

Devon and Severn Inshore Fisheries and Conservation Authority's Representation on NNB Generation Company (HPC) Limited Environmental Permit Appeal

This is a representation on behalf of Devon and Severn Inshore Fisheries and Conservation Authority (D&S IFCA) to the appeal for permit number EPR/HP3228XT/V004.

D&S IFCA object to the appeal by NNB GenCo and support the Environment Agency's approach as far as can be interpreted from the information available at this time. D&S IFCA understands that the Environment Agency has yet to make its determination. However, based on the large uncertainties identified in assessing the potential impacts of HPC on the fish assemblage highlighted in our own and other consultation responses on this matter, D&S IFCA would support the EA's refusal of the permit, as NNB GenCo have deemed to have taken place.

The main foci of our response to this appeal will be NNB GenCo's statement of the case, the SPP106 document and the TR456 document. It should be noted that D&S IFCA have not had access to the Environment Agency's technical briefs referred to and so we can only comment in general on some issues raised by NNB GenCo. D&S IFCA therefore reserve the right to add to or amend this representation.

More information on D&S IFCA can be found in Appendix A of this appeal. Appendix B contains D&S IFCA's response to the EA's 2019 consultation on this matter, much of which is relevant to and included in our representation on this appeal. The response, in full, is provided in a separate document.

1.0 The Severn Estuary Fish Assemblage and Site Integrity

1.1 Legal Aspects of the Estuary Fish Assemblage

There appears to be an omission in the Statement of the Case relating to the protection of the fish assemblage in the Severn Estuary SAC. Herbert Smith Freehills identify the 'relevant sites and species' (para 5.7-5.10) and describe the migratory fish species for which the site is designated and only refer to the estuarine fish assemblage as part of the Ramsar site. They therefore incorrectly ascertain later (para 7.2) that 'any effects on other fish species should not be relevant to the conclusion of the HRA'.

However, the 'assemblage of fish species' is a sub-feature of the Estuary feature of the Severn Estuary SAC. This assemblage was described by Bird (2008) and has specific conservation objectives. The species that form this assemblage should therefore be subject to Appropriate Assessment in their own right and are highly relevant to the conclusion of the HRA.

Furthermore, the interactions of the species in this assemblage and the way they interact with each other, the designated migratory fish species and designated habitats of the Severn Estuary SAC and SPA are of primary importance to the functioning of the Severn Estuary and the consideration of Site Integrity.

The assertion that there is 'no such thing as a biological population at the estuary level' in the TR456 report is true for some species, and untrue for others. Some fish do spend their entire life cycle in the estuary, others use the estuary for feeding,

reproduction or over-wintering (Henderson et al. 1992). The report by Bird (2008) reviews the biology and ecology of 27 species that are dependent on the Severn Estuary SAC for at least some part of their life-cycle. The habitats found within estuaries are now understood to be Essential Fish Habitat, especially for juvenile fish, therefore the part of their life spent in the estuary is critical to the overall population. Similarly, species may have a critical ecological role within the estuary even if they do not spend their entire lifecycle within it. Community dynamics are therefore an entirely relevant ecological level of integration that are central to the consideration of Site Integrity.

EC Guidance clearly states that *'The expression 'integrity of the site' shows that the focus is here on the specific site. Thus, it is not allowed to destroy a site or part of it on the basis that the conservation status of the habitat types and species it hosts will anyway remain favourable within the European territory of the Member State.'* (European Union, 2019)

The consideration of any impacts of Hinkley Point C therefore need to take place both at the correct population level and with regard to site integrity. The following section focuses on the latter the former is dealt with in section 2.4.

1.2 Site Integrity and Community Dynamics of Severn Estuary Fish

Rees et al. (2013) explore the legal and ecological meaning of the term 'Site Integrity'. They highlight the EC Guidance (European Union, 2000) which states that the integrity of the site may be defined as 'the coherence of the site's ecological structure and function, across its whole area, or the habitats, complex of habitats and/or populations of species for which the site is classified'. Rees et al (2013) demonstrate that various ecological processes at a site and network level underpin ecological integrity. Site integrity therefore requires an understanding of 'the ecosystem organisation at a location in terms of the ecosystem structure, functions, processes and connectivity, especially in relation to the features of interest and its resilience to and ability to recover from, disturbance'.

An ecological community is any assemblage of populations living in a prescribed area or habitat. A community may be of any size; the community of organisms in a rotting log or the community of plants in a deciduous forest (Krebs 2001). The community is a complex ecological unit with connections between species. The term 'fish community' is often applied to the collection of fish species which utilise an estuary, despite the fact that some of those fish only use the estuary for part of their life cycle (e.g. Elliot and Taylor 1986, Humphries et al. 1992, Henderson 2010, Schaberg et al. 2019). In fact, the term community is specifically used in the official description of the Severn Estuary EMS's designated fish assemblage (Bird 2008). The lack of consideration of processes within the Severn Estuary fish community is a particularly stark omission given that the community dynamics of fish in the Severn are among the best studied in the world (Henderson and Holmes 1987, Henderson and Holmes 1989, Holmes and Henderson 1990, Henderson and Holmes 1991, Henderson et al. 1992, Henderson and Seaby 1994, Potter et al. 1997, Henderson and Seaby 2000, Potter et al. 2001, Magurran and Henderson 2003, Henderson et

al. 2006, Henderson 2007, Henderson and Bird 2010, Henderson et al. 2011, Magurran and Henderson 2012, Henderson and Henderson 2017).

Research into estuary fish communities has been boosted in the last 20 years by discussions around developing the concept of nurseries and essential fish habitat. This work initially focused on how to define nursery areas which lead to consideration of the contributions of various nursery habitats to adult populations (Beck et al. 2001, Dahlgren et al. 2006). However, more recently there has been greater acknowledgement of the functioning of fish nurseries themselves with trophic processes, nutrient cycling and availability and the movement of nutrients by migrating animals being linked to the connectivity of fish populations within estuaries (Sheaves 2009, Sheaves et al. 2015). It is now understood that the physical and biological translocation of nutrients, migrations (ontogenetic, life history, spawning and feeding), food-web dynamics and predator prey interactions of fish in nursery areas play a crucial role in structuring biological populations, communities and assemblages and in driving the biological processes that support them (Sheaves et al. 2015). This marks a significant theoretical shift away from only considering the value of nursery areas in terms of the contribution they make to adult populations. The inclusion of the fish assemblage within the over-arching estuary feature of the Severn Estuary EMS which incorporates all aspects of the physical, chemical and biological attributes of the estuary as an ecosystem (Natural England and CCW 2009) further highlights that the fish are protected as part of a wider, connected ecosystem which is protected at the Severn Estuary level.

Henderson and Seaby (2000) identify a number of ways that the abstraction for cooling water can negatively impact a fish community and ecosystem. These include the differential mortality of different species of fish resulting in changes in competitive ability and the destruction of prey for juveniles, which leads to decreased food supply across various life-history stages. The current assessment argues that density dependence will compensate for most mortality of fish and therefore it will have negligible local impacts. However, Henderson and Seaby (2000) argue that, from an ecosystem perspective, there can never be a surplus of biological production that can be removed without impacting other parts of the system – in this case the cooling water intake is removing the production that would normally have been consumed by other organisms.

In general, longer-lived, slower growing species will tend to be more heavily impacted, being replaced by faster growing competitors (Henderson and Seaby 2000). Because of the complexity of trophic structures, the outcome for particular species may be difficult to predict (Henderson and Seaby 2000). However, impingement and entrainment kill organisms at many trophic levels so that their impact is similar to a general reduction in productivity and efficiency of energy transfer. The result is that the effects of any such losses will be far greater towards the top of the food web (Henderson and Seaby 2000).

It is extremely important to note the assertion by Henderson and Seaby (2000) that 'the deterioration in measure of ecosystem health, such as species richness, or

trophic complexity, can be quite gradual and irregular and take many years to recognise. The trend is easily lost in random variation caused by events such as exceptionally cold or warm spells or lost within other man-made changes such as eutrophication or acidification'. The assertions within the assessment that no change in fish assemblage was noted when HPA intakes were shut down, are therefore not useful.

2.0 Remaining Major Uncertainties in Estimations of Impact

D&S IFCA acknowledges the significant detail and technical nature of the calculations provided by both Cefas and that appear to have been undertaken by the EA. However, little has been done to address some of the major underlying uncertainties in the assumptions underpinning any such calculations.

2.1 Uncertainty in Impact of Moving Water Intakes Offshore

D&S IFCA is encouraged to see the EA's re-working of assessments using the correct band screen and drum screen mesh size of 5mm, the failure to account for which was a large and unacknowledged error in previous work submitted by Cefas. Despite this, D&S IFCA still has major concerns regarding the scaling from Hinkley Point B to Hinkley Point C. Specifically the implications of moving the water intake 3.3km offshore remain a large source of uncertainty, as raised in our July 2019 consultation (Appendix B, Section 2.3.1).

Cefas's reliance on the current EA guidance that offshore intakes are preferable to inshore intakes is inappropriate in this case. It is increasingly recognised that even within fish nursery areas, a mosaic of habitats connected by migration corridors are utilised by fish (Nagelkerken et al. 2015, Sheaves et al. 2015). Where fish utilise intertidal habitats at high tide (such as Bridgwater Bay), they will then have to retreat to deeper water when the tide ebbs. Fish will move to deeper waters by navigating through corridors such as deep channels (Nagelkerken et al. 2015). Exactly this behaviour has been described in Bridgwater Bay where brown shrimp *Crangon crangon* (an important prey species for many Severn Estuary fish species) migrates with the rising tide onto the intertidal flats, followed by its predators. At low water, the population and its predators become concentrated within the permanent water of the estuary (Henderson et al. 2006).

D&S IFCA previously called for a greater acknowledgement of the uncertainties and risks and a requested a review of the evidence base, which appeared to be based on a very limited amount of trawling of the new intake sites. All sampling methods have limitations and these are not sufficiently taken into account when comparing the new intake sites to the current location.

2.2 Uncertainty in Performance of LVSE Intakes

The performance of the Low Velocity Side Entry (LVSE) intakes appears to be critical in the calculations for scaling fish impingement at HPC compared to HPB. However, there are no examples of this type of intake anywhere in the World. Whilst D&S IFCA therefore accepts that the calculations must be based on modelled data, there remains uncertainty as to how the LVSE will perform in reality. As the performance of the LVSE appears critical to the assessment of impingement mortality the

uncertainties should be acknowledged more clearly, and a precautionary approach adopted.

Furthermore, previous EDF documents describe the necessity of having AFDs present in order for the LVSE to deliver the benefits outlined in TR456. D&S IFCA's requests for further clarification and evidence on this matter have not been acknowledged by work presented by NNB GenCo to date. D&S IFCA supports any effort by the EA to try to address this issue, but in reality any estimate will still be based on many assumptions which does little to remove any of the underlying uncertainty.

2.3 Barotrauma

A recent review by the Environment Agency (Horsefield 2018) of their 2010 guidance document *Cooling water options for the new generation of nuclear power stations in the UK*, has provided an update on progress since 2010. This report highlights that fish injuries caused by barotrauma may arise from fish passage through long, deeply buried tunnels. Horsefield (2018) highlights the urgent need for more research to inform mortality estimates caused by this.

To D&S IFCA's knowledge, Hinkley Point C will have long, deeply buried tunnels and the issue of barotrauma and its estimated impacts on fish mortality do not appear to have been addressed anywhere. If no data are available a precautionary approach is needed, and uncertainties should be clearly stated.

2.4 Uncertainty in Stock Identity, Population Structuring and Biocomplexity

2.4.1 The Use of ICES Stock Areas

TR456 and SPP106 rely heavily on ICES stock units and the assertion that ICES stock units are the best available science and therefore fit for purpose for the use of assessing populations of fish at a single site. The suggestion in SPP106 and elsewhere that 'fish stock identities are decided after critical review of all the scientific evidence and are subject to regular peer review when new evidence becomes available' is an oversimplification of the limitations of ICES management units and the processes and procedures used to change those boundaries. In a recent paper (published in the ICES Journal of Marine Science) led by Lisa Kerr (a former Chair of the ICES Stock Identification Methods Working Group) the authors state that:

'depending on the geographic location, there may be political, legal, cultural, and social pressures that prevent revision of stock boundaries or adding complexity to stock assessments. For example, in Europe, sampling units and intensities are currently fixed by regulation through the relatively inflexible data collection framework (EU, 2008), which creates financial consequences for member states when sampling methodology is altered to accommodate a new stock area design.' Kerr et al. (2017).

Despite increased recognition of complex population structure and stock mixing, **disparities between population structure and current management units have therefore not been reconciled** (Kerr et al. 2017). Furthermore, it is increasingly recognised that resolving differences in biological and management units for fish

stocks has two elements. Firstly, the question of spatial delineation of fish stocks and, second, the discovery of significant sub structuring within stocks, with spatial subunits having different ecological and/or demographic functions (Hidalgo et al. 2017). Even for pelagic fish with a high migration potential it has been shown that reproductive isolation can be maintained even in populations exhibiting substantial mixing during larval and adult life stages (Bekkevold et al. 2005).

For some commercial species (see below) there is considerable evidence that there may be finer-scale population structuring that is extremely relevant to fish in the Bristol Channel and Severn Estuary. For many less commercially important (but potentially ecologically important species) there is likely to be even less information and more uncertainty about the stock identity or finer scale population dynamics. Here we present evidence for three species, previously presented in our response to the EA consultation.

