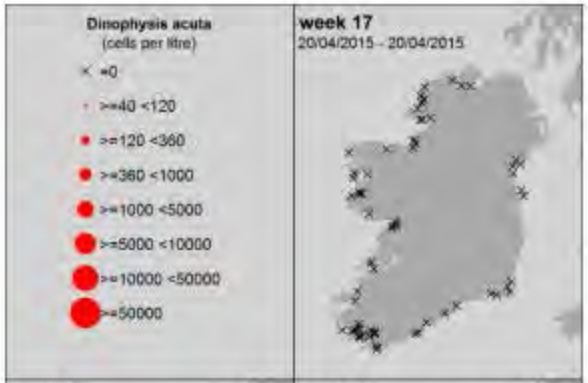
Ireland: **Last 3 weeks of available National Monitoring Programme data**

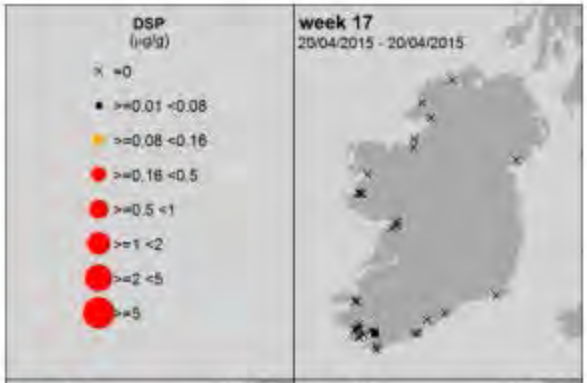
Dinophysis acuminata

Dinophysis acuta

DSP

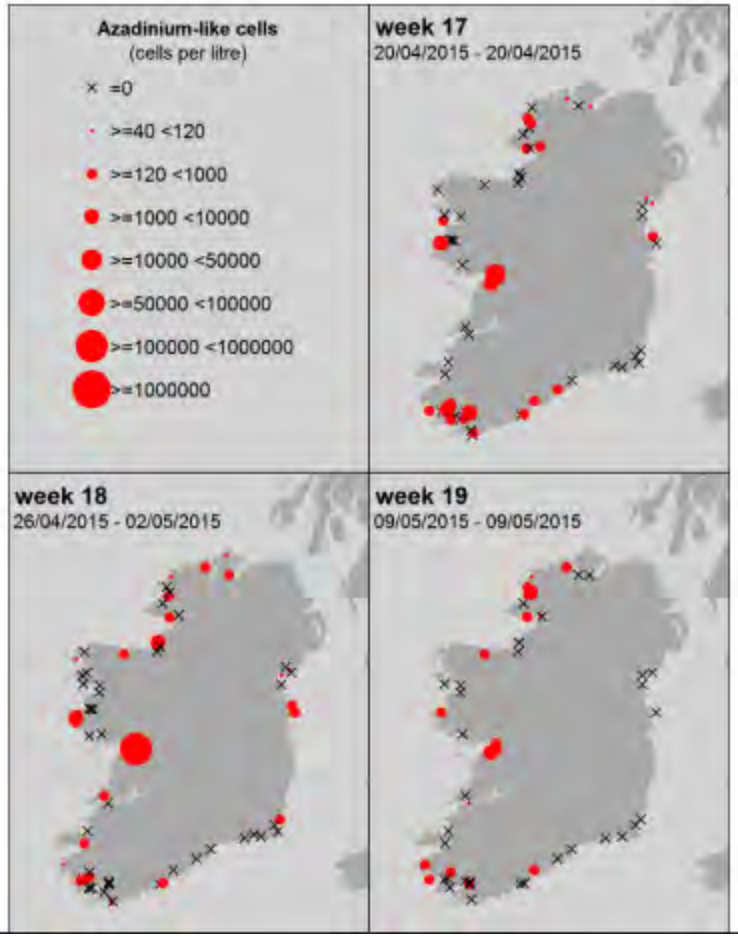




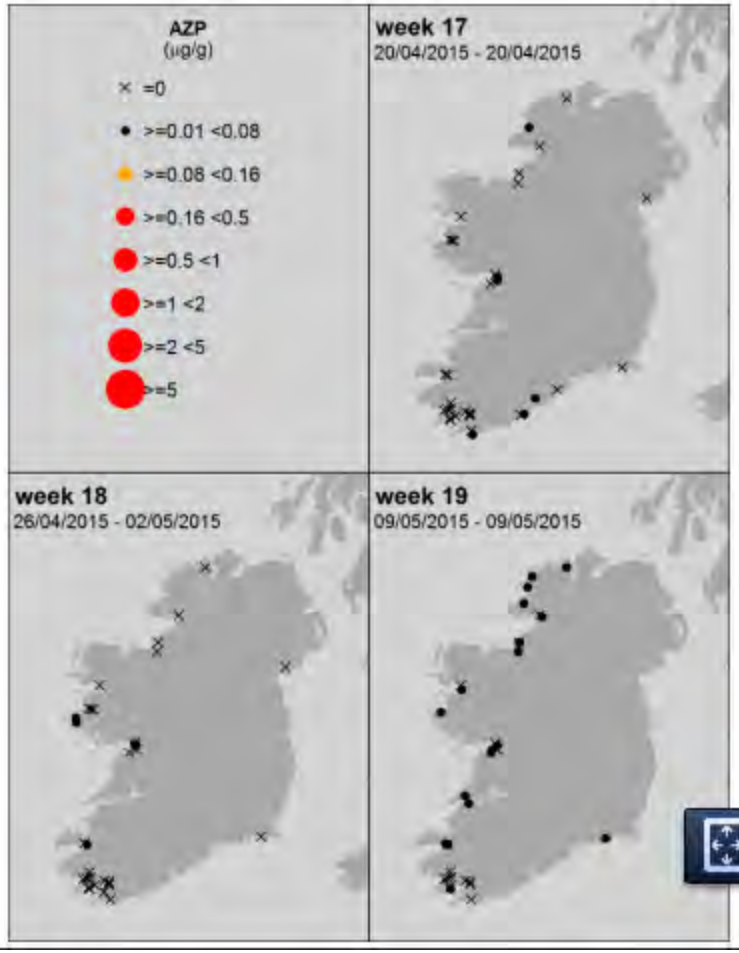


Ireland: Last 3 weeks of available National Monitoring Programme data

Azadinium – like spp.



