The Peter Spillett Lecture

Landmarks in Fish Impingement and Entrainment: Where Has 50 Years Got us? A Personal View

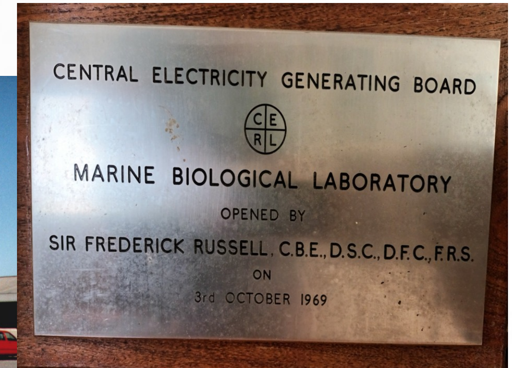
Andy Turnpenny

BSc PhD CBiol MIFM FRSB

Independent Aquatic Biology Consultant

CERL Fawley Marine Biological Laboratory (1969)

- CEGB's Fawley lab opened in 1969 on the site of the new seawater cooled oil-fired station
- Aim was to carry out research into effects of power generation on marine environment
- Fawley work scope then included:
- **Impingement and entrainment of biota**
- **Effects of thermal discharges**
- **Biofouling issues for coastal stations**



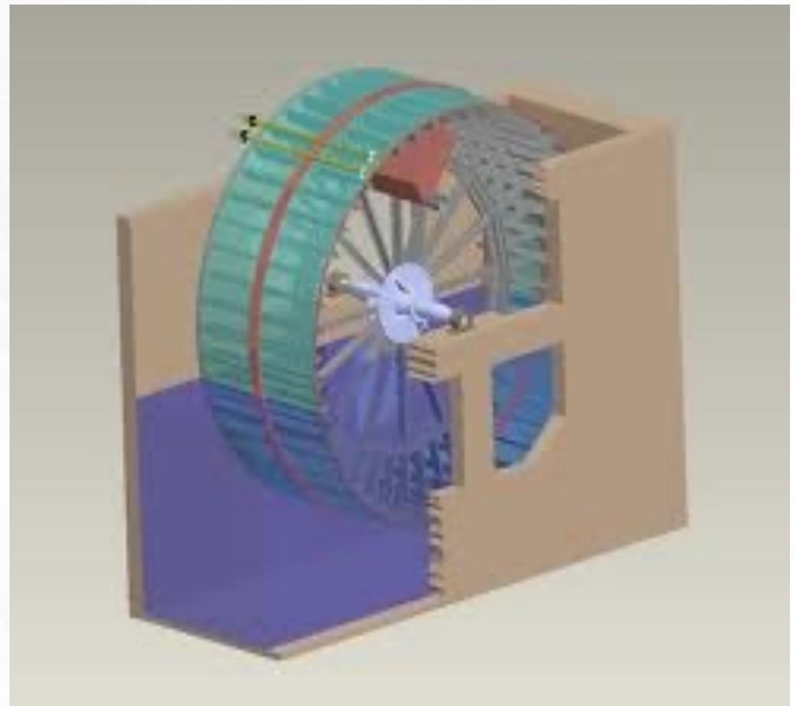
Preliminaries

- This talk will focus on power stations. Concern over salmon smolt impingement at hydroelectric stations, especially in Scotland dates back as far as the 19th Century but is not the subject of my talk today
- A note on scale: CW abstraction at coastal power stations using once through seawater cooling is on a scale of tens to >100m^3s^{-1}, comparable to the flow of a large English river
- Also I shall talk mainly about impingement

Site	Flow m^3s^{-1}
Sizewell A, B	26, 50
Fawley	64
Hinkley Point C	125
R Thames	65 (ADF)

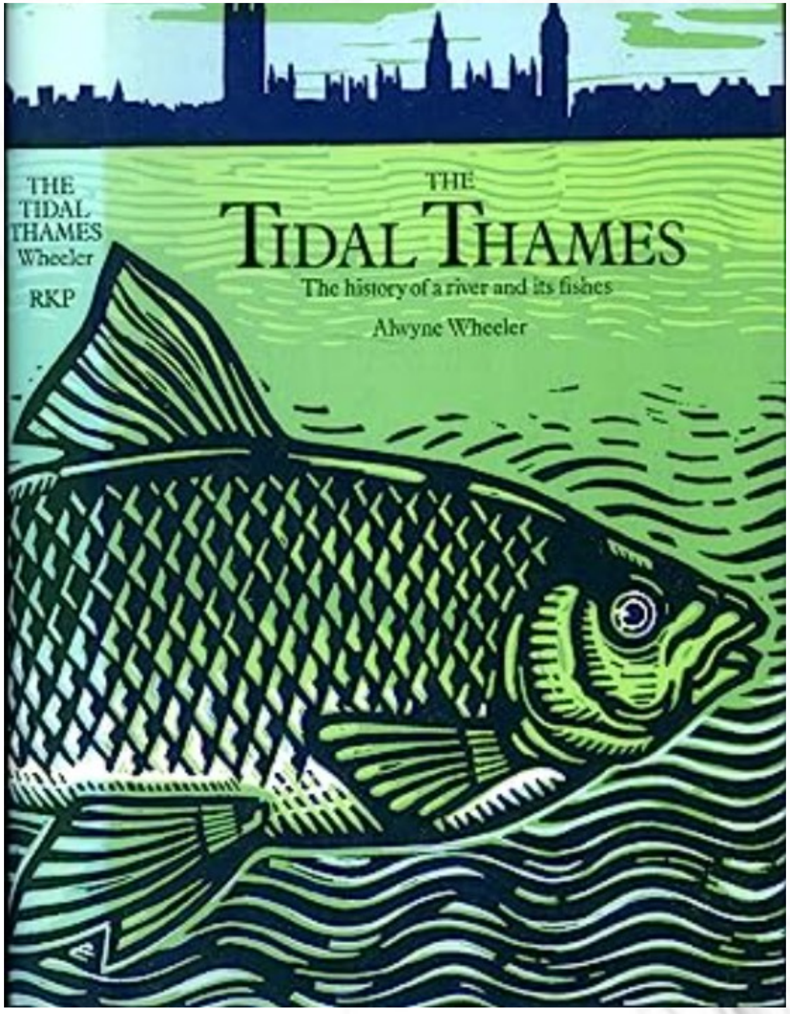
Inside an NNB Cooling Water Pump

Band & Drum Screens



Landmark 1: Early Recognition of the Issue

1960s-70s Where it all Started: Wyn Wheeler – The Tidal Thames



- During the '60s & 70s, Wyn Wheeler of the Natural History Museum charted the recovery of the Tidal Thames by monitoring occurrences of fish on the filter screens of its water-cooled power stations
- Eventually >120 spp recorded
- At this point, fish impingement seen as an asset rather than an impact