2.4.2 Population structure in cod (Gadus morhua)

In earlier reports (TR148) Cefas acknowledge the possible presence of a smaller cod stock. More recently in TR456 Cefas state that, because no information has materialised in seven years, the possibility of a separate stock unit existing has reduced. This is an incorrect assumption. Given the scale of the Hinkley Point C development, the ready access to samples from the impingement monitoring and the relatively low-cost of modern genetic techniques it is disappointing that opportunities have been missed to fill some of these evidence gaps. Almost everywhere they have been studied complex population structure has been revealed.

Complex genetic population structure was discovered in Northwest Atlantic populations of cod. Individuals inhabiting Gilbert Bay, Labrador were found to be genetically distinguishable from offshore cod on the north-east Newfoundland shelf and from inshore cod in Trinity Bay, Newfoundland (Ruzzante et al. 2000). The genetic, life history, and behavioural differences were found to extend northward from coastal Newfoundland to coastal Labrador, and in at least two cases the population subdivision observed was identifiable at the scale of an individual bay. An investigation of cod in south Icelandic waters found that individuals do not belong to one panmictic population and that this genetic difference is stable from year-to-year (Jónsdóttir et al. 2001).

Neat et al. (2014) used information from data storage tags to study the movement of cod around the British Isles. The authors found that cod living around the British Isles are comprised of at least one more distinct population unit than is currently recognised. Some individuals were found to be migratory, whilst others were not and the authors acknowledged that finer ecological structuring, even than that identified by the tagging, might exist. The authors therefore suggest that meta-population dynamics are likely to be important for cod in the British Isles. Extensive information now exists to suggest that cod in the North Sea form a number of separate stocks (Hutchinson et al. 2001, Galley et al., 2006, Holmes et al. 2008, Neat et al. 2014) with differences relating to spatial differences and also possibly inshore and offshore structuring; adults from coastal regions have been found to originate from local

nursery areas (Wright et al. 2006). Despite this, some fish undertook large migrations; therefore, North Sea cod are likely to have a meta-population structure (Holmes et al 2008).

Recent work has revealed significant population genetic structure in Norwegian cod, throughout its entire range, that follows a trend of isolation by distance. Therefore, the current management regime for coastal cod in Norway represents a simplification of the level of genetic connectivity and needs revision (Dahle et al. 2018).

It is now acknowledged that Atlantic cod have several strategies with regard to spawning. Typically, coastal cod are non-migratory and complete their entire life cycle within a restricted geographical area. In contrast, cod belonging to oceanic populations may perform long-distance spawning migrations and release eggs and larvae that are carried with ocean currents back to the nursery grounds (Knutson et al. 2011). Differentiation at continental shelf scales has been linked to the presence of biogeographical features such as submarine saddles, channels and trenches whilst at smaller spatial scales oceanographic features have been implicated in having a role in population differentiation (Ruzzante et al. 1998).

The genetic population structure of the stock has not been investigated for cod in the Bristol Channel and Celtic Sea, but there is no reason to suppose that it would be different from every other location in the north Atlantic where it has been studied. D&S IFCA therefore believes that the assessment for cod is not sufficiently precautionary. An urgent assessment of Bristol Channel cod identity is required and a more precautionary approach should be taken than the assessments presented in TR456.

2.4.3 Population Structure in Atlantic Herring (Clupea harengus)

Herring often have complex meta-population structures with an array of local populations linked by variable degrees of gene flow which can vary substantially over space and time. McQuinn (1997) found meta-population structure within the multiple spawning populations in the northeast and northwest Atlantic. Sometimes these populations are found to spawn sympatrically, with local population integrity maintained through behavioural isolation.

Low but significant genetic differentiation was found in Atlantic herring from eleven spawning locations distributed along a longitudinal gradient from the North Sea to the Western Baltic (Bekkevold et al. 2005). The differentiation was not linked to geographical distance between populations but analyses incorporating genetic, spatial, and environmental parameters indicated that isolating mechanisms are associated with the specific salinity conditions on spawning locations (Bekkevold et al. 2005). This study offers further evidence that reproductive isolation can be maintained in marine fish populations exhibiting substantial mixing during larval and adult life stages.

In other cases, isolation by distance has been found to be the primary mechanism of genetic population structure (Mariani et al. 2005). In a study of the major herring spawning aggregations in the North Sea and adjacent waters a genetically homogeneous unit off Northern Scotland was identified, and a temporally stable

pattern of isolation by distance determined predominantly by the divergence of the English Channel and Norwegian spring spawners. However, a further study of the same populations found more complex patterns of intraspecific diversity with mixed aggregations of fish with divergent genetic and life-history characteristics (Ruzzante et al. 2006). Rather than isolation by distance Ruzzante et al. (2006) identify strong natal homing over broad geographic scales as the main mechanism for maintaining intraspecific differentiation despite mixing of populations during part of their life-cycle. Therefore, herring show a variety of levels of population structure and metapopulation dynamics, with different drivers in different locations. Additionally, there is increasing evidence to suggest that such patterns are temporally stable in some locations and very dynamic in others (Ruzzante et al. 2006).

D&S IFCA has been working with local fishermen from Somerset and North Devon, Swansea University, the Blue Marine Foundation and the North Devon Biosphere Reserve under the Marine Pioneer Programme to investigate whether there are separate herring populations in the Severn Estuary and Bristol Channel. Historic data showed that there was a separate population at Milford Haven. Local fishermen reported herring spawning around Minehead and Clovelly, something that has never been documented before on the English side of the Severn Estuary/ inner Bristol Channel. D&S IFCA are awaiting the final results from Swansea University but the following results can be shared: (D.Clarke, Swansea University pers comms):

- The herring fishery at Minehead and Clovelly takes place from September to October
- Two samples of multiple fish were collected from each site in October and December 2018
- All samples contained a significant proportion of spawning (stage VI) fish. In October both samples contained more than 40% in stage VI; in December more than 60%. So it is clear that they are spawning along the North Devon/ Somerset coastline during winter.
- Age range of the fish sampled is 3-8 years old. In both cases the age range was wider in the October samples with a more limited age range in December.
- Genetic work is ongoing and further results are expected shortly. There is some indication from early results that more than one stock may be present in the Bristol Channel.
- Therefore, it is highly likely that herring in the Bristol Channel/ Severn Estuary have some degree of separation or metapopulation structure that has been undetected up to this point. Early evidence suggests that these herring are not the same population as the Milford Haven population.

It should also be noted that fish sampled at Oldbury, further upstream in the Severn Estuary, in the 1970's were found to be spring spawners (Titmus et al. 1978). Hinkley Point therefore lies between an area of autumn spawners and spring spawners and it is unknown which subpopulations may be being entrapped at Hinkley.

*2.4.4 Population Structure in European Sea Bass (*Dicentrarchus labrax*)*

The knowledge base relating to population structure of European sea bass in UK waters shows mixed results. Whilst mitochondrial DNA has identified three lineages in European waters (the UK stock falling into one lineage), microsatellite markers assessed in 2011 did not detect finer-scale genetic structuring (Coscia and Mariani 2011). However, more recent findings using stable isotope signatures to assess population connectivity around the coast of Wales have found that there are 2 sub-populations of bass in Welsh waters, using separate feeding grounds (Cambie et al. 2016). Crucially, the study found that adult sea bass from south Wales are likely to have a restricted range of movement, not only for feeding, but also for spawning, due to the proximity of Trevoise Head (Cambie et al. 2016). According to the authors this proximity of feeding and spawning grounds is likely to result in a resident population in south Wales. Bass from the English part of the Bristol Channel were not sampled as part of this work, but the paper certainly raises questions as to the residency of Bristol Channel bass as a whole. The authors suggest that further genetic work is required to understand whether these populations mix during spawning to determine whether they are separate stocks (Cambie et al. 2016). The paper also stressed the importance of estuaries as preferential feeding areas for large bass, something that has previously been under-represented in the literature.

Early findings from acoustic tracking of bass along a 120km stretch of coastline in southeast Ireland found that the majority of acoustically tagged sea bass were detected within 5km of their release location suggesting limited movement and strong evidence of feeding site fidelity (O'Neill 2017). The study also found that nearly a third of acoustically tagged sea bass in inshore waters were resident within the area of the acoustic array for the entire period of full array deployment, including the assumed spawning season (February to June). This suggests possible spawning in inshore locations or potential evidence of the occurrence of skipped spawning. In a second study of acoustically tagged bass, this time in a large estuary (Cork harbour), sea bass displayed long-term residency (mean 167 days) and inter-annual fidelity (93% return rate) to specific areas (Doyle et al. 2017). Indeed, the repeated presence of adult sea bass at relatively discrete inshore locations on an annual basis has raised the possibility of the existence of homing ability by sea bass returning to their nursery zones (Pawson et al., 2008).

Similar patterns are emerging in the results of a similar study in the D&S IFCA's District. D&S IFCA has co-funded a PhD with Plymouth University looking at the inshore ecology of European seabass in the southwest UK. As part of the PhD the Immature Bass Acoustic Stock Surveillance (I-BASS) project has tagged 146 European bass (25-60cm fork length) across three estuaries in Devon. Preliminary results (unpublished data) have demonstrated localized movements and high site fidelity to estuaries. Distance travelled in coastal areas is variable between individuals and affected by size, however is not thought to exceed 40km. Furthermore, a high proportion of individuals (including sexually mature fish) from multiple estuaries did not conduct winter spawning migrations and maintained high residency throughout the year. Individuals that did perform winter migrations also returned to the estuary which they inhabited the previous summer. O'Neill (2017) suggests that a lack of genetic population structure within UK bass stocks suggests that some mixing still occurs, primarily in spawning locations (O'Neill

2017). However, only a few migrants per generation are required to prevent genetic separation and differences in behaviour and spatial use may still be significant in the sustainable management of the species.

2.4.5. Population Structure in Other Species

It is of concern that there is very little use of the relevant published literature on population structure within any of the reports. The result is that large and important uncertainties of the level of impact exist based on uncertainties in stock identity, population structure and the possible existence of meta-populations. D&S IFCA has reviewed three species, but additional data for other species exists. Where there is no data, uncertainties must be acknowledged.

2.4.6 Implications of Unacknowledged Population Structure

In the context of the of the assessment by Cefas on the impacts of impingement by Hinkley Point C, the failure to consider the underlying population structure means that the current assessments may overestimate the geographical distribution of the stock and the size of the relevant SSB. This in turn would result in the current assessments underestimating the percentage of the stock impacted by HPC.

However, there are wider ecological implications that are likely to operate on a variety of scales, depending on the species and the nature of the population structure. These are particularly relevant when the effects of Hinkley Point C both in combination with other developments and fishing activity within the Severn Estuary and Bristol Channel are considered, but also occurring at the spatial scale in which they are currently being considered within the impingement assessment. For example, for bass where the ICES area considered includes IVb& c, VIIa, VIId-h, numerous activities including aggregate dredging, nuclear power stations, renewable energy developments, cable laying, flood defence works and coastal squeeze are operating in addition to substantial commercial and recreational fisheries. At this scale, the impacts on multiple undetected local populations take on major significance in terms of species long-term resilience.

Even weak genetic differentiation can be significant in the management of fish stocks. Only a few migrants per generation can be sufficient to maintain genetic connectivity over evolutionary timescales, but such numbers would not be sufficient to rebuild depleted stocks over ecological timeframes (Carvalho and Hauser 1995, Mariani et al. 2005). Biocomplexity in the form of genetic population structure or the diversity of life-history characteristics and adaption to local variations in spawning and nursery habitat, may help fish populations to adjust to environmental change and make them more resilient to exploitation (Hilborn et al., 2003; Hutchinson 2008). It is now thought that even diversity in life history strategy and geographic location (not necessarily reflected in genetic population structure) contributes to the resilience of populations to exploitation. This is partly because at different times different geographic regions and different life-history strategies have been the major contributors to the overall biomass of the population (Hilborn et al. 2003).

Marine conservation initiatives or fisheries management regimes that disregard or misidentify patterns of genetic and life history differences have the potential to lead to the erosion of genetic resources or even local subunits (Ruzzante et al. 2006, Watson et al. 2011, Ying et al. 2011). This problem is especially acute for marine fish population complexes with diverse and potentially locally adapted migratory components that overlap spatially and seasonally such as, but not limited to, cod and herring (Ruzzante et al. 2000, Ruzzante et al. 2006).

Where management fails to acknowledge and preserve patterns of genetic and life-history diversity there are thought to be a number of possible negative effects for marine fish populations. These include reduced resilience in the face of commercial exploitation, disturbance and environmental change and impeded population recovery from such events, compromised evolutionary potential and reduced recruitment potential (Ruzzante et al. 2006).

It is now accepted that there is an urgent need to delineate extant patterns of within-species genetic diversity and to use such knowledge for management purposes (Ruzzante et al. 2006). Priority needs to be given to ensure that the scale at which fish stock data is collected and analysed reflects the true structuring of the species (Holmes et al. 2008). Detailed spatial and seasonal information is required for assessing the impact of spatially explicit conservation measures even for widely abundant and highly migratory species with low levels of genetic differentiation (Ruzzante et al. 2006).

D&S IFCA therefore fully support the EA's review of the scale of the assessment used for each species based on the available evidence and a more precautionary approach to the delineation of stock boundaries in this context.