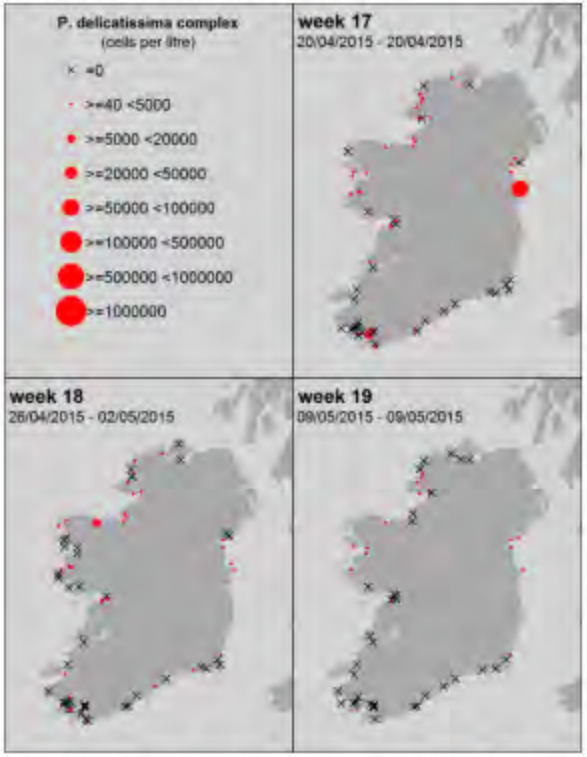
AZP



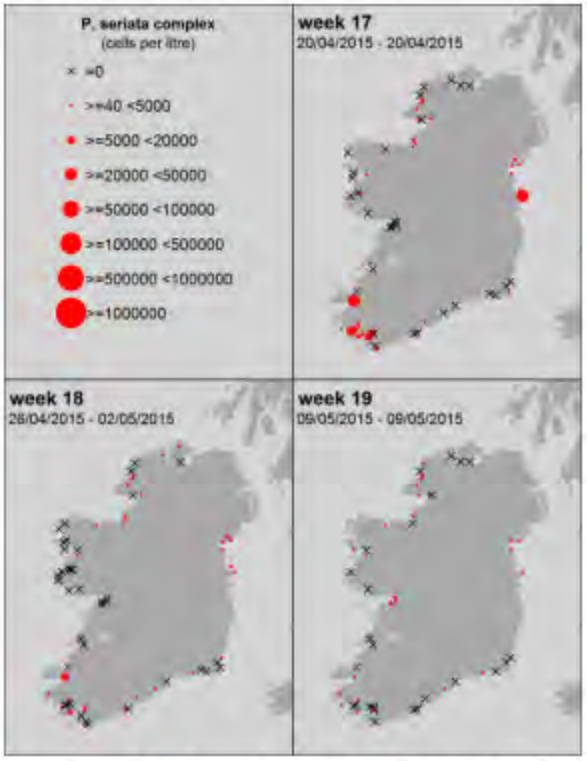
Ireland: **Last 3 weeks of available National Monitoring Programme data**

Pseudo-nitzschia spp.

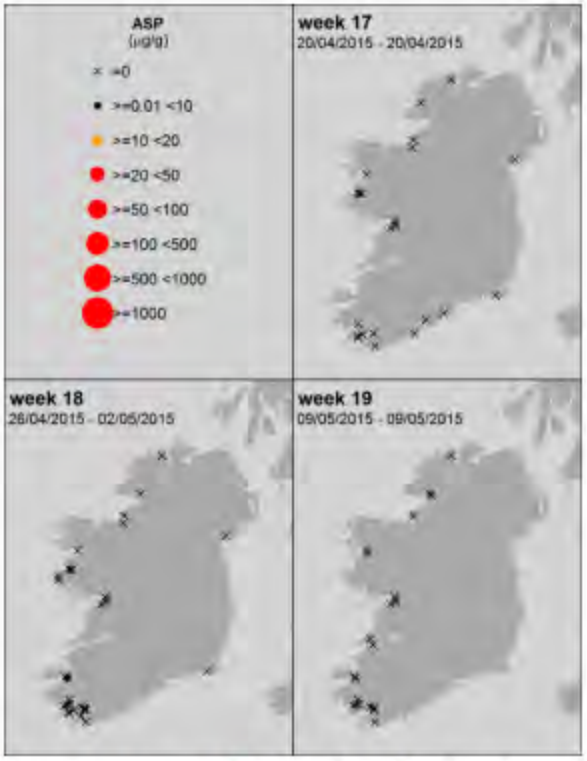
"*P. delicatissima*" complex = small cells
Taken from the literature:
3 species confirmed in Irish waters



"P. *seriata*" complex = large cells
Taken from the literature:
7 species confirmed in Irish waters