Where it first became Contentious in the UK: Dungeness Dinner-Plate Fish!

- Dungeness A commissioned in 1965
- First UK rumblings about impacts of fish Impingement when housewife tells local fish vendor '*her husband gets nice Dover sole from power station*'
- CEGB immediately allowed fishermen onto site to view screen catch over a season

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- CEGB immediately allowed fishermen onto site to view screen catch over a season
- **On inspecting the catch they quickly concluded no issue**

1960s-70s: Where it all Started: US Lawsuits, New York

- In 1972 Indian Point power plant of the Hudson River fined $US1.6m for kills of small fish, based on per capita poaching fines (Langford, 1982)
- This spawned other US lawsuits and created renewed interest in UK & Europe where the prospect of similar legal action made electricity generators nervous

Impinged fish dropping from a drum screen onto maintenance platform (coastal power station)

Spratmaggeddon! The Fish Hit Back!

Landmark 2 1970s-80s: Acquiring the Data
Quantitative Fish Impingement Surveys

The Sizewell B Public Inquiry

1970s onwards: UK & European Fish-on-Screens Surveys

- Fawley labs carried out impingement surveys at most CEGB coastal sites
- Sizewell B PWR (SZB) proposal: inshore fishers demanded impact assessment of juvenile fish catch
- Full quantitative assessment required ~40 surveys over 24 h periods across a year
- Species, numbers, sizes and biomasses of fish were recorded
- EDF also undertook surveys at French sites

UK & European Fish-on-Screens Surveys: Overview of Data

- Overall picture: large annual tonnages (2-240t/y) at some sites.
- Catches at all stations comprised mainly juveniles
- Fishing industry concerns centred on what this would mean for future stocks (under MAFF rules they were not allowed to land juveniles)

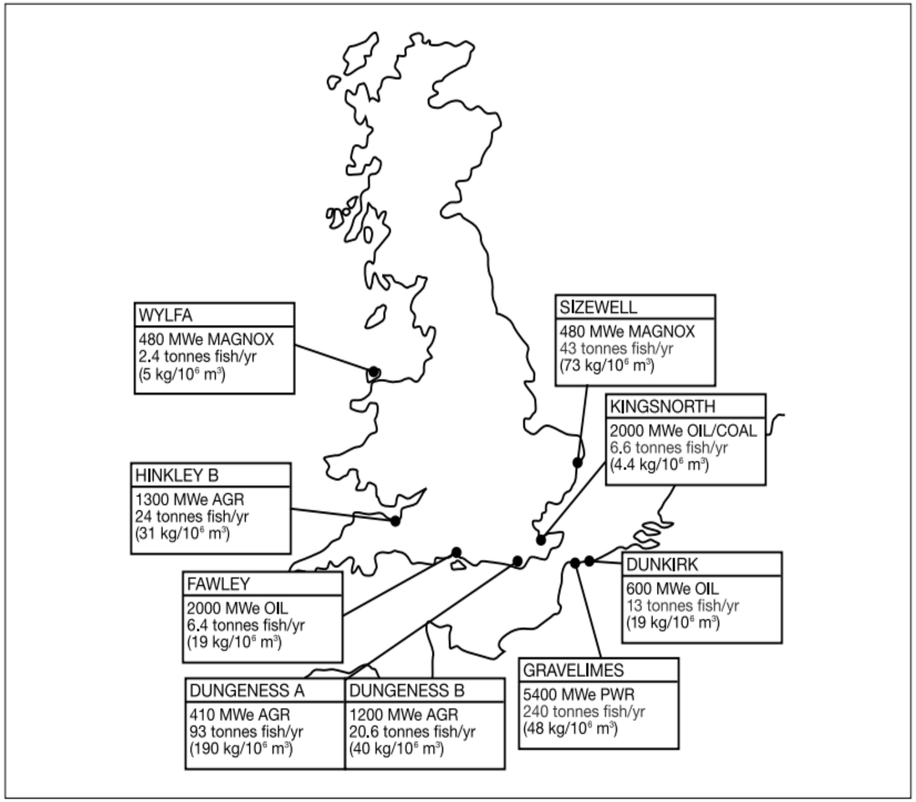

Figure 6.4 – Estimated annual total quantities of fish impinged at UK estuarine and coastal power stations

SZB: Putting losses into context: EAV, Commercial Stock Perspective

- Industry concern focused on catch of juvenile fish
- CEGB & MAFF agreed an assessment protocol for SZB based on expected survival of juveniles to adults of landing size (known as Equivalent Adult Value)
- Overall loss of biomass for commercial spp. predicted to be 14x higher than recorded biomass

Table 7.1 Sizewell A Power Station, 1981–2 Study. Estimated Annual Loss to the Fishery of Commercial-Sized Fish Due to CW Abstraction (after Turnpenny et al. 1988)

Species	*Immediate Loss (tonnes y^{-1})*	*Consequential Loss (tonnes y^{-1})*	*% of North Sea Stock taken by Power Station*
Plaice	0.03	1.0	0.00072
Sole	0.63	0.9	0.013
Dab	0.41	3.5	0.00034
Cod	1.8	2.8	0.00044
Whiting	1.5	43	0.0087
Herring	0.24	15	0.0017
Total	**4.6**	**66**	