3.0 SPP106 'Alternative Approach'

Devon and Severn IFCA do not support the approach of the 'reasonableness tests' presented in SPP106. They contain inappropriate generalisations and comparisons and are not precautionary or evidence-based in their approach.

Similarly, the 'alternative approach' of simply looking at long term trends in fish abundance compared in isolation to Hinkley Point abstraction rates is deeply flawed. This approach ignores published evidence derived from sampling at Hinkley Point B which argues that overall abundances and diversity of fish in the estuary are increasing due to environmental shifts related to climate change (Henderson 2007, Henderson et al. 2011) Sediment and water quality in the estuary has also improved, particularly with regard to heavy metal contamination, and this may partly explain the increase in fish numbers (Bird 2008). It is also interesting to note that Henderson and Bird 2010 note that 'the overall increase in fish abundance observed may reflect a general improvement in water quality and a reduction in other anthropogenic impacts such as mortality in cooling-water intakes. Certainly, the increase in abundance has occurred during the same time period as an overall decrease in water abstraction from the Severn Estuary (see Figure 4, TR456 report).

Not being able to detect a strong signal for an impact from water abstraction does not mean that there is no effect. The complexity of the ecosystem may mask the effects, but does not negate them. There is also no baseline data for an unimpacted fish assemblage as all the quantitative data for the Severn Estuary fish assemblage has been collected since water abstraction by power stations commenced in the estuary.

It is extremely important to note the assertion by Henderson and Seaby (2000) that ‘the deterioration in measure of ecosystem health, such as species richness, or trophic complexity, can be quite gradual and irregular and take many years to recognise. The trend is easily lost in random variation caused by events such as exceptionally cold or warm spells or lost within other man-made changes such as eutrophication or acidification’. The assertions within the assessment that no change in fish assemblage was noted when HPA intakes were shut down, are therefore not useful. It also highlights that changes may occur which will be extremely difficult to detect at a local level. At a population level the amount of the variation in the system (natural, and man-made) makes it extremely unlikely that trends will be detected which are directly attributable to fish mortality at Hinkley Point, but that does not mean that HPC is having a negligible effect.

4.0 Sustainability and Adaptive Management

In TR456 the water intakes for Hinkley Point C are compared to a ‘small inefficient trawler’, however the intakes differ from a trawler in one crucial way. Fisheries, particularly those in European Marine Sites, are increasingly employing adaptive management, such as the flexible permitting byelaw approach developed by D&S IFCA.

Adaptive management is seen as a key tool for effectively implementing the Ecosystem Approach (Farmer et al. 2012) and is increasingly seen as an integral part of sustainable management. Adaptive management acknowledges the high levels of uncertainty in natural systems and the difficulties of making decisions based on this uncertainty. It provides a framework for a flexible and pragmatic approach to marine management, allowing sustainable development whilst adapting management and policies to respond to new information (Farmer et al. 2012).

In the case of either new evidence about the state of a fish stock (e.g. the discovery of finer population structure, or a decline in abundance) fishing effort can be reduced using a number of mechanisms. At a Common Fisheries Policy level this can be slow, but with D&S IFCA’s Permitting Byelaws, new measures can often be brought in to change management within a few months. If new information comes to light regarding the fish stocks in the Severn Estuary, or if the intakes catch more fish than expected, or survival through the FRR is lower than expected, or climate change affects population dynamics in the estuary, there is no adaptive management measure that could be taken to reduce the impact of the Hinkley Point C intakes.

Fisheries management is moving toward a more holistic approach, as showcased in the Government’s recent 25 Year Environment Plan which indicates a move towards an Ecosystem Approach to fisheries management. There is a growing appreciation of and evidence base for the importance of early life-history stages of fish and the protection of their habitat, known as Essential Fish Habitat.

D&S IFCA therefore believes that direct cooling new nuclear power stations are falling short of the environmental standards increasingly expected for new developments, especially those occurring in or around Natura 2000 sites.

5.0 Cumulative Impact Assessment

There is currently a mismatch between the current scale of assessment and the population sizes used. Whereas impacts on fish stocks are considered over large spatial scales, only plans or projects within the Severn Estuary are considered in combination.

The Government's 25 Year Environment Plan has committed England to an Ecosystem Approach to fisheries management. An ecosystem approach must consider both the effects of fishing on the wider ecosystem and the effects of other activities on fish and fisheries. Although not a plan or project it is logical that commercial fishing, and other activities work together to reduce resilience of marine ecosystems (Willsteed et al. 2018).

Some fish stocks in the Bristol Channel are not being exploited sustainably. For example, for cod in 2018 ICES advised that, when the MSY approach is applied, there should be zero catch in 2019. It is important to consider the fish mortality at Hinkley in the context of the state of the local stocks wherever possible. This has not been undertaken so far. Although not a plan or project a qualitative assessment of the current state of the stocks under review is required to understand whether the 1% threshold is negligible given the current state of the stock.

References

- Bird, D. (2008). The biology and conservation of the fish assemblage of the Severn Estuary (cSAC). Report Number CCW/SEW/08/1. pp. 1-79.
- Beck M.W., Heck K.L., Able K.W., Childers D.L., Eggleston D.B., Gillanders B.M., Halpern B., Hays C.G., Hoshino K., Minello T.J., Orth R.J., Sheridan P.F., Weinstein M.P. (2001) The Identification, Conservation, and Management of Estuarine and Marine Nurseries for Fish and Invertebrates, *BioScience*, 51(8): 633-640
- Bekkevold, D., Aandre, C., Dahlgren, T.G., Clausen, L.A.W., Torstenssen, E., Mosegaard, H., Carvalho, G.R., Christensen, T.B., Norlinder, E., and Ruzzante (2005). Environmental correlates of population differentiation in Atlantic herring. *Evolution*, 59: 2656-2668.
- Cambie G., Kaiser M.J., Marriott A.L., Fox J., Lambert G., Hiddink J.G., Overy T., Bennet S.A., Leng M.J., McCarthy I.D. (2016) Stable isotope signatures reveal small-scale spatial separation in populations of European sea bass, *Marine Ecology Progress Series*, 546: 213-223
- Carvalho G.R. and Hauser L. (1995) Molecular genetics and the stock concept in fisheries, *Reviews in Fish Biology and Fisheries*, 4: 326-350
- Coscia I. and Mariani S. (2011) Phylogeography and population structure of European sea bass in the north-east Atlantic, *Biological Journal of the Linnean Society*, 104: 364-377

Dahle G., Quintela M., Johansen T., Westgaard J., Besnier F., Aglen A., Jørstad K.E., and Glover K.A. (2018) Analysis of coastal cod (*Gadus morhua* L.) sampled on spawning sites reveals a genetic gradient throughout Norway's coastline, *BMC Genetics*, 19:42.

Dahlgren C.P., Kellison G.T., Adams A.J., Gillanders B.M., Kendall M.S., Kayman C.A., Ley J.A., Nagelkerken I., Serafy J.E. (2006) Marine Nurseries and effective juvenile habitats: concepts and applications, *Marine Ecology Progress Series*, 312: 291-295.

Doyle, T. K., Haberlin D., Clohessy J., Bennison A., Jessopp M. (2017) Localised residency and inter-annual fidelity to coastal foraging areas may place sea bass at risk to local depletion, *Scientific Reports*, 7: 45841.

Elliot M., Taylor C.J.L. (1989) The structure and functioning of an estuarine/marine fish community in the Forth Estuary, Scotland, *Proceedings of the 21st EMBS*: 227-240.

European Union (2000). Managing Natura 2000 Sites – The provisions of Article 6 of the 'Habitats' Directive 92/43/EEC. European Communities, 2000. ISBN 92-828-9048.

European Union (2019). Managing Natura 2000 Sites – The provisions of Article 6 of the 'Habitats' Directive 92/43/EEC. Commission Notice C/2018/7621, Brussels [https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1548663172672&uri=CELEX:52019XC0125\(07\)](https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1548663172672&uri=CELEX:52019XC0125(07)). ISBN 978-92-79-98560-7; doi:10.2779/02245.

Farmer, A., Mee. L., Langmead, O., Cooper, P., Kannen, A., Kershaw, P. and Cherrier, V. 2012. The Ecosystem Approach in Marine Management. EU FP7 KNOWSEAS Project. ISBN 0-9529089-5-6

Galley E.A., Wright P.J., Gibb F.M. (2006) Combined methods of otolith shape analysis improve identification of spawning areas of Atlantic cod, *ICES Journal of Marine Science*, 63: 1710-1717

Henderson P.A. (2007) Discrete and continuous change in the fish community of the Bristol Channel in response to climate change, *Journal of the Marine Biological Association of the United Kingdom*, 87(2): 589-598.

Henderson P.A. and Bird D.J. (2010) Fish and macro-crustacean communities and their dynamics in the Severn Estuary, *Marine Pollution Bulletin*, 61: 100–114.

Henderson P.A. and Bird D.J. (2010) Fish and macro-crustacean communities and their dynamics in the Severn Estuary, *Marine Pollution Bulletin*, 61: 100–114

Henderson P.A. and Henderson R.C. (2017) Population regulation in a changing environment: Long-term changes in growth, condition, and survival of sprat, *Sprattus sprattus* L. in the Bristol Channel UK, *Journal of Sea Research*, 120: 24-34.

Henderson P.A. and Holmes R.H.A (1987) On the population biology of the common shrimp Crangon crangon (L.) (Crustacea: Caridea) in the Severn Estuary and Bristol Channel, *Journal of the Marine Biological Association of the Kingdom*, 67 (4): 825-847

Henderson P.A and Seaby R.M.H. (1994) On the factors influencing juvenile flatfish abundance in the lower Severn Estuary, England, Netherlands *Journal of Sea Research*, 32 (3-4): 321-330.

Henderson P.A. and Seaby R.M.H (2000) Technical Evaluation of US Environmental Protection Agency Proposed Cooling Water Intake Regulations for New Facilities, Pisces Conservation Ltd.

- Henderson P.A. and Holmes R.H.A (1989) Whiting migration in the Bristol Channel: a predator-prey relationship, *Journal of Fish Biology*, 34 (3): 409-416.
- Henderson P.A. and Holmes R.H.A (1991) On the population dynamics of dab, sole and flounder within Bridgwater Bay in the lower Severn Estuary, England, *Netherlands Journal of Sea Research*, 27 (3-4): 337-344.
- Henderson P.A., James D.J. and Holmes R.H.A. (1992) Trophic structure within the Bristol Channel: seasonality and stability in Bridgwater Bay. *Journal of the Marine Biological Association of the United Kingdom*, 72: 675-690.
- Henderson P.A., Seaby R.M. and Soames J.R. (2006) A 25-year study of climatic and density-dependent population regulation of common shrimp *Crangon crangon* in the Bristol Channel, *Journal of the Marine Biological Association of the United Kingdom*, 86: 287-298.
- Henderson P.A, Seaby R.M.H. and Soames J.R. (2011) Community level response to climate change: The long-term study of the fish and crustacean community of the Bristol Channel, *Journal of Experimental Marine Biology and Ecology*, 400 (1-2): 78-89.
- Hidalgo, M., Kaplan, D.M., Kerr, L.A., Watson, J.R., Paris, C.B. and Brownman, H.I. (2017). Advancing the link between ocean connectivity, ecological function and management challenges. *ICES Journal of Marine Science*, 74(6): 1702 – 1707.
- Hilborn R., Quinn T.P., Schindler D.E., and Rogers D.E. (2003) Biocomplexity and Fisheries Sustainability, *PNAS*, 100 (11): 6564-6568.
- Holmes R.H.A and Henderson P.A. (1990) High fish recruitment in the Severn Estuary: the effect of a warm year? *Journal of Fish Biology*, 36: 961-963.
- Holmes S.J., Wright P.J., Fryer R.J. (2008) Evidence from the survey data for regional variability in cod dynamics in the North Sea and West of Scotland, *ICES Journal of Marine Science*, 65: 206-215.
- Humphries P., Potter I., Loneragan R.C (1992). The fish community in the shallows of a temperate Australian estuary: Relationships with the aquatic macrophyte *Ruppia megacarpa* and environmental variables, *Estuarine, Coastal and Shelf Science*, 34 (4): 325-346.
- Hutchinson W.F. (2008). The dangers of ignoring stock complexity in fishery management: the case of North Sea cod, *Biological Letters*, 4: 693-695.
- Jónsdóttir Ó.D.B., Daníelsdóttir A. K., and Nævdal G. (2001). Genetic differentiation among Atlantic cod (*Gadus morhua* L.) in Icelandic waters: temporal stability, *ICES Journal of Marine Science*, 58: 114–122.
- Kerr, L.A., Hintzen, N.T., Cadrin, S.X., Clausen, L.W., Dickey-Collas, M., Goethel, D.R., Hatfield, E.M.C., Kritzer, J.P. and Nash, R.D.M. (2017). Lessons learned from practical approaches to reconcile mismatches between biological population structure and stock units of marine fish. *ICES Journal of Marine Science*, 74(6): 1708 – 1722.
- Knutsen H., Olsen E.M., Jorde P.E., Espeland S.H., Andre C. and Stenseth N.C. (2011). Are low but statistically significant levels of genetic differentiation in marine fishes 'biologically meaningful'? A case study of coastal Atlantic cod, *Molecular Ecology*, 20: 768-783.
- Krebs, C.J. (2001). *Ecology: The Experimental Analysis of Distribution and Abundance*. 5th Edition, Benjamin Cummings, San Francisco.

