Fixed Entangling Nets Interactions with Grey Seal

1. Introduction

The Assessing Welsh Fishing Activities (AWFA) Project is a structured risk-based approach to determining impacts from current and potential fishing activities (those undertaken from licensed and registered commercial fishing vessels), upon the features of European marine sites (EMS) in Wales.

Further details of the AWFA Project, and all completed assessments to date, can be found on the AWFA website.

The methods and process used to classify the risk of interactions between fishing gears and EMS features, as purple (high), orange (medium) or green (low) risk, can be found in the AWFA Project Phase 1 outputs: Principles and Prioritisation Report and resulting Matrix spreadsheet.

2. Assessment summary

Assessment Summary: **Fixed Entangling Nets** **Interactions with Grey** **Seal**	Direct and indirect studies that measured or estimated impacts of fixed entangling nets and other fixed net fisheries on grey seal were considered. **Assessment of impact pathway 1. Direct capture, damage, disturbance or harm to a designated species feature:** The impacts from fixed entangling nets or noise pollution associated with fishing vessels could lead to grey seal bycatch, displacement or disturbance. **Assessment of impact pathway 2. Damage to the habitat of designated species features (including through direct physical impact, pollution, changes in thermal regime, hydrodynamics, light etc.):** The impacts from nets, weights or anchors are not likely to affect the integrity of the water column habitats (see impact pathway 4 for consideration of benthic feeding activity and prey habitat) utilised by grey seal. **Assessment of impact pathway 3. Removal of prey species of a designated species feature:**

	The removal of prey species by fixed entangling nets could affect grey seals. However evidence suggests that grey seals will readily switch prey, but it is not known if dependency on alternative prey availability and quality is detrimental at the population level in the long term. **<u>Assessment of impact pathway 4. Damage to habitat of prey species:</u>** The impacts from nets, weights or anchors could cause damage to the habitat of the prey species of grey seal. Confidence in this assessment is **high** (please see section 8).

3. Feature description

Feature Description: **Grey Seal**	Grey seal (*Halichoerus grypus*) is a medium sized seal with a long muzzle and convex profile to its head (MarLIN, 2019). Adult males average 207cm, 233kg and seldom live longer than 25 years, whilst females are smaller, reaching 180cm and 155kg, and live for up to 35 years (The Mammal Society, 2017). Grey seals spend much of their time foraging for food at sea. However, they haul themselves out on to land - exposed rocks, usually on uninhabited offshore islands, or on secluded mainland beaches to rest, moult and pup. Some haul-outs can be large, consisting of hundreds of animals, particularly in spring when they undergo a moult (The Mammal Society, 2017; Duck, 2009). Grey seals are distributed on both sides of the North Atlantic Ocean and within the Barents and Baltic Seas (MarLIN, 2019). The greatest populations are found on the east coast of Canada and United States of America and in Northwest Europe (SCOS, 2018). Approximately 38% of the world's population breed in the UK, with 88% of these found in Scottish colonies (SCOS, 2018). Welsh grey seal colonies produce approximately 2.5% of the annual UK grey seal pup production, estimated in 2016 as 1650 pups (SCOS, 2018). Pembrokeshire is thought to contain the largest concentration of grey seals in southwestern Britain (Strong *et al*., 2006). In the 1990s, about 5000 seals of all age groups were, estimated to be in Pembrokeshire/West Wales based upon average annual pup counts of 1331 between 1992 to 1994 (Baines *et al*., 1995). Since then, pup production has increased markedly at the regularly monitored colonies in Pembrokeshire (Bull *et al*., 2017a, 2017b).. Smaller but important pupping colonies are also present in North Wales and pup production has also increased at these colonies (Robinson *et al*., 2020), suggesting the population of grey seals around Wales has increased, as has been seen in other parts of the UK (SCOS 2018). During the breeding season female grey seals tend to exhibit site fidelity where they return to the same pupping site to breed each year (Pomeroy *et al.,* 2000a). In Wales, pupping typically occurs during autumn at remote coastal locations such as islands, rocky beaches and in sea caves (Stringell *et al.,* 2014). In West Wales,

	pupping begins in August and peaks in October, although in recent decades, the peak pupping times have been getting earlier (Bull *et al.,* 2017a, 2017b; Morgan *et al*., 2018). Grey seal pups weigh around 14kg at birth and remain on land suckling for around three weeks, during which they can expect to gain weight at a rate up to 2kg per day (The Mammal Society, 2017). Grey seals feed on a wide variety of benthic or demersal fish species (Thompson *et al.,* 1991). Although sandeels and gadoids (such as cod and whiting) are important food sources for grey seals, overall, they are opportunistic feeders, and take whatever food source is locally abundant (The Mammal Society, 2017; Brown *et al.,* 2012).

