Ecological impact of Sizewell C on Marine Life

P. A. Henderson

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SUMMARY

- The assessment of the impact of the proposed Sizewell C is based on data collected from the intakes of Sizewell B. The Sizewell B studies quantified fish retained by the 10 mm travelling screens and the fish eggs and larvae sampled by a pump sampler. It did not quantify smaller fish species such as gobies, long, thin species, such as sand eel, pipefish, eel and lamprey nor the small sizes of common fish such as sprat, anchovy and pilchard.
- The result of inadequate sampling of fish that would penetrate the 10 mm mesh is that the number of fish that will be sucked into Sizewell C and injured and killed has been greatly underestimated. For abundant species such as gobies and sand eel this will have consequences for the ecology of the local area. For species of conservation concern such as eel and lamprey there has been a serious underestimation of the number killed.
- The 3 km intake system proposed, together with the filter screens and fish return system will suffer from biofouling because they will not be protected by a chlorination system. This will have serious consequences for the operation of the system. Biofouling of the screens and the fish return system is inevitable and this will result in loss of effectiveness in returning fish alive to the sea. Further, the shedding of biofouling from the surface of the tunnels is likely to have operational consequences as shells and other remains will pass across the screens and potentially lodge in the condenser system. Additionally, when the system is taken off-load for regular maintenance the biofouling in the tunnels will die and the water in the tunnels will go anoxic through decomposition. When restarted this cool anoxic water will be

discharged onto the seabed. No assessment of the impact of this suffocating discharge has been undertaken.

- A further major area of concern is the high abundance of jellyfish and ctenophores that occur in the waters off Sizewell. These result in the seasonal impingement and entrainment of many tonnes per day of planktonic gelatinous animals. These will be killed by the system and returned to the sea via the main outfall and the fish return system. No assessment has been made of the impacts of this large discharge of dead material upon the local ecology. In addition, it is unclear whether the fish return system would be able to handle this burden during periods of high gelatinous plankton abundance.

Introduction and summary of the main features of the proposed cooling water system (CWS)

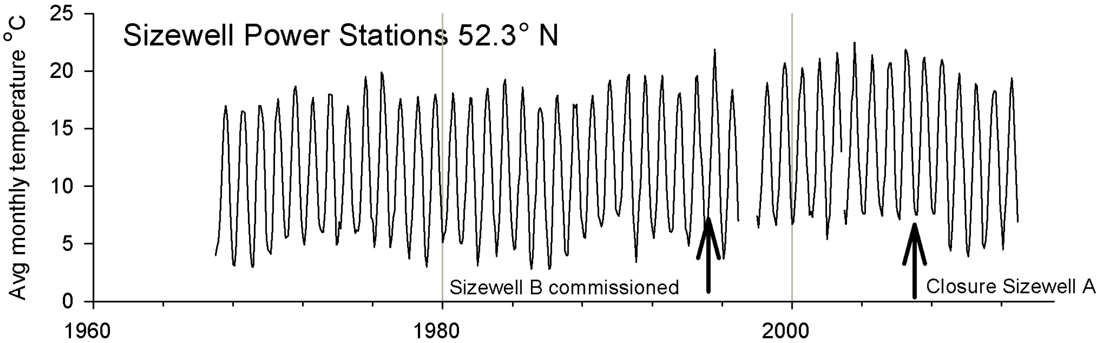
1. This document assesses the impact upon marine life of the proposed Sizewell C Nuclear Power station. During operation, the proposed Sizewell C intakes would abstract seawater at an average rate of about 132m^3/s (two x 66 m^3/s for each intake tunnel) during standard operating procedures. A maximum of 8.6% of the total cooling water flow would supply the essential and auxiliary cooling water systems and the remaining 91.4% (120m^3/s) would supply the main CWS. The proposed Sizewell C intake and outfall heads would be situated east of the Sizewell-Dunwich Bank, at around 3km from the shore, at depths of approximately 13-15m below Ordnance Datum. The intake tunnels would have a 6m internal diameter. Biofouling is a major problem at direct-cooled coastal power stations. It is proposed to control fouling by chlorination. Chlorination would occur when water temperatures exceed 10ºC. In 2030, predicted water temperatures at the Sizewell C intakes exceed 10ºC for 219 days per annum, from the beginning of May until the start of December. Towards the end of the operational life-cycle of the proposed development in the year 2085 or 2095, climate change is predicted to result in temperatures exceeding 10ºC from late April until late December, for a total of 244 days per annum.

2. Chlorination would be applied after the drum screens and the fish return system would not be chlorinated thereby preventing exposure of impinged biota to chlorine. The total residual oxidant (TRO) discharge concentration from the CW systems at the outfall would be 0.15mg/l.
3. Under normal operating conditions the cooling water discharge would have a temperature 11.6°C above seawater ambient temperature. Therefore, in summer, temperatures can exceed 30°C. A worst case scenario is when two of the four pumps are not operating but the two reactors remain running at full power. Such circumstances are unlikely, but would result in excess temperatures could potentially rising from 11.6°C to 23.2°C.
4. Sizewell C would be fitted with a fish return system (FRS). The proposed position for the FRR outfalls is ca. 475m from the forebays on the seaward flank of the outer longshore bar in water depths of 5.5-6m below ODN. Abstracted water would be transported along the intake tunnels to the station forebays where drum and band screens would impinge larger biota, including fish and crustaceans. Impinged biota would be washed off the screens and returned to sea via the FRR tunnel and headworks. Transit times along the 475m tunnel to the FRR outfalls would take approximately 13 minutes for a passive object at a discharge flow velocity of $0.3m^3/s$
5. During the 60-year operational life, each reactor unit would undergo refuelling and maintenance shutdowns (‘outages’) at approximately 18-month intervals. The duration of these outages would vary, but would typically be for up to two months.
6. This analysis is divided into 3 sections. Section 1 identifies and describes the main environmental issues of concern. Section 2 quantifies as far as possible the mortality to marine life that the proposal would produce, describing in detail why the quantifications presented by CEFAS seriously under-estimate the mortalities which will occur. Section 3 discusses the potential impact upon the marine ecosystem and points out that CEFAS, by focusing on fisheries issues, have failed to appreciate the ecological harm the plant would cause to the marine environment.