Magurran A.E. and Henderson P.A. (2003) Explaining the excess of rare species in natural species abundance distributions, *Nature*, 22: 714–716.

Magurran A.E. and Henderson P.A. (2012) How selection structures species abundance distributions, *Proceedings of the Royal Society B Biological Sciences*, 279: 3722–3726.

Mariani S., Hutchinson W.F., Hatfield E.M.C., Ruzzante D.E., Simmonds E.J., Dahlgren T.G., Andre C., Brigham J., Torstensen E. and Carvalho G.R. (2005) North Sea herring population structure revealed by microsatellite analysis, *Marine Ecology Progress Series*, 303: 245–257.

McQuinn (1997). Metapopulations and Atlantic herring, *Reviews in Fish Biology and Fisheries*, 7: 297-329.

Nagelkerken I., Sheaves M., Baker R., Connolly R. (2015). The seascape nursery: a novel spatial approach to identify and manage nurseries for coastal marine fauna, *Fish and Fisheries*, 16 (2): 362-371.

Natural England & CCW (2009). The Severn Estuary / Môr Hafren European Marine Site: Natural England & the Countryside Council for Wales' advice given under Regulation 33(2)(a) of the Conservation (Natural Habitats, &c.) Regulations 1994, as amended.

Neat F.C., Bendall V., Berx B., Wright P.J., O Cuaig M., Townhill B., Schon P.J., Lee J. and Righton D. (2014). Movement of Atlantic cod around the British Isles: implications for finer scale stock structure, *Journal of Applied Ecology*, 51: 1564-1574.

O'Neill R. 2017. *The Distribution of the European Sea Bass, Dicentrarchus labrax, in Irish Waters*. PhD Thesis, University College Cork.

Pawson et al M.G., Borwn M. Leballeur J. and Pickett G.D. (2008) Will philopatry in sea bass, *Dicentrarchus labrax*, facilitate the use of catch-restricted areas for management of recreational fisheries? 93 (1-2): 240-243.

Potter I.C., Claridge P.N., Hyndes G.A. and Clarke K.R. (1997) Seasonal, annual and regional variations in ichthyofaunal composition in the inner Severn Estuary and inner Bristol Channel, *Journal of the Marine Biological Association of the United Kingdom*, 77(2): 507-525.

Potter I.C., Bird D.J., Claridge P.N., Clarke K.R., Hyndes G.A. and Newton L.C. (2001). Fish fauna of the Severn Estuary. Are there long-term changes in abundance and species composition and are the recruitment patterns of the main marine species correlated? *Journal of Experimental Marine Biology and Ecology*, 258 (1): 15-37.

Potts G.W., and Swaby S.E. (1993) Review of the status of estuarine fishes. Pp278. English Nature Research Report No.34, Marine Biological Association/ English Nature.

Rees S.E., Sheehan E.V., Jackson E.L., Gall S.C., Cousens S.L., Solandt J., Boyer M. and Atrill M.J. (2013). A legal and ecological perspective of 'site integrity' to inform policy development and management of Special Areas of Conservation in Europe, *Marine Pollution Bulletin*, 72 (1): 14-21.

Ruzzante D. E., Taggart C. T., and Cook, D. (1998). A nuclear DNA basis for shelf and bank-scale population structure in northwest Atlantic cod (*Gadus morhua*): Laborador to Georges Bank, *Molecular Ecology*, 7: 1663–1680.

Ruzzante D.E., Wroblewski J.S., Taggart C.T., Smedbol R.K., Cook D., Goddard S.V., (2000). Bay-scale population structure in coastal Atlantic cod in Labrador and Newfoundland, Canada, *Journal of Fish Biology*, 56: 431-447.

Ruzzante D.E., Mariani S., Bekkevold D., André C., Mosegaard H., Clausens L.A.W., Dahlgren T.G., Hutchinson W.F., Hatfields E.M.C., Tortensen E., Brigham J., Simmonds, E.J., Laikre L., Larsson L.C., Stet R.J.M., Ryman N. and G.R Cavalho (2006). Biocomplexity in a highly migratory pelagic marine fish, Atlantic herring, *Proc. R. Soc. B*, 273: 1459–1464.

Schaberg S.J., Patterson J.T., Jill J.E., Guindon K.Y., Tuckett Q.M. (2019) Fish community composition and diversity at restored estuarine habitats in Tampa Bay, Florida, United States, *Restoration Ecology*, 27 (1): 54-62.

Sheaves M. (2009) Consequences of ecological connectivity: the coastal ecosystem mosaic, *Marine Ecology Progress Series*, 391: 107-115.

Sheaves M., Baker R., Nagelkerken I. and Connolly R.M. (2015) True Value of Estuaries and Coastal Nurseries for Fish: Incorporating Complexity and Dynamics, *Estuaries and Coasts* 38: 401-414

Titmus, G., Claridge, P.N. and Potter, I.C. (1978). Growth and abundance of 0-group herrings, *Clupea harengus* L., in the Severn Estuary. *Zoological Journal of the Linnean Society*, 64(3): 251 – 260.

Watson J.R., Siegel D.A., Kendall B.E., Mitarai S., Rasweiller A., Gaines S.D. (2011) Identifying critical regions in small-world marine metapopulations, *PNAS*, 108 (43): E907-E913

Willstead E.A., Birchenough S.N.R., Gill A.B and Jude A. (2018) Structuring cumulative effects assessments to support regional and local marine management and planning obligations, *Marine Policy*, 98(98): 23-32

Wright P.J., Neat F.C., Gibb F.M., Gibb I.M., Thordarson H. (2006) Evidence for metapopulation structuring in cod from west of Scotland and North Sea, *Journal of Fish Biology*, 69: 181-199

Ying Y., Chen Y., Lin L., and Gao T. (2011) Risks of ignoring fish population spatial structure in fisheries management, *Can. J. Fish. Aquat. Sci.* 68: 2101–2120

Appendix A Devon and Severn Inshore Fisheries and Conservation Authority

Devon and Severn Inshore Fisheries and Conservation Authority (D&S IFCA) is the statutory manager of sea fisheries from baselines out to six nautical miles in English waters as shown in Figure 1. The ten regional IFCAs have a shared vision:

“Inshore Fisheries and Conservation Authorities will lead, champion and manage a sustainable marine environment and inshore fisheries, by successfully securing the right balance between social, environmental and economic benefits to ensure healthy seas, sustainable fisheries and a viable industry.”

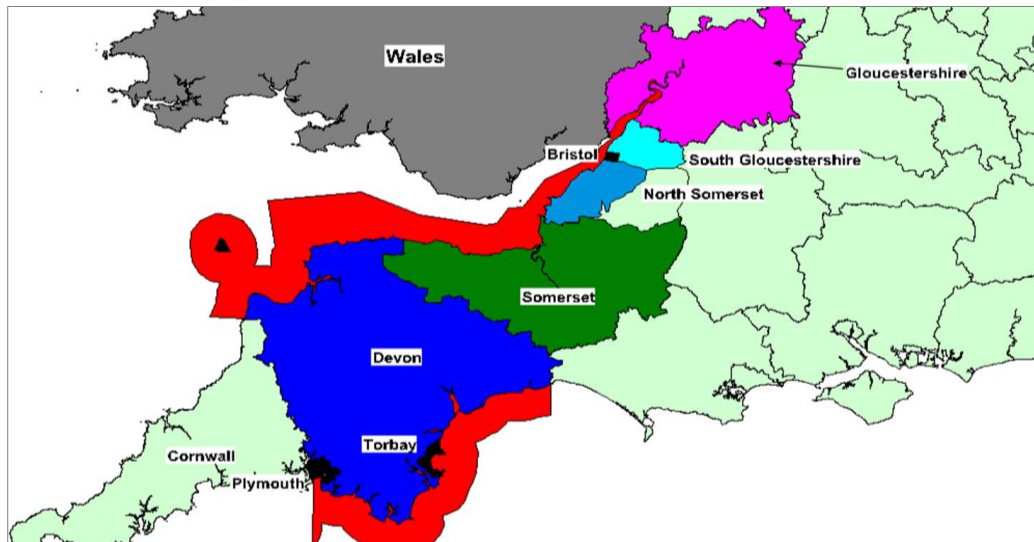


Figure 1. Marine areas under the jurisdiction of D&S IFCA, highlighted in red, extend from baselines to 6nm, or to the median line with Wales.

The D&S IFCA is the largest of the ten separate IFCA districts and has two separate coastlines. The area of the District is 4522km² and is defined in the Statutory Instrument (2010 No. 2212). The D&S IFCA District includes the areas of Devon, Somerset, Gloucestershire County Councils; Bristol City and Plymouth City Councils; North Somerset and South Gloucestershire Councils and all adjacent waters out to six nautical miles offshore or the median line with Wales. The Full Authority is comprised of 30 members drawn from relevant Local Authorities (Councillors), General Members (appointed to the Authority by the Marine Management Organisation (MMO) and Statutory Appointees representing the MMO, the Environment Agency (EA) and Natural England (NE). D&S IFCA is funded via several different funding Authorities (councils) with an additional contribution from central government. Officers are employed by D&S IFCA to conduct work on behalf of the Full Authority.

The powers and duties of the D&S IFCA are provided by the Marine and Coastal Access Act (2009); Section 153 (Management of inshore fisheries) and Section 154 (Protection of marine conservation zones) underpin much of the work conducted by the Authority. Section 153 requires that D&S IFCA manage the exploitation of sea fisheries resources within its District, and, in so doing, must:

(a) seek to ensure that the exploitation of sea fisheries resources is carried out in a sustainable way,

(b) seek to balance the social and economic benefits of exploiting the sea fisheries resources of the district with the need to protect the marine environment from, or promote its recovery from, the effects of such exploitation,

(c) take any other steps which in the authority's opinion are necessary or expedient for the purpose of making a contribution to the achievement of sustainable development, and

(d) seek to balance the different needs of persons engaged in the exploitation of sea fisheries resources in the district.

Section 154 requires that D&S IFCA seeks to ensure that the conservation objectives of any MCZ in the district are furthered. This includes the Severn Estuary European Marine Site, in which Hinkley Point C is situated.

Regarding this representation, the D&S IFCA's fisheries expertise relates to the English waters of the Severn Estuary, although comments on fish and habitats are more generic to the Severn as a whole.

**D&S IFCA Response to the Environment Agency
Consultation Regarding the EDF Energy Proposal to
Remove the Requirement for Acoustic Fish Deterrents at
Hinkley Point C**



July 2019 v1.1

Version	Author	Description	QA'd by
April 2019 (draft)	LW	Submitted to EA as first draft on request	OT
July 2019 (final)	LW	Major revision & addition for submission	OT, LP
July 2019 (final) 1.1	LW	Minor amendments	SC

Contents

1.0 Introduction	3
2.0 Technical issues relating to Hinkley Point C	4
2.1 Lack of total mortality information	4
2.2 The appropriate scale of analysis	4
2.2.1. <i>Estuarine fish community dynamics and site integrity</i>	4
2.2.2 <i>Uncertainty in stock identity, population structuring and biocomplexity</i>	6
2.2.3 <i>Implications of unacknowledged population structure</i>	12
2.2.3 <i>Importance of Bridgwater Bay and the Severn Estuary in the wider Severn Estuary – Celtic Sea ecotone</i>	13
2.3 Concerns relating to the level of uncertainty and poor evidence base for scaling of fish mortality from HPB to HPC	14
2.3.1 <i>Uncertainty in effect of moving water intake offshore</i>	14
2.3.2 <i>Uncertainty in performance of LVSE intakes</i>	14
2.3.3 <i>Unacknowledged barotrauma caused by intake tunnels</i>	15
2.3.4 <i>Uncertainty in evidence base for FRR</i>	15
2.3.5 <i>Uncertainty in the impingement datasets</i>	15
2.3.6 <i>Error in mesh screen size used for impingement assessment</i>	15
3.0 Wider guidance, policy and decision-making concerns	15
3.1 Granting permits before final design	15
3.2 Direct cooling as BAT	16
3.3 Legislative gaps for fish protection	16
3.4 Cumulative effects of developments and fishing	16
3.5 Nuclear power and adaptive management	17
4.0 References	18

1.0 Introduction

Devon and Severn Inshore Fisheries and Conservation Authority (D&S IFCA) is the statutory manager of sea fisheries from baselines out to six nautical miles. The powers and duties of D&S IFCA are provided by the Marine and Coastal Access Act (2009). The ten regional Inshore Fisheries and Conservation Authorities (IFCAs) were set up as a new type of regulator to work with stakeholder groups to achieve the long-term goal and vision of healthy seas providing ecosystem services for the future in English inshore waters. The ten IFCAs have a shared vision:

“Inshore Fisheries and Conservation Authorities will lead, champion and manage a sustainable marine environment and inshore fisheries, by successfully securing the right balance between social, environmental and economic benefits to ensure healthy seas, sustainable fisheries and a viable industry.”