SZB: Putting losses into context: EAV, Commercial Stock Perspective

- Even so, the annual catch was predicted to be less than the annual catch of a single inshore trawler
- Less than the annual catch of a single small inshore trawler

MAFF were satisfied that SZB would present no threat to North Sea fish stocks as a whole, nor local area landings

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Annual Catches at Estuarine Sites as EAVs

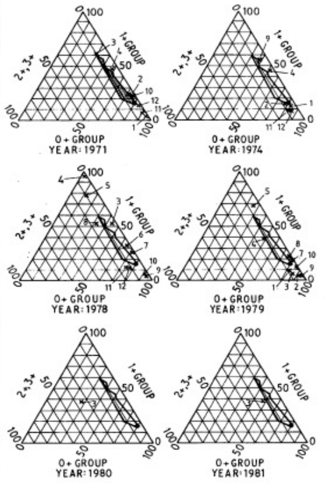
Heysham 1, Hinkley B, Fawley, Kingsnorth

Species	Age at >50% Maturity	Mean wt. at Age (kg)	Adult Equivalent Catch tonnes per annum			
			Heysham 1	Hinkley B	Fawley	Kingsnorth
Plaice	5 years	0.465	0.411	0.014	0.012	0.656
Sole	3 years	0.229	0.033	0.306	0.040	1.10
Dab	2 years	0.10	0.151	0.297	0.004	0.002
Cod	4 years	4.36	0.100	5.61	0	0.043
Whiting	2 years	0.178	0.689	10.8	0.078	4.44
Herring	2 years	0.126	1.91	0.333	5.40	4.01
			TOTAL 3.29	17.4	5.53	10.3
Total 1986 Landings:			9270 (VIIa)	5485 (VIIf)	3172 (VIId)	11655 (IVc)

Landmark 4: Assessing Impact on Non-Commercial Inshore Species

Inshore Population Studies: The Sand-Smelt (*Atherina boyerii*)

- Sand-smelt was the most frequently impinged sp. at Fawley PS.
- Parasite marker studies showed low mixing between coastal populations, hence at high risk
- A hind-casting study showed no change in population structure after 10y of station operation
- A demonstration of resilience



.7 OBSERVED MOVEMENTS OF AGE STRUCTURE OVER THE STUDY PERIOD, IN RELATION TO MODEL PREDICTIONS

Landmark 5: Learning to Design Better Intakes & Screening Systems

Working with Regulators to Identify Best Practice

Fish Swimming Speed Tests

Ensuring Fish have the Power to Escape Intake Currents

- Fish often drawn in due to high water velocities at intakes
- Fawley flume/ water tunnels allowed measurement of aerobic and burst speeds at different temperatures
- Over 20,000 individual measurements on marine and f/w fish made at Fawley
- Aim was to allow intake designs to be tailored to species, age groups and seasonality

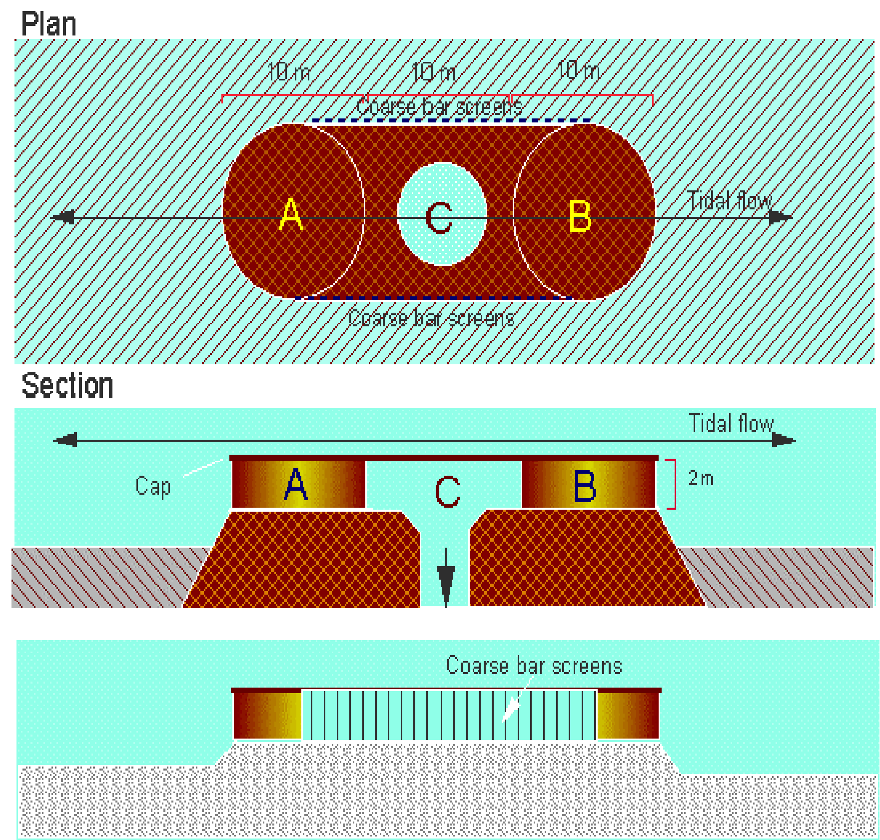
Species	*All Age Groups*				*Age 1 and older*			
	Temp °C				*Temp °C*			
	2.5°	*7.5°*	*12.5°*	*17.5°*	*2.5°*	*7.5°*	*12.5°*	*17.5°*
	Speed: cm s^{-1}				*Speed: cm s^{-1}*			
Herring	30	40	50	60	50	65	80	94
Cod	15	30	40	55	30	52	74	95
Whiting	10	25	40	50	35	55	79	102
Pout	8	15	20	29	34	60	83	105
Plaice	8	15	20	30	28	48	67	92
Flounder	10	20	30	40	28	46	66	86
Dab	2	10	20					
Sole	5	15	20					
Bass	20	35	50					
Grey Mullets	20	35	50					
Sand Smelt	10	20	30					