Geomorphological and physical background

7. The Sizewell shore is within a shallow coastal bay, bounded by the headlands of Southwold to the north and Thorpeness to the south. A submarine sandbank, called the Sizewell Bank, runs approximately parallel to the shore and about 2km offshore. This bank currently offers some protection to the coast from easterly storms and also tends to increase the retention of heat discharged by the B station.
8. Tidal streams off Sizewell run approximately parallel to the coast, ebbing to the north and flooding to the south. On spring tides, the maximum velocity reaches about 0.75ms^{-1} for a tidal range of about 2 metres.
9. Sizewell beach is composed of shingle. Sublittoral habitats are mostly composed of coarse sand. Bamber & Batten (1989) found these sediments to be inhabited by large numbers of *Spiophanes bombyx* a small tube living polycheat which is common in clean sand substrates.

Figure 1 The temperature of water entering Sizewell A and B cooling water



systems between 1968 and 2018. The reduction in temperature following the closure of Sizewell A is visible in the data.

10. The seawater temperature at Sizewell is highly seasonal rising from a minimum of around 2.5 °C during exceptionally cold winters to above 21 °C in exceptionally warm summers. The seasonal and long-term variation in temperature is plotted in Figure 1**Error! Reference source**

not found.. Salinity shows little variation and ranges between 31 and 35 parts per thousand.

The key environmental issues relating to the marine environment

11. In direct once-through systems, water is pumped from a source (the sea in this case) via large water inlet culverts directly to the plant. After passing via heat exchangers or condensers, the heated water is discharged directly back into the surface water (Figure 1). The heat is transferred from the turbine steam water to the coolant through the wall of the condenser tubes.

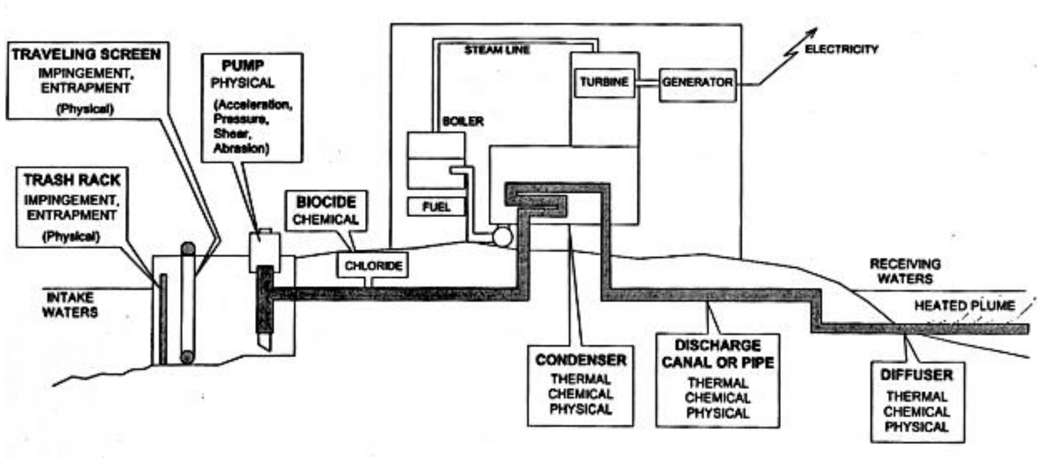


Figure 2: Schematic representation of a direct once-through cooling system, noting some of the issues discussed in the text

For once-through systems, the major environmental issues are as follows:

- Those associated with the use of large amounts of water. These include impingement and entrainment of fish and other aquatic life.
- The discharge of heated water.
- Sensitivity to biofouling and the need to add antifouling agents.
- Corrosion and scaling problems.
- The release of heavy metals.

- The use of additives and the resulting emissions to water.
- Construction of intake structures, intake canals etc.
- Changes in water flow and bed scour.
- If fish return systems are fitted, the attraction of predatory fish and birds to the discharge altering the local ecology.

Definitions of impingement and entrainment and their effects

12. It is common to separate fish and invertebrate captures at intakes into impingement and entrainment mortalities. As will be seen below, these two categories of mortality cannot be completely separated, as for some animals it is a matter of chance whether they are retained or pass across the travelling filter screens. It will be argued below that for many species the fact that only some of the population is retained on the filter screens has resulted in a gross under-estimation of the total number killed. Impingement and entrainment are therefore considered together in this section.

Impingement

13. Impingement is used here to describe the capture of fish and other organisms on the filter screens of a cooling water intake system. These organisms are washed off the screens and either collected in a trash basket for subsequent disposal or are sluiced along a channel and returned to the environment. Even when a return system is installed it will not ensure that fish and other organisms survive. Survival depends on the vulnerability of the organism to damage when it comes into contact with a hard surface. Open water fish, such as the herring family, generally have low survival following impingement, because their skins are easily damaged.