The IFCA approach is to ensure delivery of our statutory duties and to be guided by the governments Marine Policy Statement and adherence to the High-Level Marine Objectives which can be summarised as:

- Achieving a sustainable marine economy
- Ensuring a strong, healthy and just society
- Living within environmental limits
- Promoting good governance
- Using sound science responsibility

Devon and Severn IFCA has two sea boundaries. The southern boundary with the English Channel stretches from Lyme Regis to the border between Devon and Cornwall. The northern boundary with the Severn Estuary stretches from Countisbury Cove as far as Maisemore Weir to Chepstow and includes Lundy Island. It also includes the River Avon through Bristol and all other rivers entering the sea within the District. The District extends to sea from baselines to 6 nautical miles or the boundary with Welsh Territorial Waters in the north of the area.

D&S IFCA supports the High Level Objectives of the UK’s Marine Policy Statement, namely: Achieving a sustainable marine economy; ensuring a strong, healthy and just society, living within environmental limits and promoting good governance.

D&S IFCA officers have been permitted to sit on the on the Marine Technical Forum for Hinkley Point C. However, the scale of the potential impact of Hinkley Point C, a series of errors and omissions in the presented information and the lack of an assessment at the appropriate scale mean that D&S IFCA have a number of ongoing concerns about the impact of Hinkley Point C and the current guidance on environmental regulation of new nuclear power stations. This is particularly relevant in the Severn Estuary European Marine Site where the entire fish assemblage is a designated sub-feature, but extends to other non-designated sites, given the lack of spatial protection for fish in the current range of designations and the increasing acknowledgement of the need to protect fish and fish habitat to promote long-term resilience and recovery of stocks.

This is D&S IFCA’s final response, and replaces the draft response submitted to the Environment Agency on the 26th April 2019.

2.0 Technical issues relating to Hinkley Point C

2.1 Lack of total mortality information

It is currently impossible to understand the impacts of Hinkley Point C in its current design, given that no estimate of total fish mortality is provided. Total mortality associated with entrapment (impingement and entrainment), must be considered in order to assess the impacts on the Severn Estuary European Marine Site. The screening out of entrainment in the Habitat Regulations Assessment (HRA) because it does not have an effect *alone* appears to be an error in the HRA process. Although the entrainment figures would not have been directly affected by the removal of the Acoustic Fish Deterrent (AFD), significant adjustments to the impingement figures have been presented given the more advanced stage of design of the cooling water system. Therefore, entrainment figures need to be adjusted and presented alongside impingement for any meaningful assessment of impacts on fish to be undertaken. As a bare minimum, D&S IFCA would have expected entrainment to be included as an in-combination effect with impingement in the HRA.

It is therefore currently impossible to understand whether Hinkley Point C will have an impact on fish populations or site integrity following the removal of the requirement for an AFD.

2.2 The appropriate scale of analysis

2.2.1. Estuarine fish community dynamics and site integrity

The focus of the impingement assessment and HRA based only on impacts at an ICES stock level is of primary concern to D&S IFCA. D&S IFCA believe that two levels of assessment are needed: an assessment of impacts on the Site Integrity of the Severn Estuary, focused on community dynamics (this Section) and an assessment at the *appropriate* population level (see Section 2.2.2).

The assertion that there is 'no such thing as a biological population at the estuary level' in the TR456 report is strictly true for some species, and untrue for others. Such a broad statement is entirely unhelpful. Some fish do spend their entire life cycle in the estuary, others use the estuary for feeding, reproduction or over-wintering (Henderson et al. 1992). The habitats found within estuaries are now understood to be Essential Fish Habitat, especially for juvenile fish, therefore the part of their life spent in the estuary is critical to the overall population.

Rees et al. (2013) explore the legal and ecological meaning of the term 'Site Integrity'. They highlight the EC Guidance (2000) which states that the integrity of the site may be defined as 'the coherence of the site's ecological structure and function, across its whole area, or the habitats, complex of habitats and/or populations of species for which the site is classified'. Rees et al (2013) demonstrate that various ecological processes at a site and network level underpin ecological integrity. Site integrity therefore requires an understanding of 'the ecosystem organisation at a location in terms of the ecosystem structure, functions, processes and connectivity, especially in relation to the features of interest and its resilience to and ability to recover from, disturbance'. Even for those species who spend only part of their life in the estuary, community dynamics are an entirely relevant ecological level of integration that are central to the consideration of Site Integrity.

An ecological community is any assemblage of populations living in a prescribed area or habitat. A community may be of any size; the community of organisms in a rotting log or the community of plants in a deciduous forest (Krebs 2001). The community is a complex

ecological unit with connections between species. A major consideration of ecology is how strong these relationships are. Is a community an organised system of recurrent species or a haphazard collection of populations with minimal integration? How frequently is the distribution and abundance of one species determined by interactions with other species? (Krebs 2001).

The term 'fish community' is often applied to the collection of fish species which utilise an estuary, despite the fact that some of those fish only use the estuary for part of their life cycle (e.g. Elliot and Taylor 1986, Humphries et al. 1992, Henderson 2010, Schaberg et al. 2019). In fact, the term community is specifically used in the official description of the Severn Estuary EMS's designated fish assemblage (Bird 2008). The lack of consideration of processes within the Severn Estuary fish community is a particularly stark omission given that the community dynamics of fish in the Severn are among the best studied in the world (Henderson and Holmes 1987, Henderson and Holmes 1989, Holmes and Henderson 1990, Henderson and Holmes 1991, Henderson et al. 1992, Henderson and Seaby 1994, Potter et al. 1997, Henderson and Seaby 2000, Potter et al. 2001, Magurran and Henderson 2003, Henderson et al. 2006, Henderson 2007, Henderson and Bird 2010, Henderson et al. 2011, Magurran and Henderson 2012, Henderson and Henderson 2017).

Research into estuary fish communities has been boosted in the last 20 years by discussions around developing the concept of nurseries and essential fish habitat. This work initially focused on how to define nursery areas which lead to consideration of the contributions of various nursery habitats to adult populations (Beck et al. 2001, Dahlgren et al. 2006). However, more recently there has been greater acknowledgement of the functioning of fish nurseries themselves with trophic processes, nutrient cycling and availability and the movement of nutrients by migrating animals being linked to the connectivity of fish populations within estuaries (Sheaves 2009, Sheaves et al. 2015). It is now understood that the physical and biological translocation of nutrients, migrations (ontogenetic, life history, spawning and feeding), food-web dynamics and predator prey interactions of fish in nursery areas play a crucial role in structuring biological populations, communities and assemblages and in driving the biological processes that support them (Sheaves 2015). This marks a significant theoretical shift away from only considering the value of nursery areas in terms of the contribution they make to adult populations. The inclusion of the fish assemblage within the over-arching estuary feature of the Severn Estuary EMS which incorporates all aspects of the physical, chemical and biological attributes of the estuary as an ecosystem (Natural England and CCW 2009) further highlights that the fish are protected as part of a wider, connected ecosystem which is protected at the Severn Estuary level.

Key Message 1: No meaningful consideration is currently given to the structure and functioning of the fish community in the Severn Estuary, despite this being an active field of research. Export to adult populations is only one aspect of the ecological importance of the fish community and there is much recent literature to inform this. Understanding linkages between species and life history stages is crucial to understanding the impacts and how these relate to Site Integrity.

Henderson and Seaby (2000) identify a number of ways that the abstraction for cooling water can negatively impact a fish community and ecosystem. These include the differential mortality of different species of fish resulting in changes in competitive ability and the

destruction of prey for juveniles, which leads to decreased food supply across various life-history stages. The current assessment argues that density dependence will compensate for most mortality of fish and therefore it will have negligible local impacts. However, Henderson and Seaby (2000) argue that from an ecosystem perspective, there can never be a surplus of biological production that can be removed without impacting other parts of the system – in this case the cooling water intake is removing the production that would normally have been consumed by other organisms. .

In general, longer-lived, slower growing species will tend to be more heavily impacted, being replaced by faster growing competitors (Henderson and Seaby 2000). Because of the complexity of trophic structures, the outcome for particular species may be difficult to predict, (Henderson and Seaby 2000). However, impingement and entrainment kill organisms at many trophic levels so that their impact is similar to a general reduction in productivity and efficiency of energy transfer. The result is that the effects of any such losses will be far greater towards the top of the food web (Henderson and Seaby 2000).

It is extremely important to note the assertion by Henderson and Seaby (2000) that ‘the deterioration in measure of ecosystem health, such as species richness, or trophic complexity, can be quite gradual and irregular and take many years to recognise. The trend is easily lost in random variation caused by events such as exceptionally cold or warm spells or lost within other man-made changes such as eutrophication or acidification’. The assertions within the assessment that no change in fish assemblage was noted when HPA intakes were shut down, are therefore not useful. It also highlights that changes may occur which will be extremely difficult to detect at a local level. At a population level the amount of the variation in the system (natural, and man-made) makes it extremely unlikely that trends will be detected which are directly attributable to fish mortality at Hinkley Point, but that does not mean that HPC is having a negligible effect.

In the context of community dynamics D&S IFCA also believes the current species inclusion is too narrow. Meaningful quantitative descriptions for all species are not possible but a qualitative review of additional species should be included as some species who are often numerically abundant and may have a significant role within the estuary ecosystem, have not been assessed.

Key Message 2: Not being able to detect a strong signal for an impact from water abstraction does not mean that there is not one. The complexity of the ecosystem may mask the effects, but does not negate them. There is also no baseline data for an unimpacted fish assemblage as all the quantitative data for the Severn Estuary fish assemblage has been collected since water abstraction by power stations commenced.

2.2.2 Uncertainty in stock identity, population structuring and biocomplexity

The impingement assessment states that the stock units used in the assessment are the ICES 2017 definitions ‘which are the outcome of the best available international science’. D&S IFCA agrees with this statement in part, but it is important to note that:

1. Whilst based upon best-available science, there is still considerable uncertainty in the stock identity for many fish species. Indeed, ICES continues to refine and change

stock boundaries. For some commercial species (see below) there is considerable evidence that there may be finer-scale population structuring that is extremely relevant to fish in the Bristol Channel and Severn Estuary. For many less commercially important (but potentially ecologically important species) there is likely to be even less information and more uncertainty about the stock identity or finer scale population dynamics.

2. Interestingly, TR456 also gives two alternative descriptions of a stock;
 - a. A stock unit is where the effects of exploitation of a particular fishery can be recognisable
 - b. A biological stock is where there is sufficient spatial and temporal integrity for the stock to be considered as a self-perpetuating unit.

The first definition is interesting because it highlights the fisheries focus for the delineation of the ICES stocks. They are appropriate management units for managing geographically widespread anthropogenic activity. They are not designed for looking at local, or site-specific issues, and the ICES stock units would probably look extremely different if that were the case, especially given the information which relates to the second definition of stock structure for a number of species. As discussed above there are a number of *unstated* uncertainties in the identities of the stock units used for estimating impingement effects that should be acknowledged in the HRA, and other relevant assessments.

There is an increasing evidence base that current stock boundaries used to manage marine fish do not reflect the biological structure underlying population processes (Ruzzante et al. 2000, Kritzer and Sale 2004, Galley et al. 2006, Wright et al. 2006, Holmes et al. 2008, Hutchinson et al. 2008, Reiss et al. 2009, Knutsen et al. 2011, Poulsen et al. 2011, Cianelli et al. 2013, Kritzer and Liu 2013, Neat et al. 2013, Cambie et al. 2016). Even for pelagic fish with a high migration potential it has been shown that reproductive isolation can be maintained even in populations exhibiting substantial mixing during larval and adult life stages (Bekkevold et al. 2005). Meta-population dynamics are being found in increasing numbers of marine fish populations (Neat et al. 2014). There are numerous definitions of the meta-population, but the more general definitions have only two requirements: (i) populations are geographically discrete; (ii) mixing of individuals between populations is less than that within them (Akçakaya et al. 2007).

D&S IFCA therefore contests the blanket use of ICES stocks for population-level analyses; this should be reviewed on a species-by-species basis (and this does not preclude an assessment of community dynamics within the estuary – see previous section). A brief review of three species is given below. The ecological implications of such unacknowledged population structure are discussed in Section 2.2.3. Uncertainties in population structure should be acknowledged and reviewed in order to assess whether the current assessment level is correct.

Cod (Gadus morhua)

The current impingement assessment report acknowledges that, in a previous Cefas-authored report (TR148) a local spawning stock biomass (SSB) was used for cod (*Gadus morhua*) because there was a possibility that the stock identity might have been smaller than those used by ICES in 2010. No information is provided on what evidence prompted the use of smaller stock units, nor is any information provided as to why these are no longer thought to be valid. Cefas states that, because no information has materialised in seven years, the

possibility of a separate stock unit existing has reduced. In fact, much recent evidence has emerged in the published literature, to suggest that cod often have fine population structure. As such, population processes may operate at a smaller spatial scale than the stock level (the following literature only presents a small subset of the published work on cod), with spawning aggregations functioning as local populations within a metapopulation (Wright 2006).

Complex genetic population structure was discovered in Northwest Atlantic populations of cod. Individuals inhabiting Gilbert Bay, Labrador were found to be genetically distinguishable from offshore cod on the north-east Newfoundland shelf and from inshore cod in Trinity Bay, Newfoundland (Ruzzante et al. 2000). The genetic, life history, and behavioural differences were found to extend northward from coastal Newfoundland to coastal Labrador, and in at least two cases the population subdivision observed was identifiable at the scale of an individual bay. An investigation of cod in south Icelandic waters found that individuals do not belong to one panmictic population and that this genetic difference is stable from year-to-year (Jónsdóttir et al. 2001).