Figure 8.1 Measuring fish swimming speeds in a water tunnel (Fa

Improved Design for Offshore Intake Heads

Low-velocity side-entry (LVSE) Concept Design

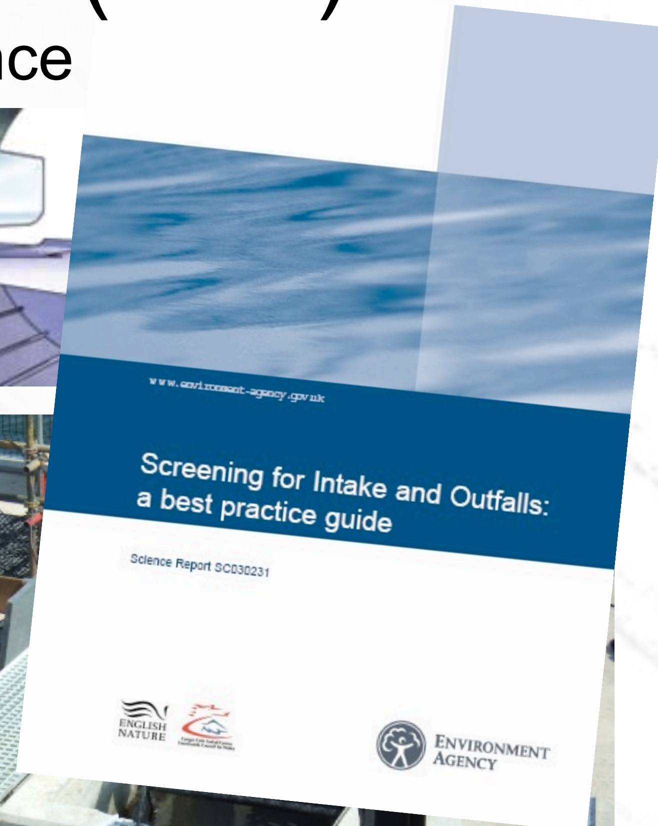
- Early intakes (SZA) of 'plughole' design bad for fish
- Velocity-cap avoids vertical currents and reduces pelagic fish entrapment
- Side-entry design to stabilise intake velocity control in tidal currents
- New low-velocity side-entry (LVSE) intake concept developed and flume tested at Fawley
- Concept intended just as a starting point for NNB designs



Fish Recovery & Return (FRR)

Giving Fish Another Chance

- Best Practice guidance reviewed international good practice and made design recommendations for each element of the system, including:
- Screen materials
- Screen bucket design
- Launder construction
- Outfall design, etcBest Practice followed in all recent CCGT station builds
  - **Barking, Great Yarmouth, Shoreham, Marchwood, Staythorpe, Pembroke**
- Progressive refinements made with experience



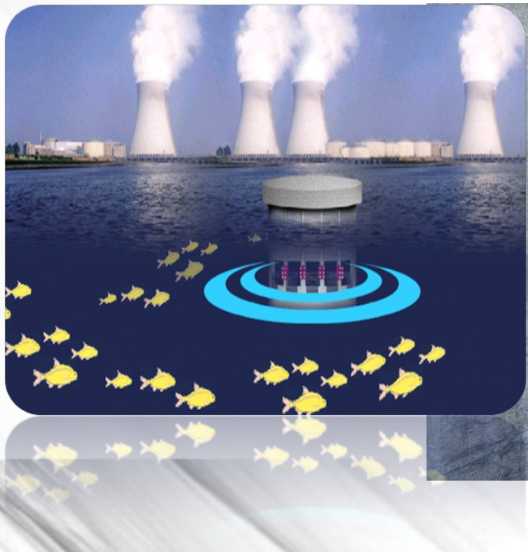
Development of Acoustic Fish Deterrent Systems

- AFDs recognised as the only likely solution for fish deflection at high flow intakes where fine screening impractical
- From 1988 FARL undertook AFD research in the lab, on fish farms and on power stations with good results, depending on fish type
- Fish Guidance Systems (FGS) was set up in 1994 to develop a suitable product for industrial use
- AFDs now in widespread use at intakes of all kinds

Development of Acoustic Fish Deterrents (AFDs)

- AFDs work by emitting a repellent sound field around or in front of intake openings
- AFDs work best with 'hearing specialist' fish such as sprat, herring, shad, cyprinids (typically >80%)
- Addition of strobe lights can help deflect other species in less turbid water, especially eels (FGS's '*SILAS*' system)

Solent News & Photo Agency
DAILY EXPRESS CITY PAGE PICS.
FISH GUIDANCE SYSTEMS STORY. LEFT TO RIGHT, WITH THE FGS 30-600 SOUND PROJECTOR, ARE DR ANDREW TURNPENNY, DR JEREMY NEDWELL AND DR DAVID LAMBERT.
BEHIND THEM LOOMS FAWLEY POWER STATION NEAR SOUTHAMPTON.
PIC BY CHRIS BALCOMBE
SNA210801