Figure 3 Rotating drum screens at a once-through seawater system. Image Dr Richard Seaby

Figure 4 Impinged fish, mostly sprats washed from a rotating filter screen into a collecting basket for disposal. Image Pisces Conservation Ltd.

Entrainment

14. Entrainment is a term used here to describe the fate of organisms that are drawn via the cooling water intake structure into the cooling system. The organisms pass through filter screens, travel along the plant’s pipe-work, and are discharged back to the environment with the

heated effluent water. Of particular concern is the entrainment of fish eggs and larvae, which may be killed in very large numbers during passage through a power plant's condensers. Recent studies show that mortality rates of entrained organisms can be as high as 97%, depending on the species and life stage entrained. It is often assumed that 100% mortality occurs.

Figure 5 Planktonic organisms entrained in a power station and collected after passage through the condenser circuit. Image P.A. Henderson

15. Unrealistically low entrainment mortality rates have been claimed in the Environmental Statement (ES). For example, for invertebrates we have the following mortality rates assumed

- for copepods are assumed to be 30% based on Entrainment Mimic Unit (EMU) evidence.
- for mysids is assumed to be 37.2% .

16. The EMU values are inappropriate for many reasons. First the entire experimental exposure time of the animals was 10 minutes. This is far too short for the Sizewell C system. The passage time along the 3 km

intake pipes is about 20 minutes, in addition time in the intake forebays, passage time across the screens and through the condensers and time in the discharge culvert when they will be exposed to elevated temperature and chlorine will make the likely exposure time closer to 30 minutes and 3 times what was studied in the EMU experiments. Second, the organisms were exposed to pressure variations mimicking conditions during passage through Sizewell B. Given the radically different design of Sizewell C, this is inappropriate.

17. The assumed mortality for mysids is even more misleading. Studies on mysids obtained from the natural population at Sizewell did not include pressure effects. When pressure effects were included, we are informed the following "**Further Entrainment Mimic Unit studies combined with statistical General Linear Models were used to predict the survival of the mysid *Neomysis integer* to entrainment conditions at Sizewell C. The effects of pressure, temperature and chlorination during conditions expected in Summer resulted in 41% to 51% survival of adult N. integer in comparison to 74% in controls (Ref. 22.84).**" These results are of no value for Sizewell as *Neomysis integer* is not amongst the common mysids present: these are as follows:

- *Schistomysis ornata* (Sars)
- *Schistomysis spiritus* (Norman)
- *Gastrosaccus spinifer* (Goës)
- *Mesopodopsis slabberi* (van Beneden)
- *Acanthomysis longicornis* (Milne-Edwards)
- *Siriella armata* (Milne-Edwards)

For fish eggs it is generally assumed that mortality is 100%. However for sole and bass it is assumed to be 80% and 60% respectively. It is unclear what has been assumed for larval fish. In para 22.8.507. it is stated that "**To be precautionary, the worst-case for larvae (assumption of 97% egg mortality) was used.**" It is impossible to understand what 97% egg mortality has to do with larval mortality.

Underestimation of juvenile fish entrainment

18. Entrainment impacts have been seriously underestimated because of the under-sampling of juvenile fish. In the ES it is stated that "**Limited numbers of some species were entrained**" and that "**It has been assumed**

that juvenile fish are 30mm at time of entrainment, based upon average size distribution data for fish impinged on Sizewell B drum screens."

19. The problem arises because impingement sampling only retains fish which do not penetrate the 10 mm mesh used on Sizewell B intake screens. Entrainment sampling was undertaken with a pump sampler placed in the intake forebay. This is an effective sampler for non-swimming life stages (eg eggs) and weakly swimming stages such as fish larvae. It is an ineffective sampler for actively swimming juvenile fish and never catches larger fish which are strong swimmers. To illustrate the problem I will consider 2 highly abundant species groups, sand gobies and sprat. Gobies are dominant fish in shallow coastal water communities throughout the world; in shallow northern European waters, sand gobies of the *Pomatoschistus minutus* species complex (Webb, 1980) are highly abundant and have been found to be important as both predators and prey.

Sand gobies

20. The first point to note is that sand goby is not a species. The ES treats it as a species which is incorrect. The *P. minutus* species complex in North Atlantic waters comprise 3 species *P. minutus, P. lozanoi* and *P. norvegicus*. P. norvegicus is an offshore species found at depths > 18 m. It would be unlikely to be caught by the Sizewell B intakes but may well be sucked into the offshore C station intakes. P. minutus and P lozanoi are closely related species: studies by Hamerlink in the 1980s demonstrated that these species had notably different ecological characteristics. P. lozanoi is smaller and predominately feeds on mysids. Mysids are highly abundant at Sizewell.
21. The filter screens have a solid square mesh of 10 mm and retain no sand goby less than 20 mm standard length (SL). Using the equation of Turnpenny (1981), a 10 mm mesh would retain all sand goby greater than 87 mm SL, which is above the maximum size observed at Sizewell. We can therefore immediately conclude that the majority of sand goby sucked into the intakes will not be retained in the impingement samples. From studies undertaken at Hinkley Point the

change in the proportion retained with size is shown in Fig 1. Between 40 to 87 mm SL retention rate rapidly increases, it is determined by both the orientation of the fish on the screen and also the presence of weed and other debris which block the screen and entangle the fish. The sigmoid curve plotted in Fig. 1 can be used to correct for mesh penetration.