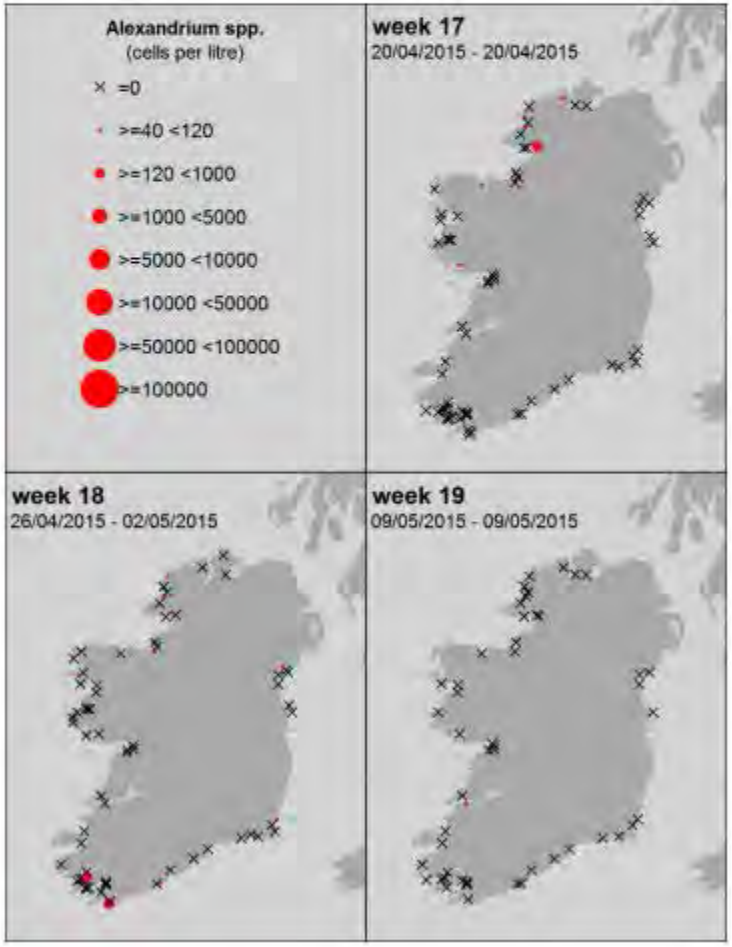
ASP



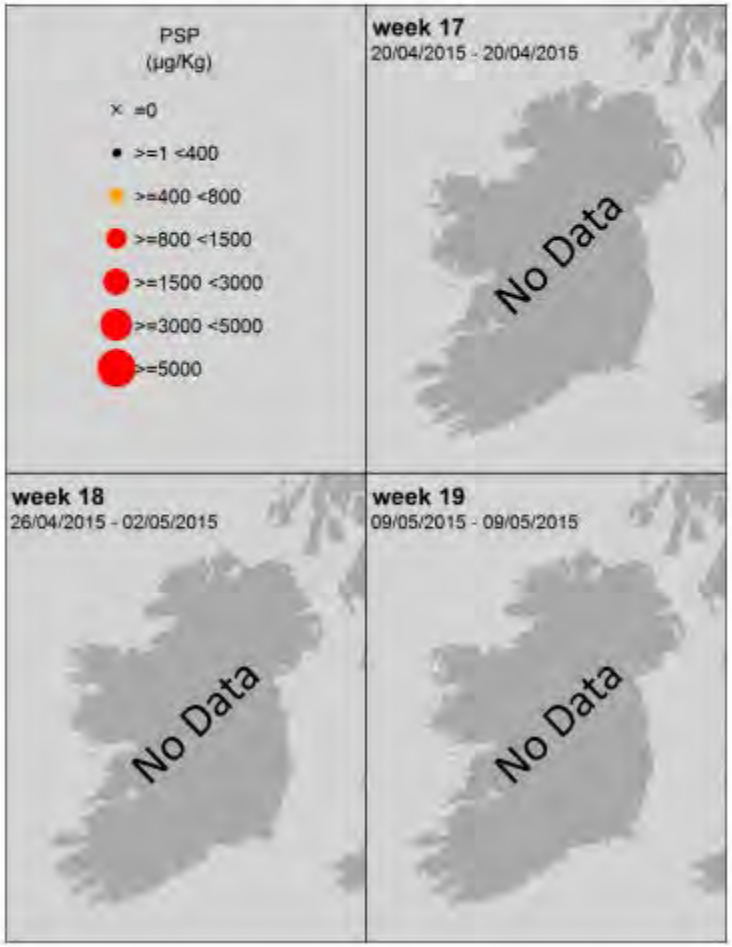
Taken from the literature: Of the 4 species (*P. fraudulenta*, *P. australis*, *P. pungens* and *P. delicatissima*) from Irish waters, tested for ASP toxins in culture work, only one, *P. australis* (from the "*P. seriata*" group) was toxic

Ireland: **Last 3 weeks of available National Monitoring Programme data**

Alexandrium spp.



PSP

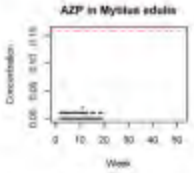
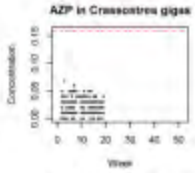
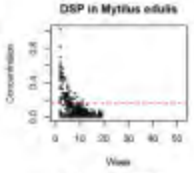
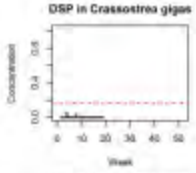
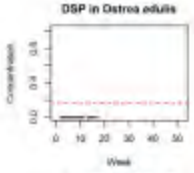
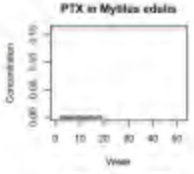
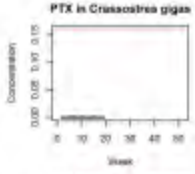
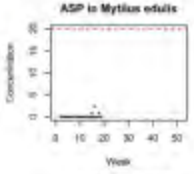
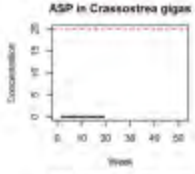
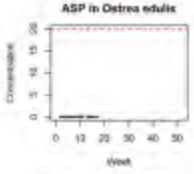
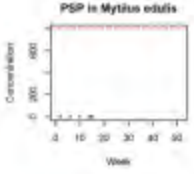
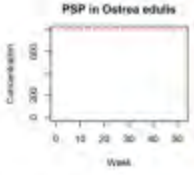