4. Gear description

Gear Description: **Fixed Entangling Nets**	Fixed entangling (or tangle) nets are a type of gill net, comprising one or more walls of loosely set transparent monofilament or multifilament netting, hung from an upper floated headline and attached to a weighted lower footrope, ensuring they hang approximately vertically in the water, and the bottom of the net sits on or near the seabed (Potter and Pawson, 1991; FAO, 2019). The entangling net is fixed to the seabed at each end by conventional anchors or weights to prevent it moving in the tide, and nets are marked at one or both ends with buoys (Potter & Pawson, 1991; Seafish, 2019). The loose-set nature of entangling nets differs from gill nets, which are set taught between their framing ropes and consequently the two methods can target different species and size of fish (Seafish, 2019). By using a different mesh size and adjusting how loosely the nets are set, different fish species can be targeted (Seafish, 2019, FAO, 2019). Although entangling nets can be deployed in midwater or near the surface depending on design and buoyancy (FAO, 2019), the focus of this assessment is bottom-set or fixed entangling nets, deployed on or just above the seabed. Fixed entangling nets usually comprise stronger and larger mesh sizes compared to gill nets, to enable larger fish to be retained, without damaging the net (Seafish, 2019). The slack nature of entangling nets makes them more effective at catching demersal species such as flatfish, monkfish and shellfish, which due to their body shape would not easily be caught in a standard gill net (Seafish, 2019). As with other types of gill net (gill, entangling and trammel), fish are typically (a) wedge-held, where the mesh catches around the body of the fish; (b) gill-held, when the mesh slips over the opercula; or (c) entangle-held, catching teeth, spines, or other protrusions (Kalaycı and Yeşilçiçek, 2012). With all fixed net fisheries, a variety of international and national regulations and local factors determine the mesh size, length, and height of nets used, including areas fished and target species (Welsh Government, 2011a, 2011b; European Council, 2013; NOAA, 2019). In small-scale inshore fisheries, as is common in Wales,

	individual entangling nets typically measuring a few hundred metres, and set in shallow or moderate depth water, could be hauled by hand or by net hauler.

5. Assessment of impact pathways

Assessment of impact pathway 1	**1. Direct capture, damage, disturbance or harm to a designated species feature** Direct evidence was found that measured or estimated some impacts of fixed entangling nets on grey seals in the UK. Additionally, indirect evidence on the impacts from other fixed net fisheries on the direct capture, damage, disturbance or harm of grey seal is also considered. In Wales grey seals were assessed to be in favourable condition in 2018 indicative site level feature condition assessments for all three Welsh SACs where grey seal is a qualifying feature (NRW, 2018b, 2018d & 2018f). The JNCC reported the status of UK grey seal populations as favourable to the EU in the most recent three rounds of Habitats Directive Article 17 reporting from 2007, 2013 and 2019 (JNCC, 2007, 2013, 2019). The distribution of grey seals overlap with fixed net fishing activity predominantly by under 12m vessels within Welsh inshore waters (0-12NM). Potentially leading to bycatch interactions through entanglement by their head, teeth, claws or limbs (Bjørge *et al*., 2002). Grey seal interactions with inshore fixed net fisheries (including fixed entangling nets) have been documented throughout their range, wherever spatial overlap occurs (Cronin *et al*., 2014; Harwood and Walton, 2002; Königson, *et al*., 2015). Direct or operational interactions include fish depredation, gear damage and incidental capture or entanglement of seals (Cosgrove *et al*., 2015). Grey seals may be potentially captured during close inspection of nets due to natural curiosity (Cronin *et al*., 2014). In a comprehensive report to the EU on UK marine mammal bycatch rates, 82 observed fishing days resulted in 23 grey seal bycatches within the 'UK gillnet' category (Northridge *et al*., 2015-2018). Based on these observations, it has been estimated that the annual bycatch for all UK gillnet fisheries combined, between 2015-2017, ranged from 572 to 610 grey seals annually. The 'fixed entangling and trammel nets' metier contributed by far the greatest proportion of estimated bycatch (511 to 536 grey seals for the same period). This proportionally higher bycatch from entangling and trammel nets (combined) suggests these fishing methods, which use larger mesh sizes and thicker diameter twine, pose a greater risk to grey seals compared with other types of fixed net fishing in the UK (Northridge et al., 2018, SCOS, 2018). Although annual grey seal bycatch estimates for 2015-2017 in southwest UK were higher than models suggested was sustainable for local populations, grey seal populations in this area (and the wider UK) have continued to increase (SCOS, 2016-2018). SCOS (2018) suggest high bycatch of mostly juvenile grey seals might not severely impact the overall population, as natural