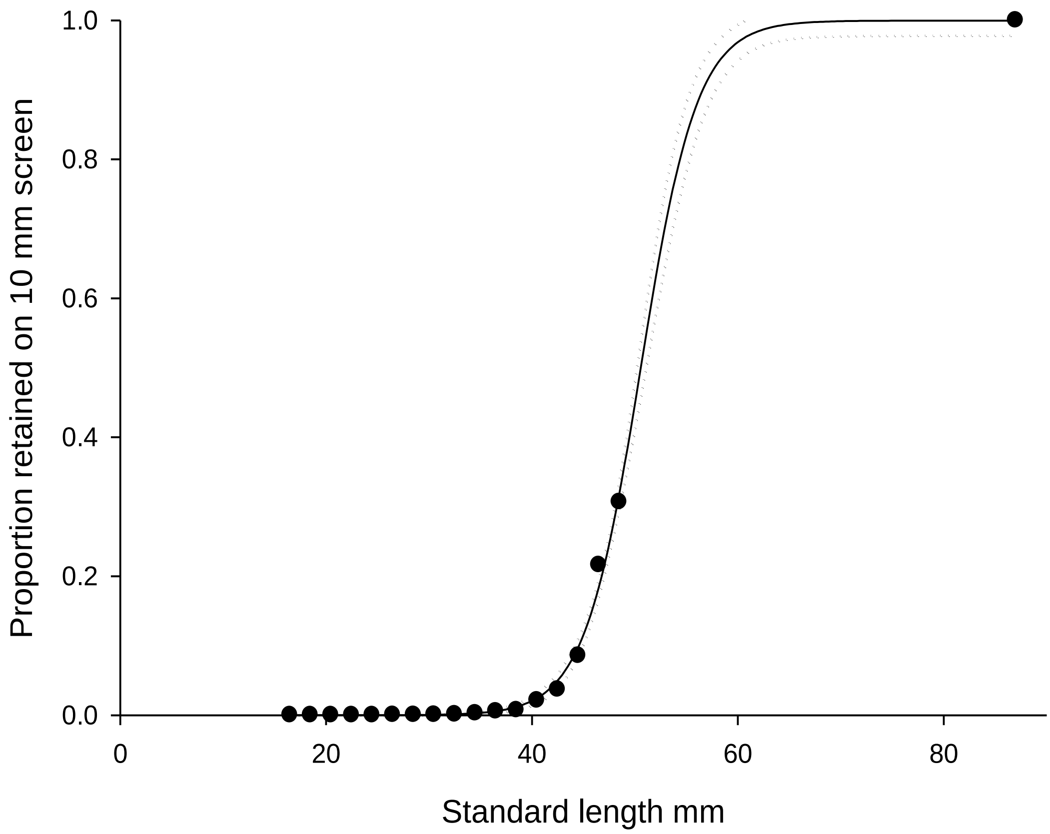


Figure 6 The change in the proportion of sand goby *Pomatischistus* sp retained on a 10 mm square mesh. The data were derived from observations undertaken in November by comparing the size distribution of plankton samples which retained the full size range with samples from the 10 mm screen. The sigmoid curve was fitted by regression and the dotted lines are 95% confidence limits.

22. Studies at Hinkley Point show that in October sand goby impinged on the 10 mm screen ranged in size from 20 to 65 mm SL. Thus only the largest individuals (which are *P. minutus*) have a high probability of being retained. Using the mesh penetration data, an impingement

estimate of 100 individuals represents a total entrainment of 1.7×10^5 individuals in the size range 20-65 mm SL. For each sand goby impinged approximately 1700 pass through the system. These individuals are too big to be caught by the pump sampler so have not been estimated by CEFAS.

23. We can give approximate calculations for the true impingement and entrainment of sand goby and compare them with the values presented in the ES. These values are given in the table below. The total number of sand goby killed each year is not about 153 million, but approximately 802 million. This difference has a profound effect upon the conclusions reached about the ecosystem impacts of the plant.

	Entrainment and impingement estimates CEFAS	Corrected for mesh penetration
larvae	133,327,662	133,327,662
Juveniles generally <20 mm SL	19,466,620	19,466,620
Larger individuals > 20 mm SL	381,612 (impingement)	648,740,400
Total	**153,175,894**	**801,534,682**

Sprat

24. Similar calculations to those presented in detail for sand goby can also be made for sprat. To illustrate the point I will use data from a study of mesh penetration of sprat undertaken using data from Southampton Water which was used to illustrate the difference in retention between a 5 mm and 10 mm mesh. I use data presented by Turnpenny (1981)

for the size distribution of sprat in Southampton Water in June (Fig 2) which shows that on a 10 mm mesh as used at Sizewell B spat need to be > 70 mm SL before they are always retained on the 10 mm filter screens.

25. Consider a situation in which 10^4 juvenile sprat > 20 mm SL are caught per day, given the size distribution shown in Figure 2, only 187 would be impinged on a 10 mm mesh. Unfortunately, sprat > 30 mm SL will be inefficiently caught by the entrainment pump sampler and so, as in the case of sand goby, the total entrainment mortality has been greatly underestimated.