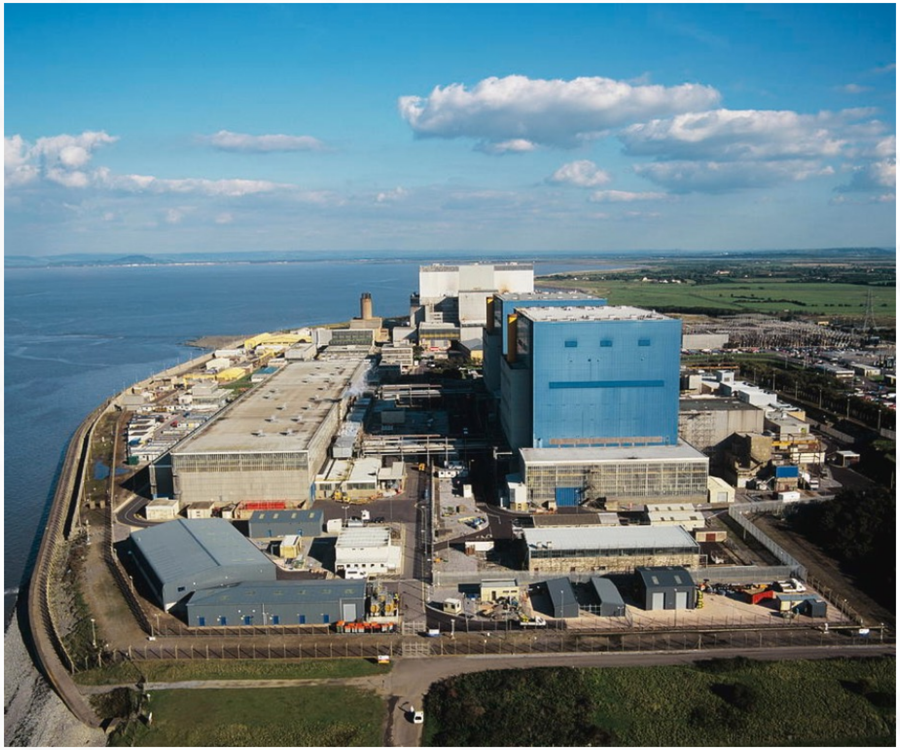
AFD Sound Projector Installations

Doel (left), Pembroke (right)

Landmark 6: New Nuclear Build (NNB) and British Energy Estuarine & Marine Science (BEEMS) Programme

1990s, A Sea Change: Privatisation and the 'Greening' of Nuclear

- Electricity privatisation made nuclear a hard sell due to nuclear waste and safety issues and was a turning point
- Nuclear Electric plc (NE) 'greening' policy to make non-nuclear aspects of their operations as green as possible, even though eg impact on stocks deemed to be low
- At the same time Habitats Directive and WFD were changing assessment pripirities



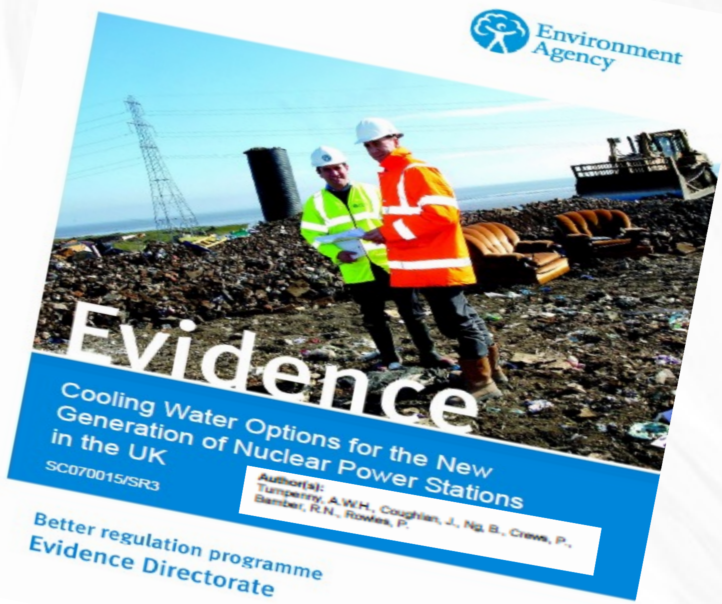
BEEMS and BEEMS Expert Panel

- In 2007 Government announced new nuclear build (NNB) programme on existing nuclear sites (**Hinkley, Sizewell, Bradwell, Oldbury, Wylfa, Sellafield**)
- BE/EDF funds BEEMS marine science programme managed by Cefas to research areas of uncertainty and establish Best Practice within NNB programme
- An Expert Panel of Regulators, academics and industry specialists set up to provide oversight
- The BEEMS programme has provided a vast body of scientific data and advice used in NNB assessment & permitting

BEEMS

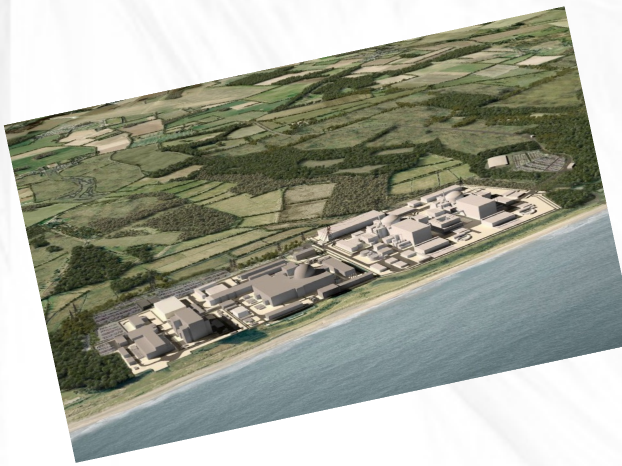
British Energy Estuarine & Marine Studies

Environment Agency 2010 Cooling Water 'Evidence' Guide



- Based partly on 2005 BP Screening, later developments and outputs of BEEMS, the document:
- Provided up-to-date to review of international good practice
- Covers impingement, entrainment and all other aspects relating to cooling water use
- A key aim was to offer guidance to regulatory permitting process for NNB and other large power station projects