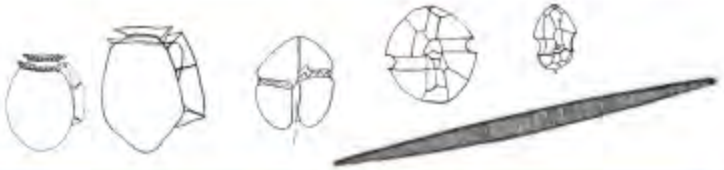
Ireland HAB & Biotoxin temporal trends

Week 20: 10 – 16 May, 2015
Week runs from Sunday to Saturday

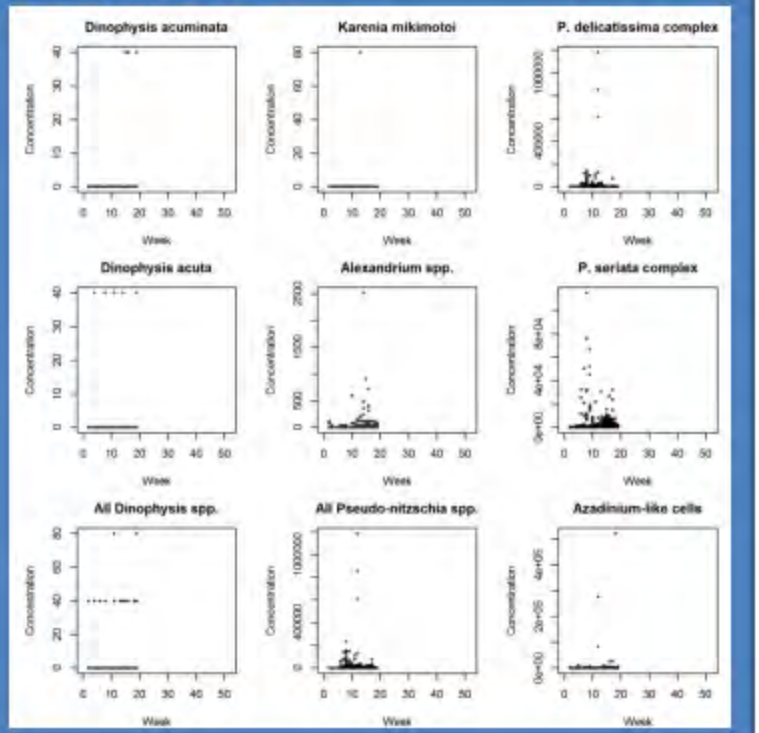
Ireland: **HABs and biotoxins** Levels from week 1 to present

Ireland: **Biotoxins**

Toxin groups	mussels	oysters	oysters
AZP AZaspiracid Poisoning			
DSP Diarrhetic Shellfish Poisoning			
PTX Pectenotoxin			
ASP Amnesic Shellfish Poisoning			
PSP Paralytic Shellfish Poisoning			



Ireland: **HABs**

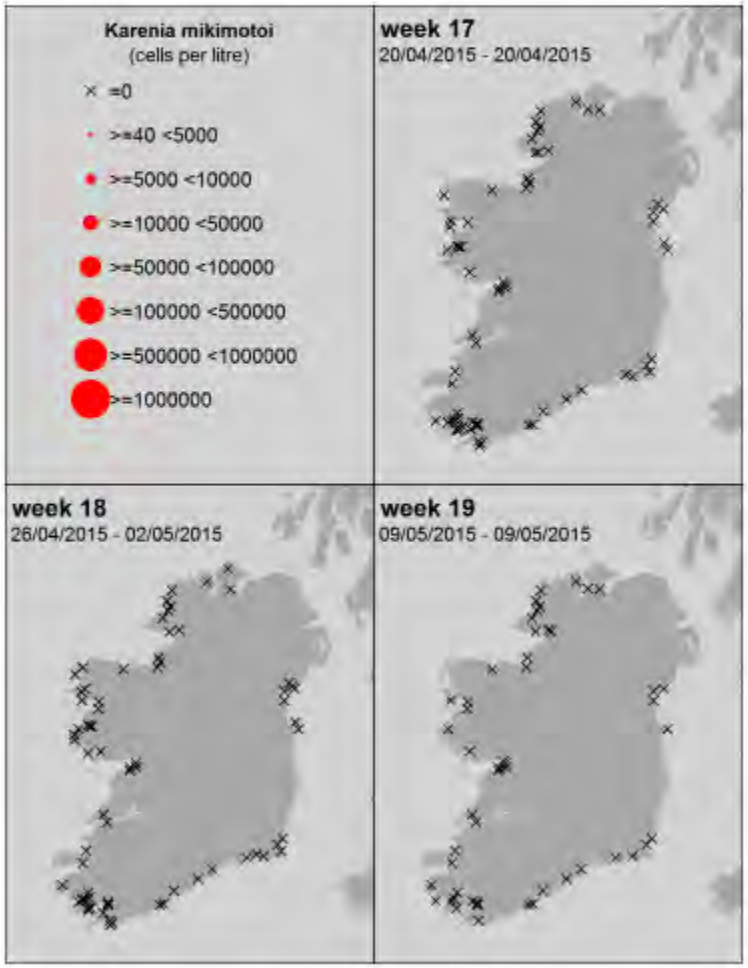


Week number: 1 to 19

EU Regulatory Limit: ASP 20 µg/g; AZP 0.16 µg/g; DSP 0.16 µg/g; PSP 800 µg/kg

Regulatory limit ■ ■■■■■

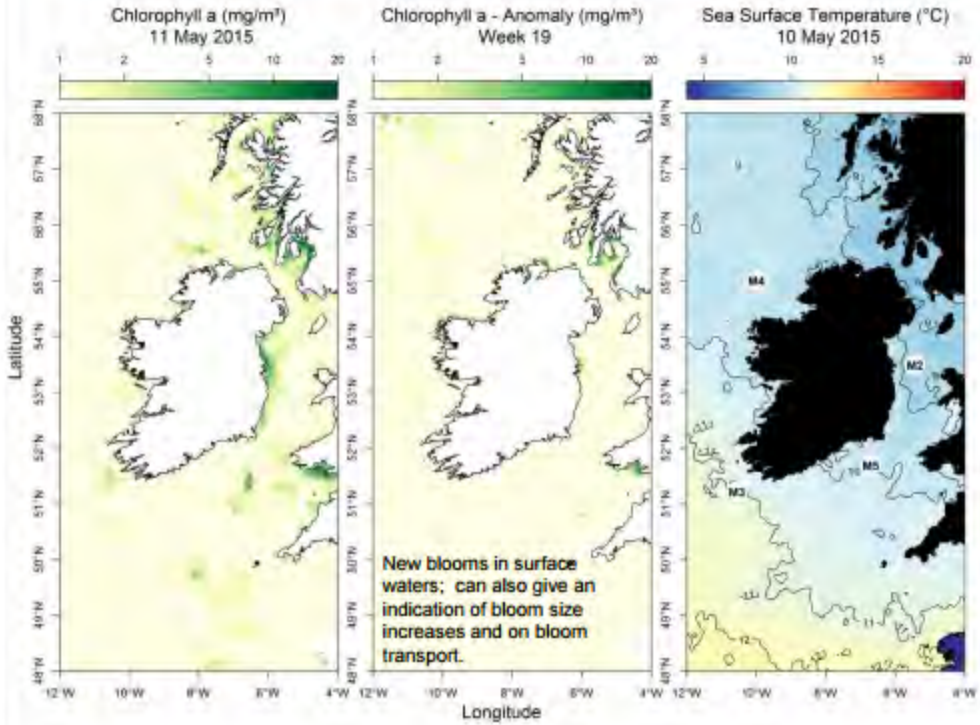
Karenia mikimotoi
(old name: *Gyrodinium aureolum*)



Ireland Satellite data: surface chlorophyll and temperature maps

Week 20: 10 – 16 May, 2015
Week runs from Sunday to Saturday

Most up to date available satellite data



SST (°C) anomaly for last week:
Data taken from the Irish data buoy network where the anomaly is the weekly difference in SST compared to the long term mean (~ 10 yrs)

NW coast (M4)	below average by 0.64 °C
SW coast (M3)	above average by 1.70 °C
SE coast (M5)	below average by 0.95 °C

What phytoplankton were blooming around the coast last week?