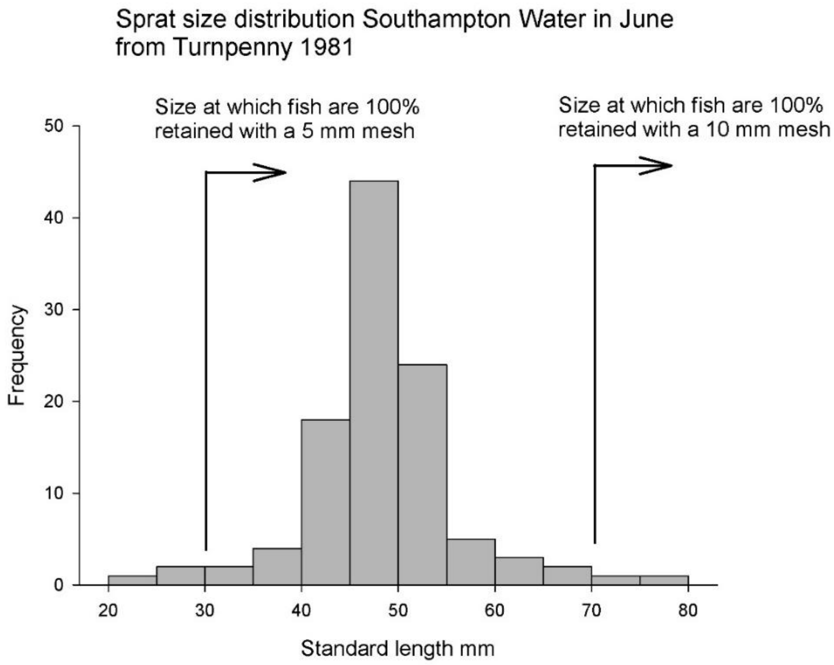


Figure 7 The size distribution of sprat in Southampton Water showing the size at which they are retained on a 5 and 10 mm mesh screen. Data from Turnpenny (1981).

26. I therefore conclude that the total mortality of sprat has been greatly under-estimated because the entrainment of juvenile sprat between 30 and 70 mm SL has not been sampled by CEFAS.

Other common species for which mortality has been greatly underestimated

27. It is inevitable that because of penetration of the 10 mm mesh that mortality associated with other small species will be greatly under-estimated. Examples include, sticklebacks (3 species), gobies such as transparent, crystal, painted, black and rock, butter fish and viviparous blenny.
28. Another class of fish which has been greatly underestimated are those with a long, thin body form that can penetrate the mesh as adults or late-stage juveniles. These include the abundant Nilsson's, greater and snake pipefish. Nilsson's pipefish is particularly abundant at Sizewell and is regularly recorded in impingement samples. The vast majority of pipefish will penetrate the screens so the number recorded in the impingement samples is probably a tiny fraction of the total that are killed. Another group of long, thin, fish which are common and have been grossly under-estimated are the sand eel, a number of species of which occur off Sizewell. ~~Finally~~, In addition, eel have certainly been underestimated as a wide size range occur in the sea and even quite long eel can wiggle through a 10 mm mesh.
29. Finally, the argument presented for the under-estimation of sprat also applied to herring, anchovy and pilchard. The situation with respect to herring is particularly noteworthy as many of the juvenile herring catch at Sizewell almost certainly derive from the local River Blackwater inshore population.

Species of conservation concern for which entrainment has been under-estimated

30. In the ES, the following statement is made: "**Smelt, twaite and Allis shad, river and sea lamprey, sea trout and Atlantic salmon are not present at the vulnerable life stage/size and do not enter the marine environment until they are too large to be entrained. Therefore, the population of these species are not considered at risk of entrainment.**"

31. Because of the penetration of a 10 mm mesh by juvenile fish this statement is completely erroneous. Juvenile smelt are recorded as impinged at Sizewell and appreciable mesh penetration of individuals less than 70 mm SL will occur. So they will be entrained. Similarly, both river and sea lamprey animals in excess of 200 mm in length will penetrate the 10 mm screen mesh and so will be entrained as lamprey below this length are found in inshore waters. Lamprey below this size do occur at Sizewell and so will be entrained. **I conclude that the entrainment of lamprey does occur and has not been estimated by CEFAS.**

Jellyfish and Ctenophores impingement and entrainment

32. Both jellyfish and ctenophores occur in considerable quantities in the waters off Sizewell and are reported in large quantities on the power station screens. There were frequent large ingresses of *Pleurobrachia pileus*, and possibly two other species known to occur inshore in the southern North Sea, *Bolinopsis infundibulum* and *Mnemiopsis leidyi*. Jellyfish can also be highly abundant, and in one 24-hr period in July 2009, > 2200 kg of jellyfish were impinged. The occasional ingress of jellyfish is notable, as cooling water filters at power stations have in recent years been blocked by jellyfish swarms. The dominant species captured is *Aurelia aurita*. Other species recorded in 2009 were *Chrysaora isosceles* and *Cyanea capillata*.
33. There have been recent concerns that jellyfish numbers have been increasing and the available data was reviewed by Purcell (2005). There is good evidence that climate change influences jellyfish abundance. Lynam et al. (2004) showed strong inverse correlations of *Aurelia aurita* bycatch in June–August from two locations in the North Sea with the preceding December–March North Atlantic Oscillation Index (NAOI). In a subsequent analysis (Lynam et al., 2005), a negative correlation between the NAOI and maximum abundance of *Cyanea capillata* was also found.
34. While it is tempting to blame recent climate change and anthropogenic disturbance for the occasionally huge densities of ctenophore and jellyfish observed on the east coast in the vicinity of Sizewell, it should be noted that high densities have been recorded for many years. For example, in June 1973 Riley recorded a *Pleurobrachia pileus* density of 28.44 individuals/m^{-3} in the sea off the Sizewell A intakes. At this density, Sizewell B when operating at full capacity would entrain

approximately 5.11 x 10^6 and Sizewell C 13.5 x 10^6 *P. pileus* per hour (132 x 60 x 60 x 28.44 = 13.5 x 10^6). As these gooseberry-sized animals are delicate and do not survive contact with screens, these would be killed and discharged dead either via the fish return system or with the cooling water discharge. Densities in the range observed by Riley are not uncommon in coastal waters of the southern North Sea. Fox et al (1999) in a study of the spring plankton of the Blackwater Estuary to the south of Sizewell reported maximum densities in 1994 of 73.4m^{-3} on 19th April. In 1996, the maximum was 27.9 m^{-3} on 19th May.