Neat et al. (2014) used information from data storage tags to study the movement of cod around the British Isles. The authors found that cod living around the British Isles are comprised of at least one more distinct population unit than is currently recognised. Some individuals were found to be migratory, whilst others were not and the authors acknowledged that finer ecological structuring, even than that identified by the tagging, might exist. The authors therefore suggest that meta-population dynamics are likely to be important for cod in the British Isles.

Extensive information now exists to suggest that cod in the North Sea form a number of separate stocks (Hutchinson et al. 2001, Galley et al., 2006, Holmes et al. 2008, Neat et al. 2014) with differences relating to spatial differences and also possibly inshore and offshore structuring; adults from coastal regions have been found to originate from local nursery areas (Wright et al. 2006). Despite this, some fish undertook large migrations therefore, North Sea cod are likely to have a meta-population structure (Holmes et al 2008).

Recent work has revealed significant population genetic structure in Norwegian cod, throughout its entire range, that follows a trend of isolation by distance. Therefore, the current management regime for coastal cod in Norway represents a simplification of the level of genetic connectivity and needs revision (Dahle et al. 2018).

It is now acknowledged that Atlantic cod have several strategies with regard to spawning. Typically, coastal cod are stationary and complete their entire life cycle within a restricted geographical area. In contrast, cod belonging to oceanic populations may perform long-distance spawning migrations and release eggs and larvae that are carried with ocean currents back to the nursery grounds (Knutsen et al. 2011). Differentiation at continental shelf scales has been linked to the presence of biogeographical features such as submarine saddles, channels and trenches whilst at smaller spatial scales oceanographic features have been implicated in having a role in population differentiation (Ruzzante et al. 1998).

The genetic population structure of the stock has not been investigated for cod in the Bristol Channel and Celtic Sea, but there is no reason to suppose that it would be different from every other location in the north Atlantic where it has been studied. D&S IFCA therefore believes that the assessment for cod is not sufficiently precautionary. An urgent assessment

of Bristol Channel cod identity is required and a more precautionary approach should be taken in the current assessment.

Atlantic Herring (Clupea harengus)

Herring often have complex meta-population structures with an array of local populations linked by variable degrees of gene flow which can vary substantially over space and time. McQuinn (1997) found meta-population structure within the multiple spawning populations in the northeast and northwest Atlantic. Sometimes these populations are found to spawn sympatrically, with local population integrity maintained through behavioural isolation

Low but significant genetic differentiation was found in Atlantic herring from eleven spawning locations distributed along a longitudinal gradient from the North Sea to the Western Baltic (Bekkevold et al. 2005). The differentiation was not linked to geographical distance between populations but analyses incorporating genetic, spatial, and environmental parameters indicated that isolating mechanisms are associated with the specific salinity conditions on spawning locations (Bekkevold et al. 2005). This study offers further evidence that reproductive isolation can be maintained in marine fish populations exhibiting substantial mixing during larval and adult life stages.

In other cases, isolation by distance has been found to be the primary mechanism of genetic population structure (Mariani et al. 2005). In a study of the major herring spawning aggregations in the North Sea and adjacent waters a genetically homogeneous unit off Northern Scotland was identified, and a temporally stable pattern of isolation by distance determined predominantly by the divergence of the English Channel and Norwegian spring spawners. However, a further study of the same populations found more complex patterns of intraspecific diversity with mixed aggregations of fish with divergent genetic and life-history characteristics (Ruzzante et al. 2006). Rather than isolation by distance Ruzzante et al. (2006) identify strong natal homing over broad geographic scales as the main mechanism for maintaining intraspecific differentiation despite mixing of populations during part of their life-cycle.

Therefore, herring show a variety of levels of population structure and metapopulation dynamics, with different drivers in different locations. Additionally, there is increasing evidence to suggest that such patterns are temporally stable in some locations and very dynamic in others (Ruzzante et al. 2006).

D&S IFCA has been working with local fishermen from Somerset and North Devon, Swansea University, the Blue Marine Foundation and the North Devon Biosphere Reserve under the Marine Pioneer Programme to investigate whether there are separate herring populations in the Severn Estuary and Bristol Channel. Historic data showed that there was a separate population at Milford Haven. Local fishermen reported herring spawning around Minehead and Clovelly, something that has never been documented before on the English side of the Severn Estuary/ inner Bristol Channel. D&S IFCA are awaiting the final results from Swansea University but the following results can be shared, with a final report expected in August 2019 (D.Clarke, Swansea University pers comms):

- The herring fishery at Minehead and Clovelly takes place from September to October
- Two samples were collected from each site in October and December 2018

- All samples contained a significant proportion of spawning (stage VI) fish. In October both samples contained more than 40% in stage VI; in December more than 60%. So it is clear that they are spawning along the North/Devon Somerset coastline during winter.
- Age range of the fish sampled is 3-8 years old. In both cases the age range was wider in the October samples with a more limited age range in December.
- Genetic work is ongoing and further results are expected shortly. There is some indication from early results that more than one stock may be present in the Bristol Channel.

Therefore, it is highly likely that herring in the Bristol Channel/ Severn Estuary have some degree of separation or metapopulation structure that has been undetected up to this point. Early evidence suggests that these herring are not the same population as the Milford Haven population.

Bass (Dicentrarchus labrax)

The knowledge base relating to population structure of European sea bass (*Dicentrarchus labrax*) in UK waters shows mixed results. Whilst mitochondrial DNA has identified three lineages in European waters (the UK stock falling into one lineage), microsatellite markers have failed to detect any more-recent or finer-scale genetic structuring (Coscia and Mariani 2011). However, more recent findings using stable isotope signatures to assess population connectivity around the coast of Wales have found that there are 2 sub-populations of bass in Welsh waters, using separate feeding grounds (Cambie et al. 2016). Crucially, the study found that adult sea bass from south Wales are likely to have a restricted range of movement, not only for feeding, but also for spawning, due to the proximity of Trevoise Head (Cambie et al. 2016). According to the authors this proximity of feeding and spawning grounds is likely to result in a resident population in south Wales. Bass from the English part of the Bristol Channel were not sampled as part of this work, but the paper certainly raises questions as to the residency of Bristol Channel bass as a whole. The authors suggest that further genetic work is required to understand whether these populations mix during spawning to determine whether they are separate stocks (Cambie et al. 2016). The paper also stressed the importance of estuaries as preferential feeding areas for large bass, something that has previously been under-represented in the literature.

Early findings from acoustic tracking of bass along a 120km stretch of coastline in southeast Ireland found that the majority of acoustically tagged sea bass were detected within 5km of their release location suggesting limited movement and strong evidence of feeding site fidelity (O'Neil 2017). The study also found that nearly a third of acoustically tagged sea bass in inshore waters were resident within the area of the acoustic array for the entire period of full array deployment, including the assumed spawning season (February to June). This suggests possible spawning in inshore locations or potential evidence of the occurrence of skipped spawning. In a second study of acoustically tagged bass, this time in a large estuary (Cork harbour), sea bass displayed long-term residency (mean 167 days) and inter-annual fidelity (93% return rate) to specific areas (Doyle et al. 2017). Indeed, the repeated presence of adult sea bass at relatively discrete inshore locations on an annual basis has raised the possibility of the existence of homing ability by sea bass returning to their nursery zones (Pawson et al., 2008).

Similar patterns are emerging in the results of a similar study in the D&S IFCA's District. D&S IFCA is currently co-funding a PhD with Plymouth University looking at the inshore ecology of European seabass in the southwest UK. As part of the PhD the Immature Bass Acoustic Stock Surveillance (I-BASS) project has tagged 146 European bass (25-60cm fork length) across three estuaries in Devon. Preliminary results (unpublished data) have demonstrated localized movements and high site fidelity to estuaries. Distance travelled in coastal areas is variable between individuals and affected by size, however is not thought to exceed 40km. Furthermore, a high proportion of individuals (including sexually mature fish) from multiple estuaries did not conduct winter spawning migrations and maintained high residency throughout the year. Individuals that did perform winter migrations also returned to the estuary which they inhabited the previous summer.

O'Neil (2017) suggests that a lack of genetic population structure within UK bass stocks suggests that some mixing still occurs, primarily in spawning locations (O'Neil 2017). However, only a few migrants per generation are required to prevent genetic separation and differences in behaviour and spatial use may still be significant in the sustainable management of the species (see Section 2.2.3).

Therefore, despite a lack of detection of genetic structuring, studies have revealed behavioural and ecological structuring which may, in the long-term, result in genetic structuring.

Other species

It is of concern that there is very little use of the relevant published literature on population structure within any of the reports, given that the revision of ICES stocks takes time and would be based on the findings of any such literature. The result is that large and important uncertainties of the level of impact exist based on uncertainties in stock identity, population structure and the possible existence of meta-populations. D&S IFCA has reviewed three species, but additional data for other species exists. Where there is no data, uncertainties must be acknowledged.

An additional element of population structure – geographic separation of size class/ life history stages

Many species are spatially separated at different life-history stages with larval retention at spawning grounds, spatial segregation of juveniles inside separate coastal and estuarine nursery grounds and limited individual movements of adults (Archambault et al. 2018).

However, causes of juvenile growth and mortality are fine-grained, local processes, but population and larger scale consequences are the outcome of large numbers of these processes occurring over extensive networks of nurseries (Ciotti et al. 2013). The functional role of juvenile habitats for marine fishes must be addressed within a fine-grained and spatially extensive framework (Ciotti et al. 2013). Marine fish populations are under the influence of multiple environmental and anthropogenic stressors. Hydrographic variability, climatic cycles and long-term climate change impact fish populations (Archambault et al. 2018). These act together with pollution, habitat destruction and fishing pressures (Archambault 2018) and mortality caused through water abstraction. These stressors have different impacts at different stages of the life-cycle, however life-cycle approaches integrating impacts of these multiple stressors remain rare. Additionally, less attention has been given to understanding how quantitative implications for spatial structure of populations

and patterns of connectivity between life-history stages interacts with spatially structured stressors (Archambault et al. 2018). Results of the first such study on the common sole (*Solea solea*) emphasised the importance of coastal nursery habitat quantity and quality for the population renewal (Archambault et al. 2018). Whilst nursery habitat loss and degradation is not directly comparable with mortality from fish entrapment, it illustrates that populations are sensitive to processes occurring at this life-history stage. It is for this reason that the Severn Estuary was designated as an EMS, and the fish assemblage was directly protected.

Within the area of distribution of a population spatial structure is also maintained through the preservation of the population age structure, as individuals of different ages/ sizes and sexes are typically distributed differently over space due to stage/ age specific requirements and size-related migrations capabilities. Erosion of population spatial structure can be caused by human-induced or environmental factors. Human exploitation can cause local depletions, reduced spatial occupancy, and alteration of the population demographic and genetic structures. Also, the two factors work synergistically: a population that is impacted through anthropogenic reasons is more likely to go through further changes to its spatial structure due to additional environmental changes (Cianelli et al. 2013).

Key Message 3: ICES stock boundaries are not precautionary. Much scientific evidence exists to suggest many species have complex meta-population structures which are likely to apply in the Severn Estuary- Bristol Channel Ecotone.

2.2.3 Implications of unacknowledged population structure

In the context of the of the assessment by Cefas on the impacts of impingement by Hinkley Point C, the failure to consider the underlying population structure means that the current assessments may overestimate the geographical distribution of the stock and the size of the relevant SSB. This in turn would result in the current assessments underestimating the percentage of the stock impacted by HPC.

However, there are wider ecological implications that are likely to operate on a variety of scales, depending on the species and the nature of the population structure. These are particularly relevant when the effects of Hinkley Point C both in combination with other developments and fishing activity within the Severn Estuary and Bristol Channel are considered, but also occurring at the spatial scale in which they are currently being considered within the impingement assessment. For example, for bass where the ICES area considered includes IVb& c, VIIa, VIId-h, numerous activities including aggregate dredging, nuclear power stations, renewable energy developments, cable laying, flood defence works and coastal squeeze are operating in addition to substantial commercial and recreational fisheries. At this scale, the impacts on multiple undetected local populations take on major significance in terms of species long-term resilience.

It is only since the development of more sensitive genetic and biochemical markers that the existence and significance of spatial and temporal genetic structure for highly abundant and widely distributed migratory marine fish has become uncontroversial (Ruzzante et al. 2006). Even weak genetic differentiation can be significant in the management of fish stocks. Only a few migrants per generation can be sufficient to maintain genetic connectivity over evolutionary timescales, but such numbers would not be sufficient to rebuild depleted stocks

over ecological timeframes (Carvalho and Hauser 1995, Mariani et al. 2005). Biocomplexity in the form of genetic population structure or the diversity of life-history characteristics and adaptation to local variations in spawning and nursery habitat, may help fish populations to adjust to environmental change and make them more resilient to exploitation (Hilborn et al., Hutchinson 2008). It is now thought that even diversity in life history strategy and geographic location (not necessarily reflected in genetic population structure) contributes to the resilience of populations to exploitation. This is partly because at different times different geographic regions and different life-history strategies have been the major contributors to the overall biomass of the population (Hilborn et al. 2003).

Marine conservation initiatives or fisheries management regimes that disregard or misidentify patterns of genetic and life history differences have the potential to lead to the erosion of genetic resources or even local subunits (Ruzzante et al. 2006, Watson et al. 2011, Ying et al. 2018). This problem is especially acute for marine fish population complexes with diverse and potentially locally adapted migratory components that overlap spatially and seasonally such as, but not limited to, cod and herring (Ruzzante et al. 2000, Ruzzante et al. 2006).