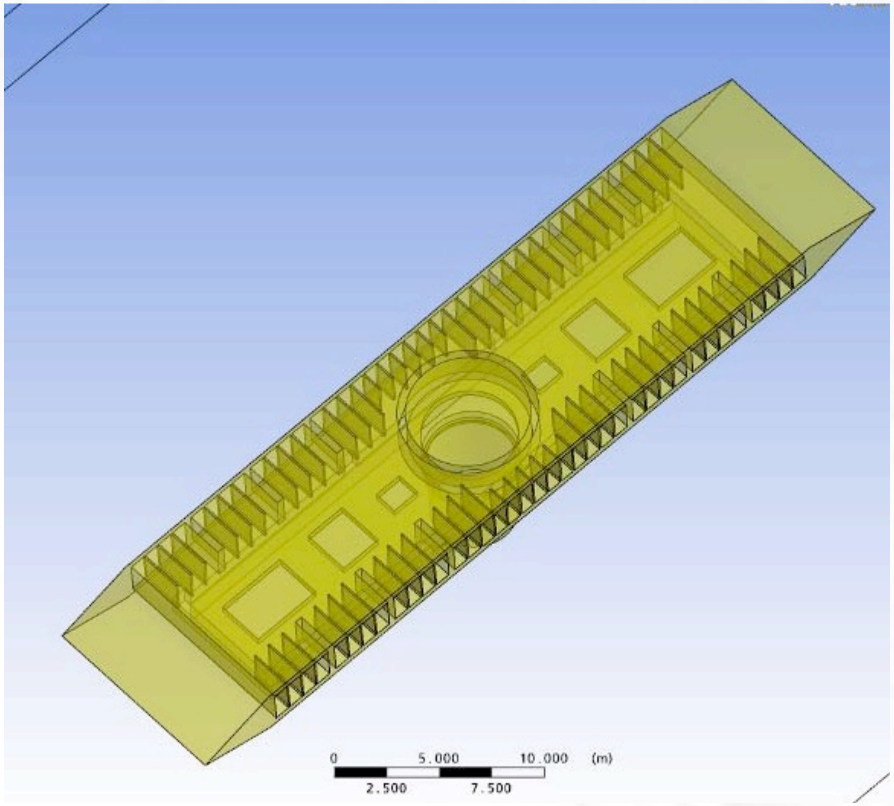
Realisation of Best Practice at NNB Sites

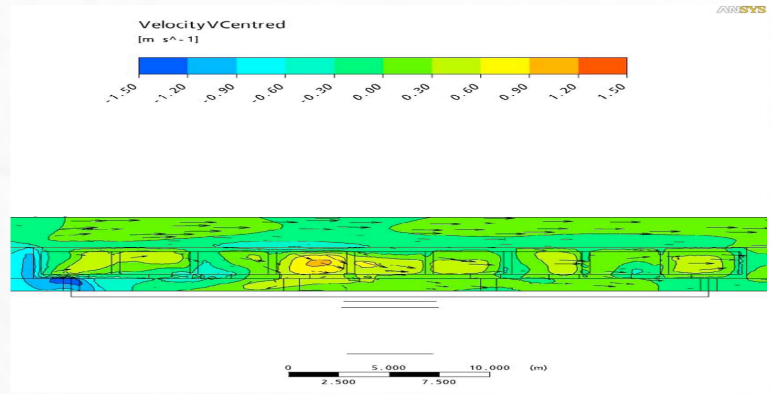


The Hinkley Point C Intake Head

Elaboration of the LVSE Concept into an Engineered Reality

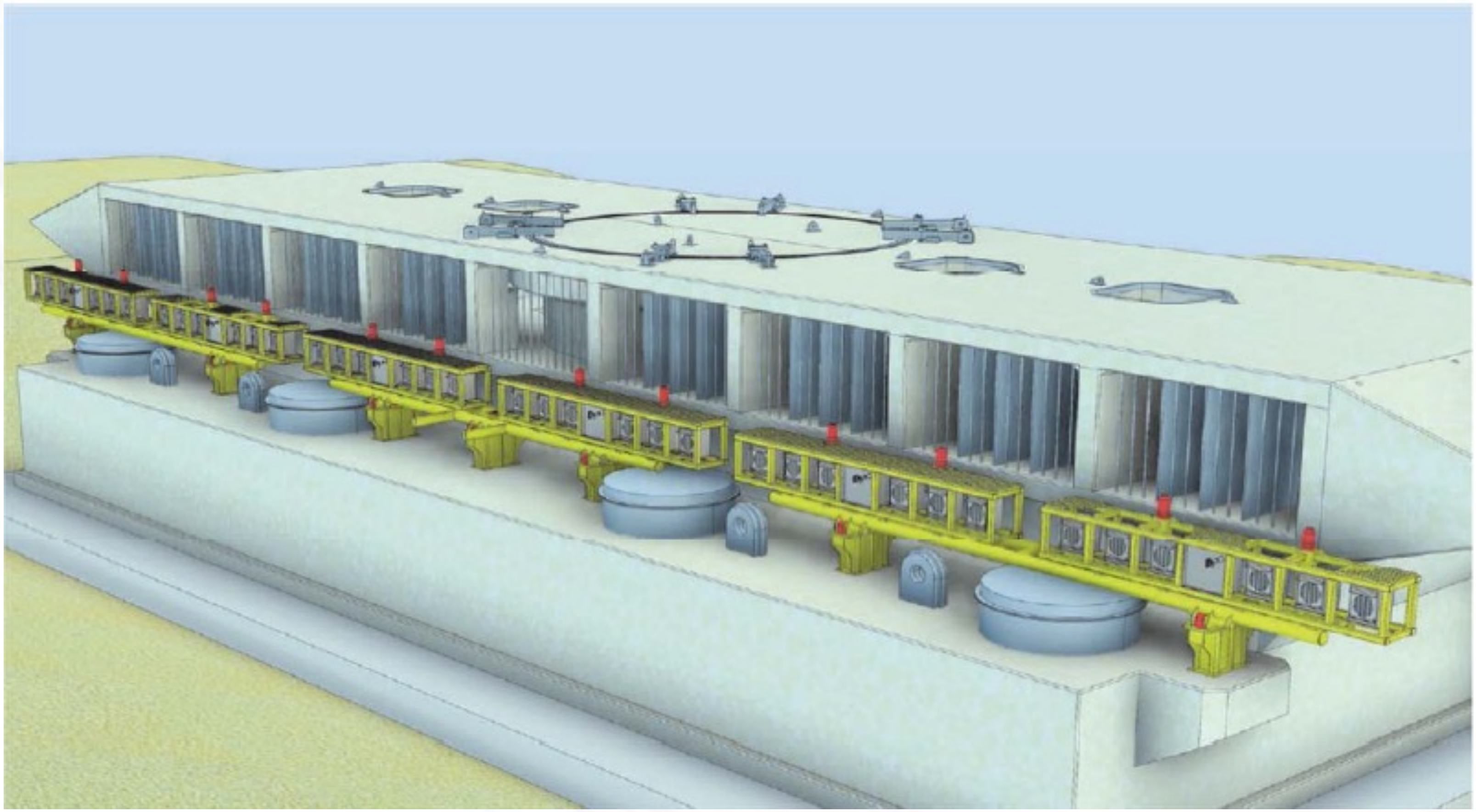
(Jacobs Engineering, HR Wallingford, EDF)