35. Jellyfish also occur in the plankton off Sizewell and include unidentified medusae, the crystal jellyfish (*Aequorea victoria*), the compass jellyfish (*Chrysaora hysoscella*) and the moon jellyfish (*Aurelia aurita*). Abundance is low throughout most of the year but increases in August and September. At the Sizewell C sampling location, a September peak of 4.2 (± 3.5) individuals / m^3 was observed between 2014 -2017. This indicates that a September impingement rate of individual jelly fish would be 1.99 x 10^6 per hour (132 x 60 x 60 x 4.2 = 1.99 x 10^6). A huge number of individuals would be killed per day and the majority of these animals would be discharged via the fish return system.
36. **The huge amount of dead jellyfish and ctenophore released into the sea can be expected to have a major impact on the local ecology and has not been assessed in the ES.**

Biofouling and the use of Chlorine

37. The protection of the intake structure and the pipework of a plant from fouling by mussels and other organisms often requires the use of anti-fouling agents.
38. Bivalve animals, especially mussels, can and do settle and grow in cooling systems; their larvae and juvenile stages pass through intake filter screens. Within the system the animals can cause blockages, while detached mussel shells can cause erosion-corrosion in condenser tubes, thereby threatening plant integrity. Historically mussels had to be cleared by hand from culverts on a regular basis. Many coastal power stations control fouling by chlorination. Chlorination products

are frequently released into the receiving waters at low levels with the discharge water. Chlorination is important as it will reduce entrainment survival and will kill a high proportion of the bacteria and other micro-organisms present in the intake water.

39. The ES states the following: "**Sizewell is categorised to be a high-risk site in respect of potential fouling by marine organisms (e.g. mussels, tube worm, anemones etc) and low velocities act to enable settlement of the planktonic larvae of these organisms (which then grow into adults and their presence can restrict water flow and potentially block the cooling water system). Consequently, very low flow velocities are not suitable for the Sizewell C intake design. However, a design that is side entry and placed orthogonal to the tidal flow does not affect biofouling risk and so these elements have been retained to mitigate entrapment of marine animals.**"
40. It is clear that the inevitability of biofouling build-up on solid surfaces is accepted and one of the consequences is that a low velocity intake head which would have helped to reduce fish and invertebrate capture is not proposed.

Biofouling of screens, fish return system and intake culverts and their impact on wildlife and the power plant

41. The ES notes that: "**In contrast to the Sizewell B strategy, chlorine would not be added to the system upstream of the Sizewell C drum and band screens.**"
42. The result is that it is inevitable that the walls of the intake culverts, the fish return system and the drum and band screens will become fouled and this will have potentially major impacts on both the operation of the plant and also the local environment. First consider the scale of the fouling that will arise. The 3000 m long 6 m diameter intake culverts will each have a fouled surface area of 84,950 m^2. The total unchlorinated hard surface available to fouling organisms, including the intake head works, screens and fish return system will be around 200,000 m^2. This is the addition of a large area of novel habitat to a region characterised by soft, mobile, sediments and will result in a change in ecosystem function.

43. The threat to the power station from biofouling has been dismissed with the simple statement " **the intake tunnels for Sizewell C are very large (6m internal diameter)and are assessed to be capable of incurring some fouling without having a significant effect on flow rates (fouls occur on the walls of cooling water systems but the depth of material that can attach and survive there is finite; the large diameter of the intakes can accommodate a degree of fouling);•in addition to the large diameter, flow rates in the intake tunnels are in excess of 2m/s and at such speeds settlement of fouling organisms is very unlikely; at the drum and band screens.**"
44. The problem is that it is not the reduction in flow rates that will first impact the power station but the shedding of lumps of biofouling comprising sea squirts, mussels, oyster, barnacles, anemones, tube worms and starfish amongst other organisms. This material will both block and penetrate the 10 mm mesh screens and has the potential to block and cause erosion of condensers and other bits of the plant. The assertion that a velocity in excess of 2 m/s will make fouling unlikely is incorrect. The velocity close to the culvert wall will be less than 2m/s because of boundary effects and once fouling organisms have settled, possibly during periods when pumping rates are low, they will increase the boundary effect and rapidly colonise.
45. It is claimed that fouling of the screens will not occur because of high pressure washing. A system of low- and high-pressure washers are used at Marchwood Power Station filter screens in conjunction with the fish return system. The system was found to foul and they have been forced to install chlorination at the intake in front of the screens. I believe this will also be found to be the case at Sizewell C. A particular area of concern relates to starfish. These are rarely a biofouling problem with short intake tunnels. However, the 3 km intake tunnels create a huge area for starfish to colonise. When they are washed onto screens they attach tenaciously and are hard to wash off. A large starfish ingress occurred when Sizewell B first started operation. The potential for a far more serious problem at Sizewell C exists.
46. Fouling within the unchlorinated fish return system is inevitable and this will inevitably impact upon its utility and ability to return fish alive to the environment.