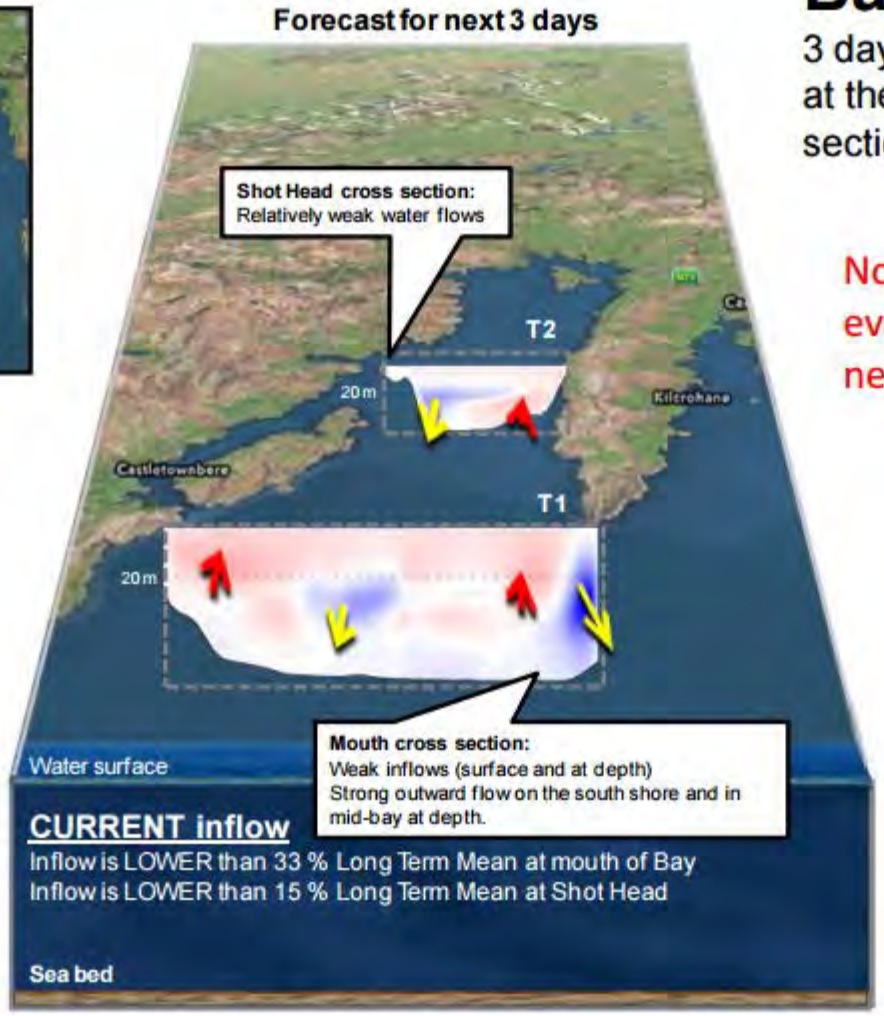
Region	Predominant Phytoplankton	Cells/L (rounded)
north:	**Diatoms:**	
	Asterionellopsis spp.	1,680,000
	Chaetoceros (Hyalochaete) spp.	81,000
	Other:	
	Microflagellate spp.	150,000
west:	**Diatoms:**	
	Chaetoceros (Hyalochaete) spp.	370,000
	Leptocylindrus danicus	250,000
	Guinardia delicatula	175,000
	C. closterium / N. longissima	130,000
	Licmophora spp.	95,000
SW:	**Diatoms:**	
	Thalassiosira spp. (20-50 µm)	580,000
	Leptocylindrus danicus	280,000
south:	**Diatoms:**	
	Asterionellopsis spp.	105,000
	Thalassiosira nordenskioeldii	35,000
	Skeletonema spp.	35,000
	Chaetoceros socialis	30,000
east:	**Diatoms:**	
	Skeletonema spp.	1,325,000
	Bacteriastrum spp.	425,000
	Guinardia delicatula	420,000
	Asterionellopsis glacialis	245,000

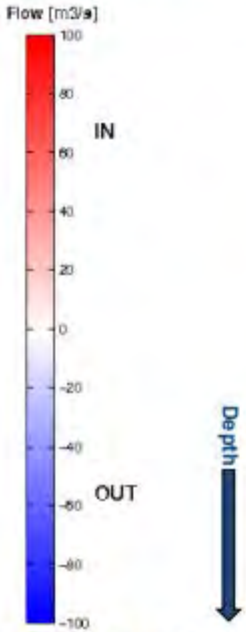
Source EPA:
Phaeocystis colonies in Wexford Harbour, Monday 11 May 2013. The presence of *Phaeocystis* marks a transition period between phytoplankton floral assemblages found in spring and summer.