Where management fails to acknowledge and preserve patterns of genetic and life-history diversity there are thought to be a number of possible negative effects for marine fish populations. These include reduced resilience in the face of commercial exploitation, disturbance and environmental change and impeded population recovery from such events, compromised evolutionary potential and reduced recruitment potential (Ruzzante et al. 2006).

It is now accepted that there is an urgent need to delineate extant patterns of within-species genetic diversity and to use such knowledge for management purposes (Ruzzante et al. 2006). Priority needs to be given to ensure that the scale at which fish stock data is collected and analysed reflects the true structuring of the species (Holmes et al. 2008). Detailed spatial and seasonal information is required for assessing the impact of spatially explicit conservation measures even for widely abundant and highly migratory species with low levels of genetic differentiation (Ruzzante et al. 2006).

Key Message 4: Assessments based on inappropriate stock boundaries are likely to underestimate the impacts at a local level, and have the potential to decrease species resilience, especially when in-combination issues are considered.

2.2.4 Importance of Bridgwater Bay and the Severn Estuary in the wider Severn Estuary – Bristol Channel ecotone

The Severn Estuary is the largest example of a coastal plain estuary in the United Kingdom and one of the largest estuaries in Europe. It is comprised of 73,715.4 ha, two thirds of which are subtidal and one third of which is intertidal (Natural England & CCW 2009). Crucially the Severn Estuary contributes approximately 30% of the UK Natura 2000 resource for estuaries, by area (Natural England & CCW 2009) and it ranks as one of the top ten estuaries in the UK for the number of marine estuarine-opportunistic fish species it supports (Potts & Swaby 1993). Its role as a nursery area has long been acknowledged but very little

research has been done regarding the spatial distribution of fish either within the estuary, or the movement of fish between the estuary and the Bristol Channel. Numerous studies have confirmed the importance of Bridgwater Bay as a nursery area for a wide range of species (Henderson & Holmes 1991, Henderson et al. 1992, Henderson and Seaby 1994). Some very preliminary results from surveys using riley push nets to sample intertidal flatfish conducted by Plymouth University and D&S IFCA in 2018 and 2019 suggest that, for sole (*Solea solea*) Bridgwater Bay is a preferred location compared to intertidal mudflats elsewhere in the Severn Estuary (Weston-Super-Mare and Sand Bay). Based on its size, position and diversity of habitats (Potts and Swaby 1993) it is therefore likely that the Severn Estuary is a very important nursery area within the wider Bristol Channel. However, as with other estuary-ocean ecotones, as well as more information on population structure, further work is needed on the functional significance of habitats within the estuary and over larger spatial scales (Able 2005) in order to quantify the contribution of the Severn nursery area.

2.3 Concerns relating to the level of uncertainty and poor evidence base for scaling of fish mortality from HPB to HPC

2.3.1 Uncertainty in effect of moving water intake offshore

D&S IFCA is concerned about the assessment of the impacts of moving the water intakes offshore and believe the current EA guidance that offshore intakes are preferable to inshore intakes is a huge oversimplification. It is increasingly recognised that even within fish nursery areas, a mosaic of habitats connected by migration corridors are utilised by fish (Nagelkerken et al. 2015, Sheaves 2015). Where fish utilise intertidal habitats at high tide (such as Bridgwater Bay), they will then have to retreat to deeper water when the tide ebbs. Fish will move to deeper waters by navigating through corridors such as deep channels (Nagelkerken et al. 2015). Exactly this behaviour has been described in Bridgwater Bay where *Crangon crangon* migrates with the rising tide onto the intertidal flats, followed by its predators. At low water, the population and its predators become concentrated within the permanent water of the estuary (Henderson et al. 2006).

D&S IFCA is therefore concerned about the evidence base for moving the intake offshore and would support a greater acknowledgement of the uncertainties, the risks and a review of the evidence base. Information on the tidal state when sampling the proposed site of the offshore intakes would inform whether some of these risks have already been considered.

2.3.2 Uncertainty in performance of LVSE intakes

The performance of the Low Velocity Side Entry (LVSE) intakes appears to be critical in the calculations for scaling fish impingement at HPC compared to HPB. However, there are no examples of this type of intake anywhere in the World. Whilst D&S IFCA therefore accepts that the calculations must be based on modelled data, there remains uncertainty as to how the LVSE will perform. As the performance of the LVSE appears critical to the most recent assessment of impingement mortality the uncertainties should be acknowledged more clearly, and a precautionary approach adopted.

Recently D&S IFCA has been made aware of the reference within previous EDF documents to the necessity of having AFD present in order for the LVSE to deliver the benefits outlined in TR456. This needs further clarification and evidence ASAP.

2.3.3 Unacknowledged barotrauma caused by intake tunnels

A recent review by the Environment Agency (Horsefield 2018) of their 2010 guidance document *Cooling water options for the new generation of nuclear power stations in the UK*, has provided an update on progress since 2010. This report highlights that fish injuries caused by barotrauma may arise from fish passage through long, deeply buried tunnels. Horsefield (2018) highlights the urgent need for more research to inform mortality estimates caused by this.

To D&S IFCA's knowledge, Hinkley Point C will have long, deeply buried tunnels and the issue of barotrauma and its estimated impacts on fish mortality do not appear to have been addressed anywhere. If no data are available a precautionary approach is needed, and uncertainties should be clearly stated.

2.3.4 Uncertainty in evidence base for FRR

There appears to be little information presented on the effect of AFD removal on clupeid inundations and downstream effects on FRR survivability. This is a large area of concern for D&S IFCA.

Similarly, there is little information presented on the effects of FRR on predator attraction and ecological effects caused by the return of dead fish and risk of predation to any fish returned alive.

2.3.5 Uncertainty in the impingement datasets

The CIMP data used for the impingement assessments is now nearly 10 years old. It needs to be considered carefully whether this is still fit for purpose.

2.3.6 Error in mesh screen size used for impingement assessment

It appears that an incorrect mesh screen size has been used in the impingement assessment, or that no consideration of the effects of the reduction of the mesh screen at HPC on impingement has been given in the scaling between HPB and HPC. This appears to be a major weakness and must be corrected. It also highlights the importance of having information on both impingement and entrainment to understand overall mortality of fish as a change in mesh size will presumably alter both the numbers impinged and entrained.

Key Message 5: The scaling of fish mortality from HPB to HPC appears to include some major errors in its approach (e.g. mesh size of drum screens). There are also large uncertainties in the scaling, partly due to a very limited evidence base. D&S IFCA does not consider the scaling to be sufficiently precautionary in its approach.

3.0 Wider guidance, policy and decision-making concerns

3.1 Granting permits before final design

As described in the EA's 2010 evidence paper on cooling water options, often the key mitigation measures are only finalised after the EIA stage, during the construction phase:

'The timing of the various design process stages is linked to the phases of the development of the power station. For example, the design concept and environmental impact need to be

established for inclusion in the Environmental Statement. On the other hand, the structural design of individual system components may not be finalised until the construction phase.'

This allows a system which will consent the building of a nuclear power station based on an estimation of its potential to impact fish and fisheries, using what D&S IFCA believes to be a very narrow evidence base for the effectiveness of fish protection/ mitigation measures. If those estimates prove to be an underestimation and a post-hoc analysis of monitoring data shows that the assumptions of the EIA/ HRA were incorrect, or planning decisions affect the estimations made in the original HRA/EIA the new station may already be in the construction phase.

3.2 Direct cooling as BAT

D&S IFCA does not believe that direct cooling of new nuclear power stations should be considered Best Available Technique in any coastal or estuarine areas. In a review of best available technology in a US context, Henderson and Seaby (2000) argue that direct cooled power stations use such large volumes of water that there is no available suite of technologies that can be used to ensure that fish deaths and the impact on other aquatic life can be reduced to the levels that are achievable with less consumptive forms of closed-cycle cooling (Henderson and Seaby 2000).

Fisheries management is moving toward a more holistic approach, as showcased in the Government's recent 25 Year Environment Plan which indicates a move towards an Ecosystem Approach to fisheries management. There is a growing appreciation of and evidence base for the importance of early life-history stages of fish and the protection of their habitat, known as Essential Fish Habitat. D&S IFCA therefore believes that there should be a move away from direct cooled new nuclear power stations in coastal and estuarine locations towards closed circuit cooling.

3.3 Legislative gaps for fish protection

The inclusion of the fish assemblage as a sub-feature of the Severn Estuary European marine site is the exception, rather than the rule. In other estuarine and coastal areas where water is to be abstracted, D&S IFCA is concerned about the lack of targeted legislation to protect fish.

A recent review of the current implementation of cumulative effects assessments found that there is no consistency or standardisation in approach by developers (Willsteed et al. 2018). D&S IFCA believes a strategic review of the potential implications of new nuclear power stations on inshore fish communities should be undertaken by the relevant authorities.

3.4 Cumulative effects of developments and fishing

The Government's 25 Year Environment Plan has committed England to an Ecosystem Approach to fisheries management. An ecosystem approach must consider both the effects of fishing on the wider ecosystem and the effects of other activities on fish and fisheries. Although not a plan or project it is logical that commercial fishing, and other activities work together to reduce resilience of marine ecosystems (Willsteed et al. 2018).

Some fish stocks in the Bristol Channel are not being exploited sustainably. For example, for cod in 2018 ICES advised that, when the MSY approach is applied, there should be zero catch in 2019. It is important to consider the fish mortality at Hinkley in the context of the

state of the local stocks wherever possible. This has not been undertaken so far. Although not a plan or project a qualitative assessment of the current state of the stocks under review is required to understand whether the 1% threshold is negligible given the current state of the stock.

3.5 Nuclear power and adaptive management

In TR456 the water intakes for Hinkley Point C are compared to a ‘small inefficient trawler’, however the intakes differ from a trawler in one crucial way. Fisheries, particularly those in European Marine Sites, are increasingly employing adaptive management, such as the flexible permitting byelaw approach developed by D&S IFCA.

Adaptive management is seen as a key tool for effectively implementing the Ecosystem Approach (Farmer et al. 2012) and is increasingly seen as an integral part of sustainable management. Adaptive management acknowledges the high levels of uncertainty in natural systems and the difficulties of making decisions based on this uncertainty. It provides a framework for a flexible and pragmatic approach to marine management, allowing sustainable development whilst adapting management and policies to respond to new information (Farmer et al. 2012).

In the case of either new evidence about the state of a fish stock (e.g. the discovery of finer population structure, or a decline in abundance) fishing effort can be reduced using a number of mechanisms. At a Common Fisheries Policy level this can be slow, but with D&S IFCA’s Permitting Byelaws, new measures can often be brought in to change management within a few months. If new information comes to light regarding the fish stocks in the Severn Estuary, or if the intakes catch more fish than expected, or survival through the FRR is lower than expected, or climate change affects population dynamics in the estuary, there is no adaptive management measure that could be taken to reduce the impact of the Hinkley Point C intakes.

D&S IFCA therefore believes that direct cooling new nuclear power stations are falling short of the environmental standards increasingly expected for new developments, especially those occurring in or around Natura 2000 sites.

Key Message 6: In the highly dynamic marine environment sustainable development relies on and an ability to adapt management to ever-changing conditions, especially for fish communities which are already responding to climate change and other human stressors. Adaptive management is not an option for managing fish mortality at direct cooled nuclear power stations, which calls into question the long-term sustainability of such developments.