47. There is one major impact of fouling of the culverts which has not been considered in the ES. We are informed that, "**During the 60-year operational life, each reactor unit would undergo refuelling and maintenance shutdowns ('outages') at approximately 18-month intervals. The duration of these outages would vary, but would typically be for up to two months.**"
48. When pumping stops all the water in an intake culvert will stop moving and as the animals and plants present in the culvert die, their decomposition will remove the oxygen from the water. This will in turn cause the biofouling community on the culvert wall to perish resulting in almost complete anoxia. Initially, this might seem one solution to the biofouling problem, however it creates the problem that a large amount of shell and other remains of fouling organisms will enter the system when the pumps are restarted. From an environmental viewpoint there is the potential for a serious impact on the natural environment as the anaerobic water passes through the system and is discharged. The scale of the potential problem can be appreciated from the volume of water concerned. The volume held in a single 3000 m long 6 m diameter pipe is approximately π x 9 x 3000 = 84,823 m^3. The release of this volume of anoxic, and probably cool, water onto the seabed will likely cause widespread death to life on the seabed in the vicinity of the discharge. If both intakes are started at the same time the total discharge of anoxic water would be great than 160,000 m^3. I could find no mention of this issue within the ES.

The impact of chlorination on fish

49. The ES makes the completely erroneous assertion that, "**In line with best practice (Ref. 6.6), Sizewell C would not add chlorine to any part of the cooling system where fish are present.**"
50. This comment is made because chlorination is planned to be applied after water has passed across the 10 mm screens. As has been discussed above many fish will also pass across the 10 mm band screens and so will be subjected to chlorination. This chlorination will contribute to the mortality rate during entrainment.

The effects of thermal discharges

51. Once through cooling water systems discharge considerable quantities of warm water to the environment (for Sizewell C 11.6°C above ambient). As the density of water declines with increasing temperature, the heated water discharge initially floats on the surface so that the seabed in the vicinity of the point of discharge is often little impacted by warmed water (Figure 8).

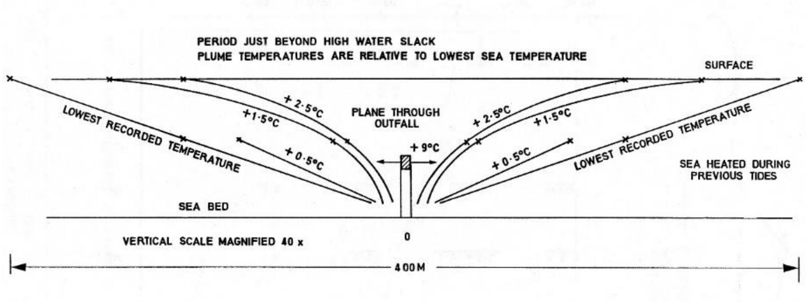


Figure 8 Cross section of a typical offshore power station discharge plume showing the general change in temperature with depth. Note that in the vicinity of the discharge point the warm water does not impinge the seabed. This diagram was based on data collected at Sizewell A, Suffolk by Parker (1977).

52. Because fish can avoid warm water it is unlikely that the thermal discharge will cause any excess mortality. However, this does not mean that the proposed thermal discharges will not have an impact upon the ecology of the region. It is well known that some fish species aggregate within the vicinity of power station discharges. The reasons are complex and not fully understood. However, there is good evidence that in winter the warmed water can be attractive, particularly if it also holds dead and dying organisms that were entrained through the cooling water system.

Changes in community composition in the vicinity of Sizewell

53. Over the period of power station sampling from the 1960s to 2012 there have been three notable changes in the North Sea inshore fish community in the vicinity of Sizewell. These are summarised below and followed by some general comments on the impact of Sizewell C on the marine ecology of the area.

The decline in elasmobranches

54. The first change is in the reduced abundance and species composition of sharks and rays. Studies undertaken at Sizewell, an open, fully exposed, marine habitat with mobile sediments, has shown a marked loss of larger elasmobranch species. An examination of historical records for elasmobranches not recorded at Sizewell since 1982 suggests long-term population change. The spurdog, *Squalus acanthias*, was not caught at Sizewell after 1982. Daan et al. (2005) noted that, while this species occurred over the entire North Sea, few have been observed along the continental coast and their distribution map indicates a general avoidance of the southern North Sea. This was not always the case~~,~~: Collins (1933) reports the species (under the synonym Acanthias vulgaris) as abundant in Suffolk, and "at times very common at Southwold." The catch per unit effort of spurdog by commercial fishermen has also declined since the 1970s (Daan et al., 2005). The nurse hound *Scyliorhinus stellaris* is reported by Daan et al. (2005) as "extremely rare". While this species was probably never abundant; Collins (1933) states that it is taken rather rarely by trawlers, but at Aldeburgh he notes it is "common at rare intervals by long-lining". The numerous historical records for the Suffolk coast indicate a 20th century decline for nurse hound. Daan et al. (2005) state that cuckoo ray, *Leucoraja naevus*, is largely restricted to Scottish waters with a southerly extension along the English coast. This was probably always the case as the species is not reported by Collins (1932) and captures at Sizewell in 1982 are probably of no significance in terms of long-term trends. The same is true for the undulate ray, *Leucoraja undulata*, which Daan et al. (2005) note is only known from a single record from the Norfolk coast. Two elasmobranches, the lesser spotted dogfish, *Scyliorhinus canicula*, and thornback ray, *Raja clavata*, have remained abundant. The general decline in rays in the North Sea since the 2nd World War has previously been noted by Walker & Heessen (1996) who implicate over-fishing as the cause and note that "thornback ray virtually disappeared from the Dutch coastal area in 1958". It is curious that thornback ray remains abundant in British waters which are also heavily fished. One elasmobranch, the starry

smooth hound, *Mustelus asterias*, has greatly increased in abundance in impingement samples between 1982 and 2011. Daan et al. (2005) also show an increase in the catch per unit effort of *Mustelus* sp. in the 1990s. Collins (1933) notes occasional records since 1895 suggesting the species was uncommon off the Suffolk coast in the early 20th century. The decline in elasmobranches is further demonstrated by the loss of two once common species which had already occurred prior to power station sampling in the 1970s. These are the common skate, *Dipturus batis*, which Collins (1933) describes as found along the whole coast "by no means rarely" and spotted ray, *Raja montagui*, which he also considered "common".