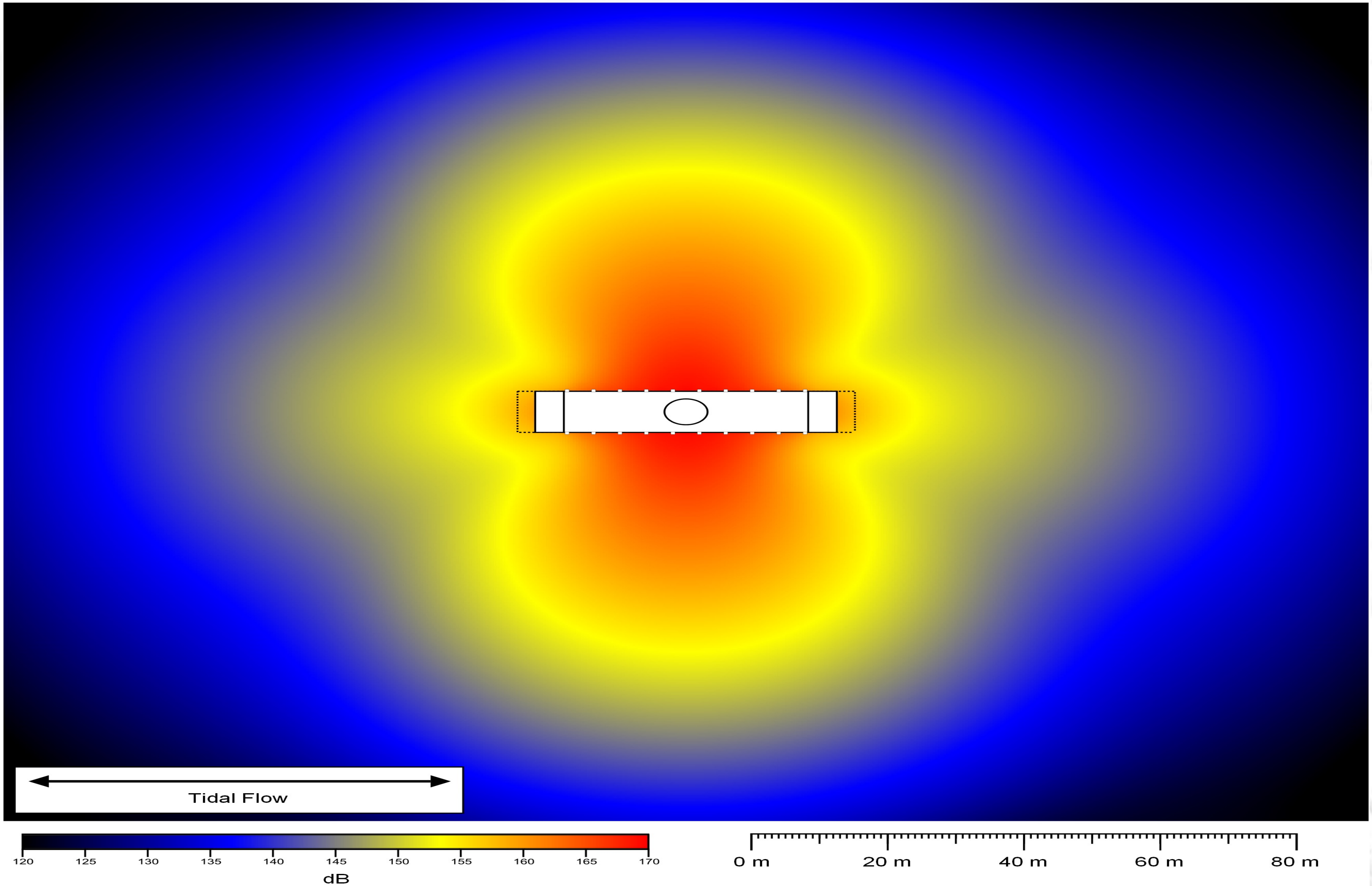
- Compliant with nuclear safety
- Constructable in a dockyard
- Meet velocity criteria around the tidal cycle

Example of AFD Installation on LVSE Head



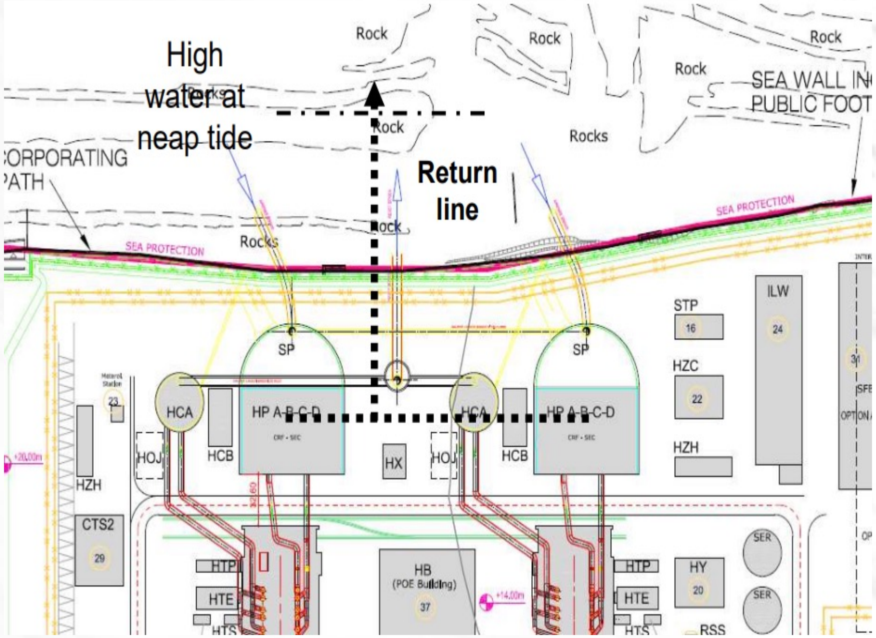
PrISM Model of Sound Field for Offshore Head