4.0 References

- Able K.W. (2005) A re-examination of fish estuarine dependence: Evidence for connectivity between estuarine and ocean habitats, *Estuarine, Coastal and Shelf Science*, 64: 5-17
- Akçakaya H. R., Mills G. and Doncaster C. P. (2007) The role of metapopulations in conservation. In, Macdonald, David W. and Service, Katrina (eds.) *Key Topics in Conservation Biology*. Oxford, UK. Blackwell Publishing, pp. 64-84.
- Archambault B., Rivot E., Savina-Rolland M., and Le Pape O. (2018) Using a spatially structured life cycle model to assess the influence of multiple stressors on an exploited coastal nursery-dependent population, *Estuarine, Coastal and Shelf Science*, 201: 95-104
- Beck M.W., Heck K.L., Able K.W., Childers D.L., Eggleston D.B., Gillanders B.M., Halpern B., Hays C.G., Hoshino K., Minello T.J., Orth R.J., Sheridan P.F., Weinstein M.P. (2001) The Identification, Conservation, and Management of Estuarine and Marine Nurseries for Fish and Invertebrates, *BioScience*, 51(8): 633-640
- Bird, D. (2008) The biology and conservation of the fish assemblage of the Severn Estuary (cSAC). Report Number CCW/SEW/08/1. pp. 1-79.
- Cambie G., Kaiser M.J., Marriott A.L., Fox J., Lambert G., Hiddink J.G., Overy T., Bennet S.A., Leng M.J., McCarthy I.D. (2016) Stable isotope signatures reveal small-scale spatial separation in populations of European sea bass, *Marine Ecology Progress Series*, 546: 213-223
- Carvalho G.R. and Hauser L. (1995) Molecular genetics and the stock concept in fisheries, *Reviews in Fish Biology and Fisheries*, 4: 326-350
- Cianelli et al (2013) Theory, consequences and evidence of eroding population spatial structure in harvested marine fishing: a review, *Marine Ecology Progress Series*, 480: 227-243
- Ciotti et al. (2013) Spatial variation in growth rate of early juvenile European plaice *Pleuronectes platessa*, *Marine Ecology Progress Series*, 475:213-232
- Coscia I. and Mariani S. (2011) Phylogeography and population structure of European sea bass in the north-east Atlantic, *Biological Journal of the Linnean Society*, 104: 364-377
- Bekkevold D., André C., Dhalgren T.G., Clausen L.A.W., Torstensen E., Mosegaard D., Carvahlo G.R., Christensen T.B., Norlinder E. and Rizzante E. (2005) Environmental correlated of population differentiation in Atlantic herring, *Evolution*, 59(12): 2656–2668
- Dahle G., Quintela M., Johansen T., Westgaard J., Besnier F., Aglen A., Jørstad K.E., and Glover K.A. (2018) Analysis of coastal cod (*Gadus morhua* L.) sampled on spawning sites reveals a genetic gradient throughout Norway's coastline, *BMC Genetics*, 19:42
- Dahlgren C.P., Kellison G.T., Adams A.J., Gillanders B.M., Kendall M.S., Kayman C.A., Ley J.A., Nagelkerken I., Serafy J.E. (2006) Marine Nurseries and effective juvenile habitats: concepts and applications, *Marine Ecology Progress Series*, 312: 291-295
- Doyle, T. K., Haberlin D., Clohessy J., Bennison A., Jessopp M. (2017) Localised residency and inter-annual fidelity to coastal foraging areas may place sea bass at risk to local depletion, *Scientific Reports*, 7: 45841
- Elliot M., Taylor C.J.L. (1989) The structure and functioning of an estuarine/marine fish community in the Forth Estuary, Scotland, *Proceedings of the 21st EMBS*: 227-240

Farmer, A., Mee. L., Langmead, O., Cooper, P., Kannen, A., Kershaw, P. and Cherrier, V. 2012. The Ecosystem Approach in Marine Management. EU FP7 KNOWSEAS Project. ISBN 0-9529089-5-6

Galley E.A., Wright P.J., Gibb F.M. (2006) Combined methods of otolith shape analysis improve identification of spawning areas of Atlantic cod, ICES Journal of Marine Science, 63: 1710-1717

Henderson C.J. (2019) Contrasting effects of mangroves and armoured shorelines on fish assemblages in tropical estuarine seascapes, ICES Journal of Marine Science, fsz007, <https://doi.org/10.1093/icesjms/fsz007>

Henderson P.A. and Holmes R.H.A (1987) On the population biology of the common shrimp *Crangon crangon* (L.) (Crustacea: Caridea) in the Severn Estuary and Bristol Channel, Journal of the Marine Biological Association of the Kingdom, 67 (4): 825-847

Henderson P.A. and Holmes R.H.A (1989) Whiting migration in the Bristol Channel: a predator-prey relationship, Journal of Fish Biology, 34 (3): 409-416

Henderson P.A. and Holmes R.H.A (1991) On the population dynamics of dab, sole and flounder within Bridgwater Bay in the lower Severn Estuary, England, Netherlands Journal of Sea Research, 27 (3-4): 337-344

Henderson P.A., James D.J. and Holmes R.H.A. (1992) Trophic structure within the Bristol Channel: seasonality and stability in Bridgwater Bay. Journal of the Marine Biological Association of the United Kingdom, 72: 675-690

Henderson P.A and Seaby R.M.H. (1994) On the factors influencing juvenile flatfish abundance in the lower Severn Estuary, England, Netherlands Journal of Sea Research, 32 (3-4): 321-330

Henderson P.A. and Seaby R.M.H (2000) Technical Evaluation of US Environmental Protection Agency Proposed Cooling Water Intake Regulations for New Facilities, Pisces Conservation Ltd.

Henderson P.A., Seaby R.M. and Somes J.R. (2006) A 25-year study of climatic and density-dependent population regulation of common shrimp *Crangon crangon* in the Bristol Channel, Journal of the Marine Biological Association of the United Kingdom, 86: 287-298

Henderson P.A. (2007) Discrete and continuous change in the fish community of the Bristol Channel in response to climate change, Journal of the Marine Biological Association of the United Kingdom, 87(2): 589-598

Henderson P.A. and Bird D.J. (2010) Fish and macro-crustacean communities and their dynamics in the Severn Estuary, Marine Pollution Bulletin, 61: 100–114

Henderson P.A, Seaby R.M.H. and Soames J.R. (2011) Community level response to climate change: The long-term study of the fish and crustacean community of the Bristol Channel, Journal of Experimental Marine Biology and Ecology, 400 (1-2): 78-89

Henderson P.A. and Henderson R.C. (2017) Population regulation in a changing environment: Long-term changes in growth, condition, and survival of sprat, *Sprattus sprattus* L. in the Bristol Channel UK, Journal of Sea Research, 120: 24-34

Hilborn R., Quinn T.P., Schindler D.E., and Rogers D.E. (2003) Biocomplexity and Fisheries Sustainability, PNAS, 100 (11): 6564-6568

- Holmes R.H.A and Henderson P.A. (1990) High fish recruitment in the Severn Estuary: the effect of a warm year? *Journal of Fish Biology*, 36: 961-963
- Holmes S.J., Wright P.J., Fryer R.J. (2008) Evidence from the survey data for regional variability in cod dynamics in the North Sea and West of Scotland, *ICES Journal of Marine Science*, 65: 206-215
- Humphries P., Potter I., Loneragan R.C (1992) The fish community in the shallows of a temperate Australian estuary: Relationships with the aquatic macrophyte *Ruppia megacarpa* and environmental variables, *Estuarine, Coastal and Shelf Science*, 34 (4): 325-346
- Hutchinson W.F. (2008) The dangers of ignoring stock complexity in fishery management: the case of North Sea cod, *Biological Letters*, 4: 693-695
- Johannessen A., Nøttestad L., Fernö A., Langård L., and Skaret G. (2009) Two components of Northeast Atlantic herring within the same school during spawning: support for the existence of a metapopulation? *ICES Journal of Marine Science*, 66: 1740–1748
- Jónsdóttir Ó.D.B., Daniélsdóttir A. K., and Nævdal G. (2001) Genetic differentiation among Atlantic cod (*Gadus morhua* L.) in Icelandic waters: temporal stability, *ICES Journal of Marine Science*, 58: 114–122
- Knutsen H., Olsen E.M., Jorde P.E., Espeland S.H., Andre C. and Stenseth N.C. (2011) Are low but statistically significant levels of genetic differentiation in marine fishes ‘biologically meaningful’? A case study of coastal Atlantic cod, *Molecular Ecology*, 20: 768-783
- Krebs, C.J. (2001) *Ecology The experimental analysis of distribution and abundance*. 5th Edition, Benjamin Cummings, San Francisco
- Kritzer J.P. and Sale P.F. (2004) Metapopulation ecology in the sea: from the Levin’s model to marine ecology and fisheries science, *Fish and Fisheries*, 5: 131-140
- Kritzer J. and Liu O.R (2013) *Fishery Management Strategies for Addressing Complex Spatial Structure in Marine Fish Stocks in Stock Identification Methods (Second Edition)*, Applications in Fishery Science: 29-57
- Magurran A.E. and Henderson P.A. (2003) Explaining the excess of rare species in natural species abundance distributions, *Nature*, 22: 714–716
- Magurran A.E. and Henderson P.A. (2012) How selection structures species abundance distributions, *Proceedings of the Royal Society B Biological Sciences*, 279: 3722–3726
- Mariani S., Hutchinson W.F., Hatfield E.M.C., Ruzzante D.E., Simmonds E.J., Dahlgren T.G., Andre C., Brigham J., Torstensen E. and Carvalho G.R. (2005) North Sea herring population structure revealed by microsatellite analysis, *Marine Ecology Progress Series*, 303: 245–257
- McQuinn (1997) Metapopulations and Atlantic herring, *Reviews in Fish Biology and Fisheries*, 7: 297-329
- Nagelkerken I., Sheaves M., Baker R., Connolly R. (2015) The seascape nursery: a novel spatial approach to identify and manage nurseries for coastal marine fauna, *Fish and Fisheries*, 16 (2): 362-371

Natural England & CCW (2009) The Severn Estuary / Môr Hafren European Marine Site: Natural England & the Countryside Council for Wales' advice given under Regulation 33(2)(a) of the Conservation (Natural Habitats, &c.) Regulations 1994, as amended.

Neat F.C., Bendall V., Berx B., Wright P.J., O Cuaig M., Townhill B., Schon P.J., Lee J. and Righton D. (2014) Movement of Atlantic cod around the British Isles: implications for finer scale stock structure, *Journal of Applied Ecology*, 51: 1564-1574

Olds A.D., Nagelkerken I., Huijbers C.M., Gilby B.L., Pittman S.J and Schlacher T.A. (2018) Connectivity in Coastal Seascapes, in Pittman S.J. *Seascape Ecology*, John Wiley & Sons , UK

O'Neill R. 2017. The distribution of the European sea bass, *Dicentrarchus labrax*, in Irish waters. PhD Thesis, University College

Pawson et al M.G., Borwn M. Leballeur J. and Pickett G.D. (2008) Will philopatry in sea bass, *Dicentrarchus labrax*, facilitate the use of catch-restricted areas for management of recreational fisheries? *93 (1-2): 240-243*

Potter I.C., Claridge P.N., Hyndes G.A. and Clarke K.R. (1997) Seasonal, annual and regional variations in ichthyofaunal composition in the inner Severn Estuary and inner Bristol Channel, *Journal of the Marine Biological Association of the United Kingdom*, 77(2): 507-525

Potter I.C., Bird D.J., Claridge P.N., Clarke K.R., Hyndes G.A.. and Newton L.C. (2001) Fish fauna of the Severn Estuary. Are there long-term changes in abundance and species composition and are the recruitment patterns of the main marine species correlated? *Journal of Experimental Marine Biology and Ecology*, 258 (1): 15-37

Potts G.W., and Swaby S.E. (1993) Review of the status of estuarine fishes. Pp278. English Nature Research Report No.34, Marine Biological Association/ English Nature

Poulsen N.A., Hemmer-Hanson J., Loeschcke V., Carvalho G.R., Nielsen E.E. (2011) Microgeographical population structure and adaptation in Atlantic cod *Gadus morhua*: spatio-temporal insights from gene-associated DNA markers, *Marine Ecology Progress Series*, 436: 231-243

Rees S.E., Sheehan E.V., Jackson E.L., Gall S.C., Cousens S.L., Solandt J., Boyer M. and Atrill M.J. (2013) A legal and ecological perspective of 'site integrity' to inform policy development and management of Special Areas of Conservation in Europe, *Marine Pollution Bulletin*, 72 (1): 14-21

Reiss H., Hoarau G., Dickey-Collas D. and Wolff W.J. (2009) Genetic population structure of marine fish: mismatch between biological and fisheries management units, *Fish and Fisheries*, 10 (4): 361-395

Ruzzante D. E., Taggart C. T., and Cook, D. (1998) A nuclear DNA basis for shelf and bank-scale population structure in northwest Atlantic cod (*Gadus morhua*): Labrador to Georges Bank, *Molecular Ecology*, 7: 1663–1680

Ruzzante D.E., Wroblewski J.S., Taggart C.T., Smedbol R.K., Cook D., Goddard S.V., (2000) bay-scale population structure in coastal Atlantic cod in Labrador and Newfoundland, Canada, *Journal of Fish Biology*, 56: 431-447

Ruzzante D.E., Mariani S., Bekkevold D., André C., Mosegaard H., Clausens L.A.W., Dahlgren T.G., Hutchinson W.F., Hatfields E.M.C., Tortensen E., Brigham J., Simmonds

E.J., Laikre L., Larsson L.C., Stet R.J.M., Ryman N. and G.R Cavalho (2006) Biocomplexity in a highly migratory pelagic marine fish, Atlantic herring, *Proc. R. Soc. B*, 273: 1459–1464

Ryman N., Utter F., Laikre L. (1995) Protection of intraspecific diversity of exploited fishes, *Reviews in Fish Biology and Fisheries*, 5: 417-446

Schaberg S.J., Patterson J.T., Jill J.E., Guindon K.Y., Tuckett Q.M. (2019) Fish community composition and diversity at restored estuarine habitats in Tampa Bay, Florida, United States, *Restoration Ecology*, 27 (1): 54-62

Sheaves M. (2009) Consequences of ecological connectivity: the coastal ecosystem mosaic, *Marine Ecology Progress Series*, 391: 107-115

Sheaves M., Baker R., Nagelkerken I. and Connolly R.M. (2015) True Value of Estuaries and Coastal Nurseries for Fish: Incorporating Complexity and Dynamics, *Estuaries and Coasts* 38: 401-414

Watson J.R., Siegel D.A., Kendall B.E., Mitarai S., Rasweiller A., Gaines S.D. (2011) Identifying critical regions in small-world marine metapopulations, *PNAS*, 108 (43): E907-E913

Willstead E.A., Birchenough S.N.R., Gill A.B and Jude A. (2018) Structuring cumulative effects assessments to support regional and local marine management and planning obligations, *Marine Policy*, 98(98): 23-32

Wright P.J., Neat F.C., Gibb F.M., Gibb I.M., Thordarson H. (2006) Evidence for metapopulation structuring in cod from west of Scotland and North Sea, *Journal of Fish Biology*, 69: 181-199