The rehabilitation of the Thames and the influence on the ecology at Sizewell

55. A second notable change since the 1960s has been the rehabilitation of polluted estuaries and the Thames. Water quality in the Thames Estuary was so poor that from about 1920 to 1964 that fish were absent from Fulham to Tilbury (Thomas, 1998). From about 1964 fish began to increase in abundance and species richness so that by the 1980s a fauna of similar richness to other healthy large northern European estuaries had become re-established. The return of fish to the Thames with improved water quality was documented by Wheeler (1979) using power station sampling at West Thurrock, Kingsnorth and other stations. From the mid-1960s up to 1991 between Fulham and Tilbury 112 fish species had been recorded. Power station catch rates indicate that fish densities within the Thames Estuary had recovered to levels similar to those observed in relatively unpolluted coastal waters. This productive habitat is a now a major nursery for the fish of the southern North Sea and probably a major influence on species abundance and richness in adjacent coastal waters including those off Sizewell. Abundant species spawning within the estuary include smelt, *O. eperlangus*. Smelt did not return to the Thames in significant numbers until 1977 (Thomas, 1998), although they were already abundant along the East Anglian coast and at Sizewell in 1974 suggesting the presence of fish spawned in continental estuaries. There are now a number of dominant North Sea species which use the Thames as a nursery area.

The most highly abundant are bass, D. labrax, sprat, S. sprattus, herring, C. harengus, sole, S. solea and flounder, P. flesus. There has been a marked increase in herring, C. harengus, caught at Sizewell since the 1970s which likely reflects the recovery of coastal herring stocks from overfishing. Herring larvae are now seasonally common in the Thames Basin and are probably mainly derived from the spawning ground at the mouth of the River Blackwater (Henderson & Whitehouse, 1984) and possibly a smaller spawning ground in Herne Bay.

The huge increase in bass

56. The third large-scale change in the Southern North Sea has been in the abundance of bass. As this species reaches the limit of its geographical range within British North Sea waters, recent climate warming is a candidate explanation. The present distribution suggests that it is the lack of warm summer conditions, rather than winter minimum temperature, that restricts the present distribution to the southern North Sea; the winter minimum from 50 to 55 °N is notably similar, while the summer maximum varies by about 5 °C. There is, however, no simple relationship between sea water temperature and bass abundance. The seawater temperature record over the 20th and 21st centuries does not show a pattern of warming that could explain the recent increase in bass abundance. Bass were already abundant at Kingsnorth in the Medway estuary in the early 1970s and they were noted by Collins (1932) as “not uncommon at Southwold” and commercially fished in Alde-mouth and Shingle-street in the first 3 decades of the 20th century. A partial explanation may relate to the increased availability of rich nursery grounds in the Thames Basin since the 1960s upon which great numbers of bass depend. Once the Thames estuary dissolved oxygen levels were restored, mysids and the brown shrimp, *Crangon crangon*, upon which juvenile bass feed, became highly abundant and bass rapidly colonised. It is also possible that commercial fishing in the southern North Sea changed the fish community in ways that favoured bass. For example, the decline in herring and the increase in sprat would have given adult bass increased prey. Further, the decline in other predators, such as cod, may have

increased the niche space for bass. Mankind has also created artificial habitats within which bass thrive, for example power station heated discharges are used by bass during the winter~~,~~ : they offer both a warm water refuge and feeding grounds. It is suspected that the large bass population present in the vicinity of Sizewell is attracted by the power station discharges.

Potential changes to the marine ecology linked to Sizewell C

57. The first point to note is that we do not presently have the data to make a correct assessment of the overall ecological impact. This is because the full estimates of the number of animals entrained and killed has not been estimated. It is clear, however, that the mortality of fish and crustaceans is far greater than presented in the ES and by CEFAS because they have not sampled juvenile and small fish, prawns and crabs that will penetrate the 10 mm screens.
58. It is clear that Sizewell C, if built, would kill extraordinary numbers of organisms, particularly fish, crustaceans, ctenophores and jellyfish and these dead animals will be deposited on the sea floor in the vicinity of the plant. The effect upon the local ecology will be profound as it will (1) generate a major decomposer community and (2) attract large numbers of scavengers. Oddly the ES considers the impact of dead fish (although the quantity is greatly underestimated as it does not included entrained biomass), however, the massively greater quantity of dead ctenophore and jellyfish biomass has been ignored.
59. In addition, the occasional discharge of large volumes of anoxic water will have a highly deleterious effect on the benthic communities.
60. The impact on species of conservation concern also has the potential to be far greater than has been presented. For example, mesh penetration by smelt, river and sea lamprey and eel make the estimates of the number killed highly likely to be gross underestimates. With commoner species which are given protection from over-exploitation the level of mortality that would occur is impossible to justify. For example, bass landings by anglers are controlled, yet seemingly millions of bass can be killed per year at Sizewell C with no effect. Similarly, great concern has been expressed since the 1960s for the health of the Blackwater herring population and fishery. Many of the

herring impinged and killed at Sizewell are likely Blackwater herring, a fact that is not considered in the ES.

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