(dBre1uPa at mid intake depth: courtesy Fish Guidance Systems Ltd)



Overcoming FRR Design Issues at HPC

- Nuclear stations have additional issues not found on CCGTs
  - **Larger CW flows**
  - **50mm forebay bar screens**
  - **Pipe cannot penetrate sea wall, so elevator required**
- Comprehensive analysis of FRR issues undertaken by EDF allow FRR to be viable at HPC and other NNB sites



2013 HPC Development Consent Order

The Hinkley Point C (Nuclear
Generating Station) Order 2013: S.I. 2013:248 (as amended)

The Planning Inspectorate

HinkleyPointC
Helping Britain Achieve Net Zero
EDF CGN

- The DCO for Hinkley Point C granted in 2013 sets out specific commitments relating to minimisation of impacts on fish during cooling water abstraction
- These include the incorporation of AFD at the intake points, LVSE head designs and FRR facility with dedicated return line
- The commitments are **fully compliant with EA Best Practice**
- A satisfactory conclusion of the design and planning process!

Landmark 8: EDF Apply to Remove Requirement for AFD

15th February 2019

HINKLEY POINT C PROJECT
CASE FOR REMOVAL OF THE REQUIREMENT TO INSTALL AN ACOUSTIC FISH DETERRENT

Water Discharge Activity Environmental Permit Variation Application or Acoustic Fish Deterrent Removal

Environmental Permit EPR/HP3228XT

EDF's Position – in a Nutshell

- *“Engineering and health and safety assessments also prepared to support the optioneering and detailed design of the intake arrangements have informed the decision that an effective acoustic fish deterrent technology is not available for application in the offshore environment at HPC”*

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- *“The revised predictions of impingement effects at HPC confirm that the current detailed design of the intake heads, exclusion system and the fish recovery and return system will result in negligible effects on ecologically or socio□economically important species.”*

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2021-22: HPC AFD Public Inquiry

SoS rejects application by EDF to omit AFD

- In Sept 2022 SoS rejected the application to remove AFD from the permit. But EDF do not plan to include ADF.
- Environment Agency finds it has no powers to regulate abstraction from estuary of sea waters below the LW mark, hence have limited options to impose mitigations.
- It remains to be seen how this apparent permitting failure will affect fish populations and estuarine ecology over the lifetime of the station, or whether compensatory measures can be enforced to offset risks.

Is Direct Seawater Cooling Still BAT?

- EU BAT reference for Industrial Cooling Systems recognised direct seawater cooling as BAT for coastal stations
- In 2008 Cambrensis, reviewing the Pembroke CGGT case on behalf of CCW, challenged this, suggesting it was no longer defensible
- The 2010 EA Cooling Water Evidence reviewed the case and concluded as follows:

(CCGT) power station at Pembroke, the findings of our study indicate that direct cooling can be BAT for estuarine and coastal sites, provided that best practice in planning, design, mitigation and compensation are followed. The potential BAT-status of direct cooling has essentially been preserved owing to improved understanding of survivability of the entrainment process, and substantial developments in impingement mitigation techniques since the BREF was written. As per the BREF advice, there may

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- I will leave further discussion of this important point to Adam Waugh in Wednesday's session!

So where has 50 years got us?

We have the ways, but do we have the will?

And Finally....Fish Entrainment and CW System Passage

- Screening is impractical for fish eggs and larvae at large seawater cooled stations
- Instead emphasis is on siting intakes in low-risk locations
- Impacts assessed using EAV methods
- Survival prospects investigated using the Entrainment Mimic unit, which simulates physical, thermal and biocide stresses of passage
- Some hardier lifestages can survive these stress levels

Species	Stage	%Mortality at 0.2 ppm TRO and ~10°C ΔT (%)	Stressors causing significant mortality
Crustacea			
Acartia tonsa (Copepoda)	Adults	20	Pressure, TRO
Crangon crangon (common shrimp)	Larvae	25	TRO with°C
Homarus gammarus (lobster)	Larvae	8	Physical damage
Elminius modestus (barnacle)	Nauplii	0	
Fish			
Dicentrarchus labrax (sea-bass)	Eggs	46	ΔT
Dicentrarchus labrax (sea-bass)	Larvae	44	TRO, ΔT
Solea solea (Dover sole)	Eggs	7	Pressure with ΔT
Solea solea (Dover sole)	Postlarvae	92	TRO, ΔT
Psetta maxima (turbot)	Eggs	7	Pressure with ΔT
Psetta maxima (turbot)	Larvae	70	Physical damage
Anguilla anguilla (silver eel)	Larvae	52	TRO[a]
Mollusca			
Crassostrea gigas (Pacific oyster)	Larvae	95	TRO
Mytilus edulis (common mussel)	Larvae	0	
Mytilus edulis (common mussel)	Spat	35	TRO

[a]eel larvae were tested at 2 ppm TRO

Landmarks 1970s-2020s

1970s

- Dungeness: dinner-plate fish
- US lawsuits
- Quantitative surveys- European collaborations

1980s

- Putting losses into context: EAV, commercial stock & population studies

1990s

- Development of mitigation techniques -fish deflection, intake design,& FRR
- CEGB privatisation: greening of nuclear
- 2000s
- EA Best Practice Screening Guide 2005,Rollout of Best Practice on new-build CCGTs
- NNB Programme and BEEMS EP, EA Cooling Water advisory 2010
- 2017?? HPC Development Consent Order

2020-23

- HPC AFD Public Inquiry- SoS rejects application by EDF to omit AFD