Bantry Bay

3 day estimated water flows at the mouth and mid-bay sections of Bantry Bay

No big water exchange event predicted in the next few days





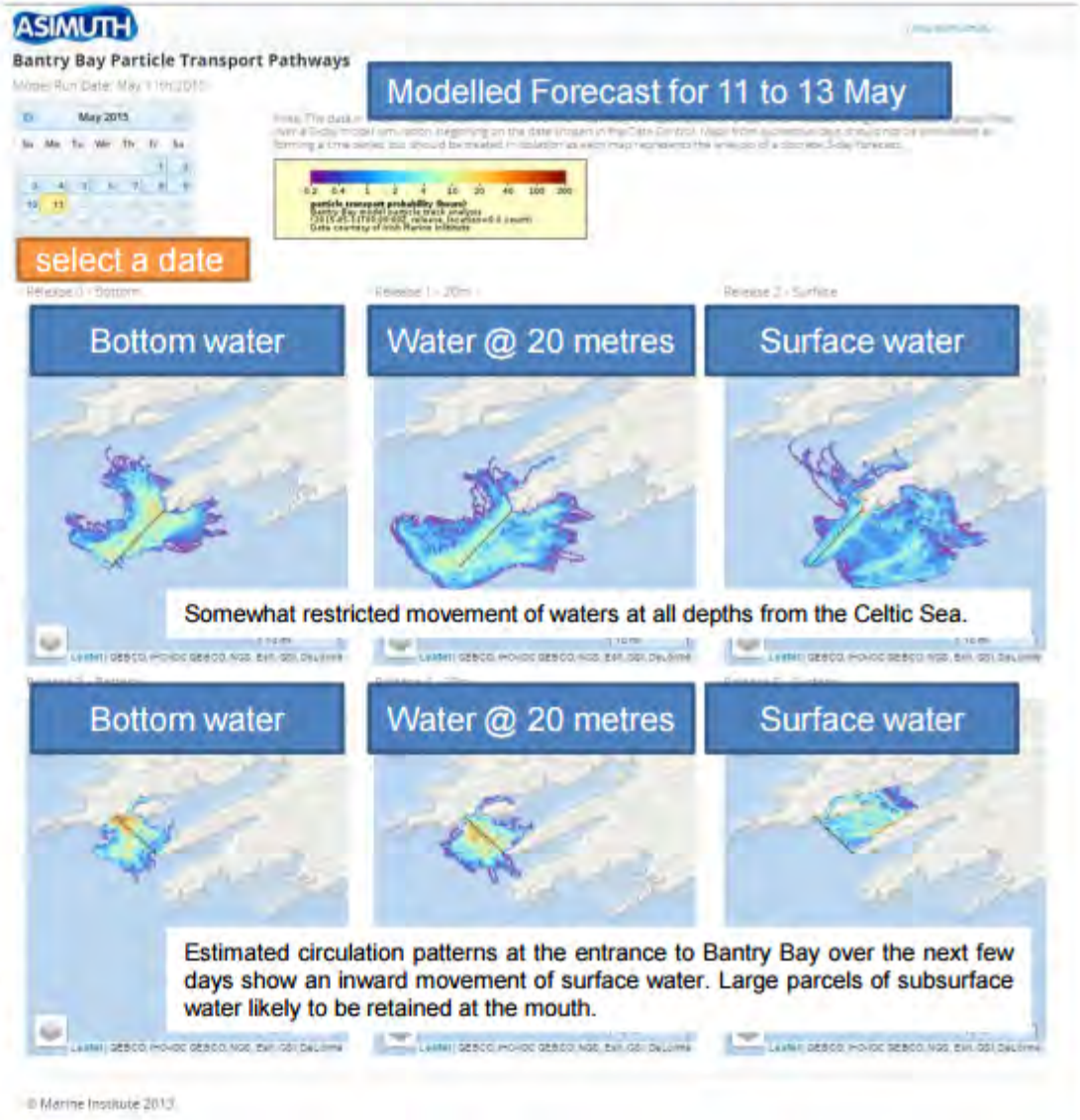
11 – 13 May, 2015 (forecast ends at 00:00 hrs)

Please go to http://vis.marine.ie/particles/ to view daily forecasts in more detail

The maps show the **most likely transport pathways for the next 3 days of phytoplankton** found along the **presented transects** (black lines off Mizen Head and the Mouth of Bantry Bay) and **water depths** (bottom, 20 metres and surface)

Reddish colours represent areas where phytoplankton remain longest

Cooler colours represent areas where phytoplankton remain for shorter periods



Ireland: **Predictions**

Prediction for this week:

ASP event: Low risk
AZP event: Low risk
DSP event: Low risk
PSP event: Low risk

Why do we think this?

ASP : No toxins recorded. *Pseudo-nitzschia* spp. found at 28 out of 53 sites nationwide. However, cell levels are low (max = ~ 2,000 cells/L) and populations only represent a maximum of 2 % of the total phytoplankton present.

AZP: Very low levels of toxins (i.e. Background levels of 0.01 to 0.04 µg/g) picked up at 18 sites nationally. *Azadinium*-like species recorded at 20 sites - cell levels are relatively low with maximum recorded in the west (~ 6,000 cells/L). Since historic data shows events in the past have occurred at this time of the year, some caution is advised.

DSP: Background levels of toxins detected in SW last week (range = 0.02 to 0.06 µg/g). *Dinophysis acuta* present at limit of detection (40 cells/L) at 1 site in the southwest. *Dinophysis acuminata* found at low cell levels (40 cells/L) at one site in the west. Over the last week, outputs from the SW physical model show continued weak "downwelling". While we do not know what phytoplankton species are/have been present in offshore waters, *Dinophysis* spp., if present, could be carried into the bay with this weak "downwelling" event. SST in the SW is nearly 2 °C above normal.

PSP: Historically this a low risk period of the year for all sites. *Alexandrium* species present at 2 sites nationally; maximum cell levels in the west @ ~ 80 cells/L. No biotoxins recorded.


Oceanic Warming
OBSERVATIONS
UNDERSTANDING
PREDICTIVE
Stormines
Acidification

CHANGES IN HABS:

Based on the UK and RoI national monitoring programmes for HAB species, there is evidence that no ‘new’ HAB species have become established in UK and RoI waters through climate driven range expansion or human introductions.

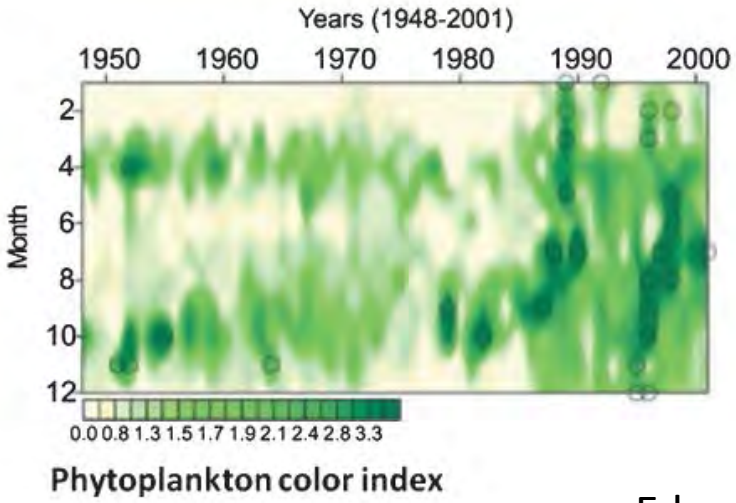
Bresnan et al 2013
Marine climate change impacts partnership: science review

CHANGES IN HABS:

Increase in Phytoplankton Biomass in CPR data from the NEA and North Sea

Both in coastal water and open sea areas

Link appears to be with warmer temperatures



Edwards 2004

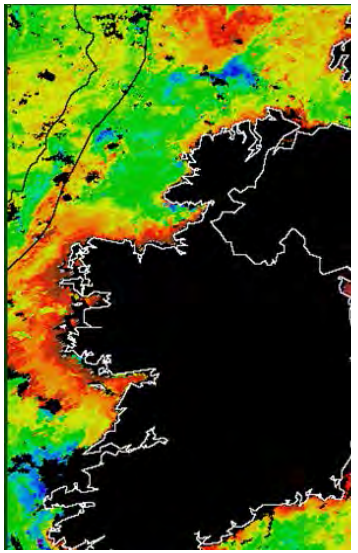
CHANGES IN HABS:

High Biomass Species:

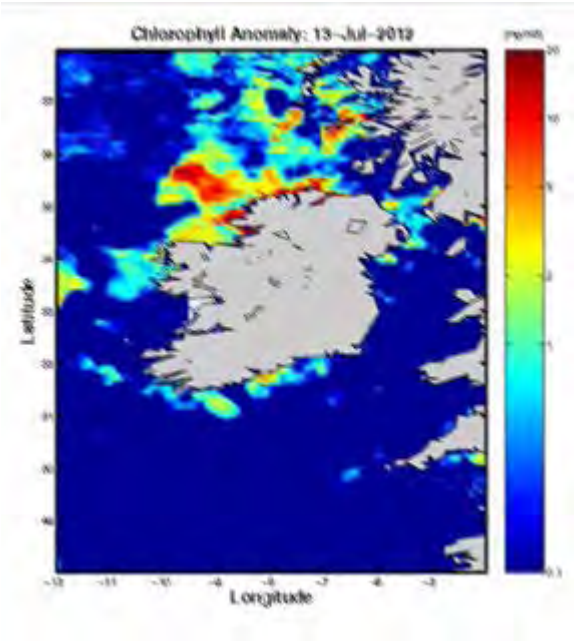
Karenia mikimotoi

Increase in incidence has been suggested as a Potential impact of climate change

Bresnan et al (2010)



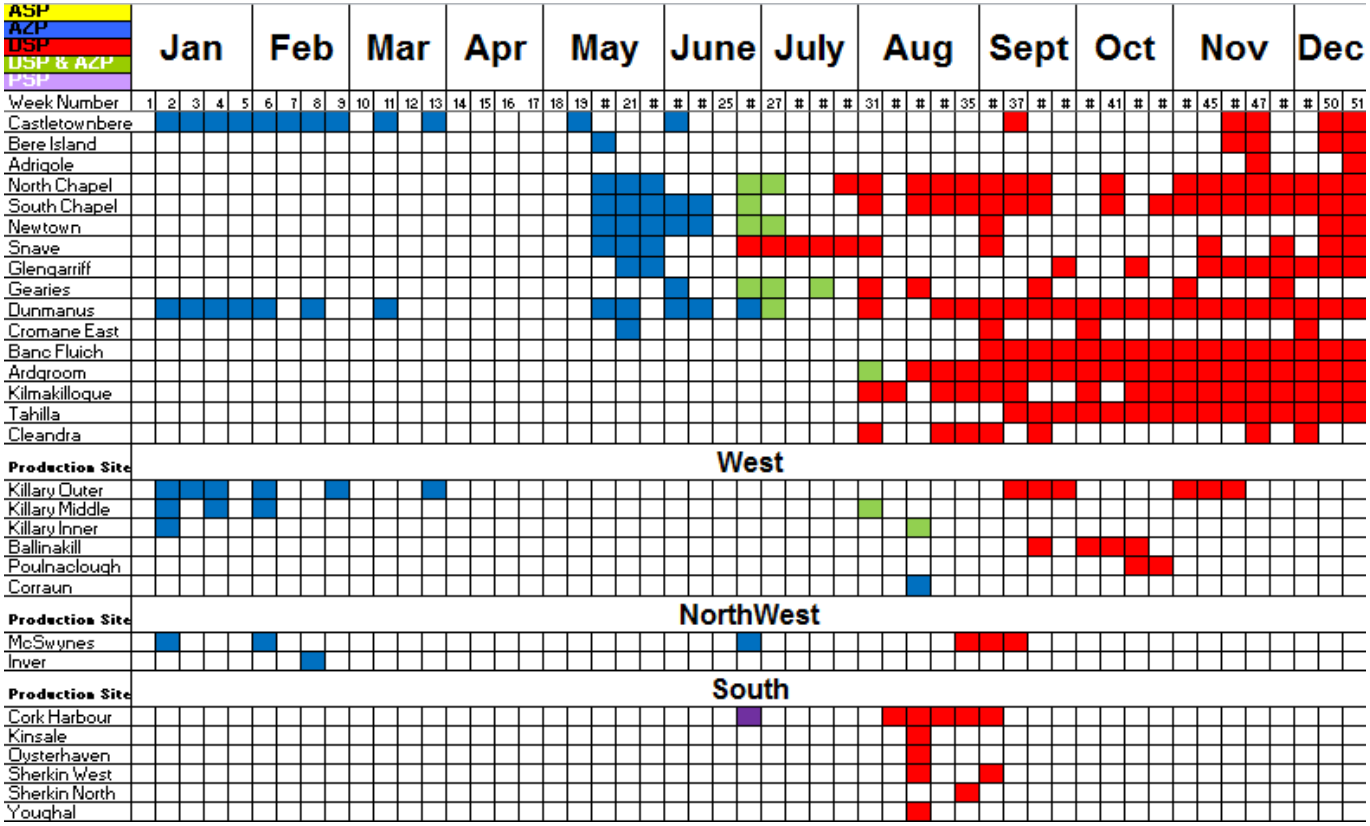
2005
June-August



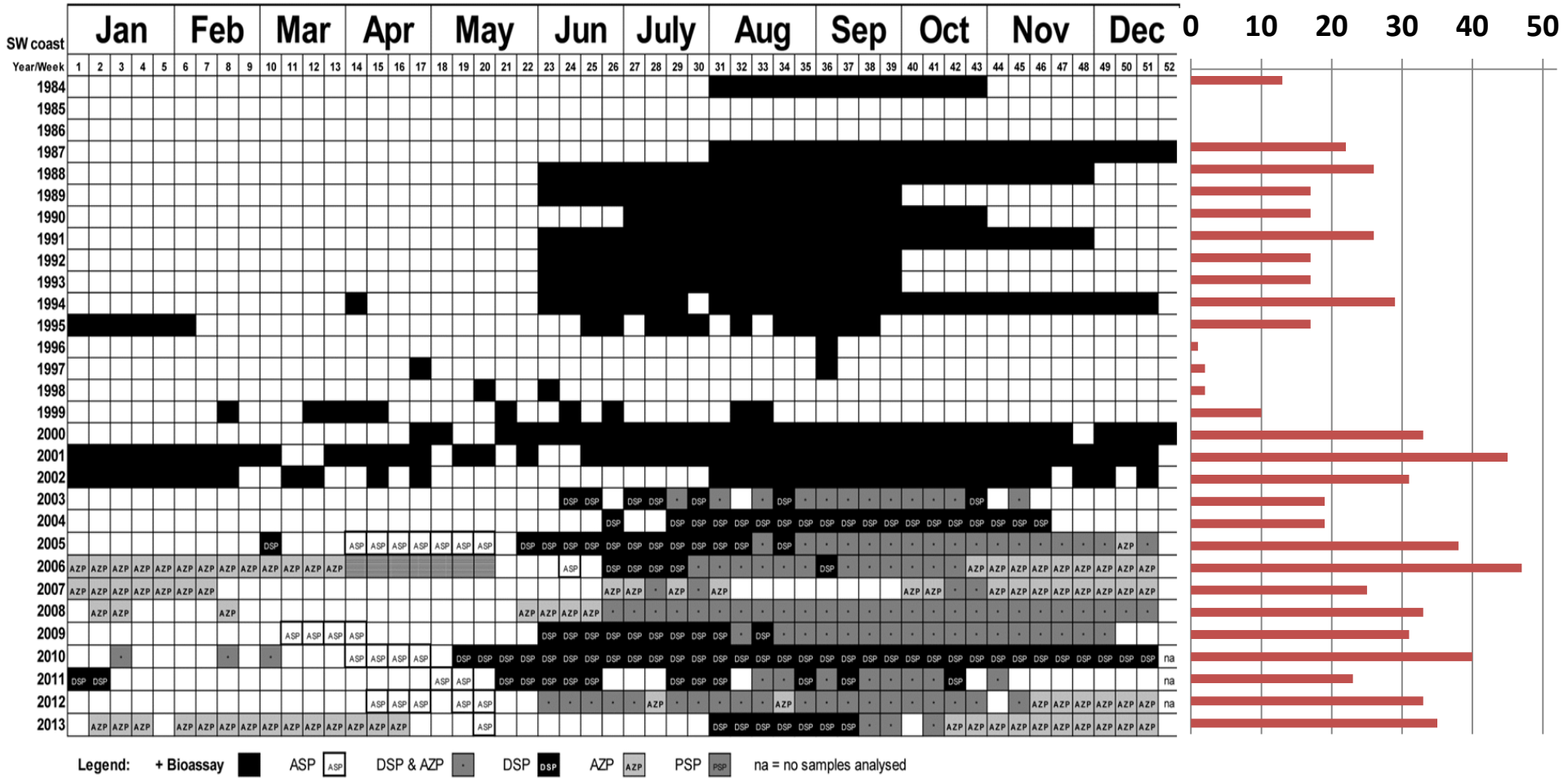
2012
May - September

CHANGES IN HABS:

Shellfish toxins:*)*



Irish Shellfish Production area Closures in 2014



Shellfish Production Area Closures
1984 to 2013

Number of weeks closures

CHANGES IN HABS:

Summary

- There is evidence to show that there is a prolonged growth season

Since the mid 70's which is concurrent with elevated sea water temperatures in the NEA and North sea

- There have been some prolonged occurrences of both high biomass

blooms that have resulted in various vertebrate and invertebrate mortalities

- There have also been various shellfish toxic episodes of various severity

and duration observed in the same time span

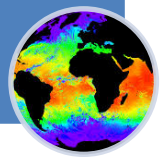
- The time series of these HAB events is not sufficiently long to judge whether there

is a climate change involvement in these observations

CHANGES IN HABS: WHAT COULD HAPPEN…

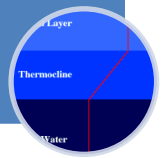
- Increase in SST may facilitate expansion of warmer water species into colder regions
- *Gymnodinium catenatum* or *Ostreopsis* spp. into Irish waters

Sea Surface Temperature



- Onset of stratification earlier in the year will favour Dino growth for a longer duration
- Increased wind may reduce stratification and favour diatoms

Stratification

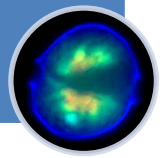


- Elevated freshwater discharges due to increased precipitation may increase the nutrients and stratification in coastal areas
- Increased turbidity

Runoff and Flooding

- Changes in light, pH, temperature and nutrient supply affect the toxicity of certain species

Algal Toxicity



- Complex relationship that has yet to be fully resolved.
- Low pH may affect the ratio of nutrients important for phytoplankton growth

Ocean Acidification

- Variation in oceanic currents may influence ecosystem structure

Oceanic Circulation

CHANGES IN HABS: WHAT IT MEANS FOR SHORT TERM FORECASTING…

Monitoring Programmes		
	Phytoplankton	New HAB species may be observed, their relevance as yet unknown
	Toxin Analysis	Novel toxins, of unknown severity observed. Early warning unknown
Satellites		
	SST	Leading to range expansion towards polar regions
	Ocean Colour	High biomass blooms, and turbidity
Models		
	Particle Tracking	Alterations in coastal currents
	Biological behaviour	Improved models that take biology into account developed
History		
	Bay Profiles Previous patterns	Historical patterns will be less relevant

This project is supported by the EC FP7 Programme, Space Theme, Grant Agreement No.: 261860
www.asimuth.eu

1 Daithi O'Murchu Marine Research Station
2 Marine Institute
4 IPIMAR
5 Scottish Association for Marine Science
3 Ifremer
6 Instituto Superior Técnico
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8 HOCER
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