	mortality of juvenile greys seals is higher than that of adults irrespective of bycatch, whilst the remaining adults continue to breed. Additionally, immigration by grey seals from other areas (UK and elsewhere) might balance out potentially unsustainable bycatch rates (SCOS, 2018). Mesh sizes and twine thickness are known to affect grey seal bycatch rates, with larger mesh sizes and thicker twine diameter in bottom-set nets increasing the risk (Northridge *et al*., 2003; Cosgrove *et al*., 2013, Cosgrove *et al*., 2016). Fixed nets with a thicker twine diameter (0.6mm) results in a significantly higher seal bycatch rate, compared to thinner (0.4mm) twine (Northridge *et al*., 2003). Thinner twine is easier to break by seals caught in the nets, leading to a greater number of holes in the thinner twine nets being found (Northridge *et al*., 2003). An investigation into grey seal depredation and bycatch in fixed net fisheries within the Irish Sea observed 55 individuals being caught within 124 entangling net hauls. Most of the bycaught seals were within a larger mesh size net: 47 seals caught within a mesh size of 320mm compared to 8 seals caught within a mesh size 270mm (Cosgrove *et al*., 2013). Day to day activities of the grey seal, which includes frequent short-distance feeding trips and square-profile dives, may increase the risk of bycatch within bottom-set fixed entangling nets especially within populations that remain close to the haul out sites inshore (Bjørge *et al*., 2002). Pinnipeds including grey seals rely on their eyes for navigation above and below water (Fjälling *et al*., 2007; Hanke *et al*., 2009). There is some disagreement in the science relating to the ability of grey seals to detect static fishing nets. There is some evidence suggesting that foraging grey seals do not see bottom-set nets until it is too late for them to escape (Wilson, 2003; Cosgrove *et al*., 2013). Another report highlights that fishers report fewer depredation interactions with nets set at night, perhaps highlighting that seals are unable to see well at night (Fjälling *et al*., 2007). Additionally, fewer grey seals have been reported to be bycaught in inshore fixed nets (including entangling nets) in clearer less turbid waters, compared to areas with greater turbidity (Luck *et al*., 2019). Conversely, several authors also demonstrate grey seals diving, foraging and navigating in the dark and at night (Sjöberg, *et al*., 1995; Thompson, *et al*., 1991; Cameron, 2009), where vision is unlikely to be the seal's primary sense. This apparent difference in opinion suggests more research is required to understand the importance of the vision of a seal when foraging in complete darkness, and specifically, whether seals are able to detect fixed nets when foraging in low light conditions. Juvenile grey seals, less than a year old, are most vulnerable to bycatch in static gear including fixed entangling nets (Bjørge *et al*., 2002; Cosgrove *et al*., 2013). The higher rate of juvenile bycatch may reflect greater curiosity towards novel objects, lesser physical strength required to escape entanglement, and less developed physiological diving responses compared to adults (Bjørge *et al*., 2002; Carter *et al*., 2017). Underwater noise pollution may also impact grey seal populations. Grey seals use sound for communication both above and below water, with sounds classified into seven low frequency types ranging from growls to clicks

	and utilising frequencies from 100-3000Hz (Asselin et al., 1993). Activities that cause loud underwater noise have the potential to injure or disturb grey seals in four ways depending on the persistence and pressure (loudness) of the sound: 1) temporary or permanent damage to the ear from high pressure sounds, 2) masking sounds used for communication or foraging, 3) causing avoidance of habitat/area, or 4) inducing physiological changes such as increased stress hormone levels (Götz and Janik, 2013; Merchant et al., 2016). Grey seals reportedly move away from loud or unpleasant sources of sound (Götz and Janik, 2010), especially those invoking the startle reflex response such as some Acoustic Harassment Devices (AHD) which are widely used in Scottish salmon aquaculture (Götz and Janik, 2013). Prolonged exposure to AHDs can lead to sensitisation and sustained spatial avoidance behaviour (Götz and Janik, 2011). Conversely, grey seals can also learn to be attracted to specific noises representing a food source, a learned response known as the 'dinner bell' effect. Examples include Acoustic Deterrent Devices (ADD) (Götz and Janik, 2013) and winch sounds relating to the setting or retrieving of nets (Cosgrove *et al*., 2015). Any activities that produce underwater noise have the potential to disturb grey seal. Commercial fishing contributes to ambient noise, including low frequency sound from engines and gear winching and hauling, and high frequency sound from the use of sonar and fish finding equipment (Evans & Hintner, 2012). Side scan sonar and echo sounders, typically used on fishing vessels, produce loud and high frequency but narrow sound beams, which are only likely to affect marine mammals if they happen to transect the narrow beam (Evans & Hintner, 2012). Depending on the fishery, the operation of the gear and the intensity of the activity it is possible that the impacts from fixed entangling nets or noise pollution associated with fishing vessels could lead to grey seal bycatch and displacement/disturbance respectively.
Assessment of impact pathway 2	**2. Damage to the habitat of designated species features (including through direct physical impact, pollution, changes in thermal regime, hydrodynamics, light etc.)** No studies were found that directly measured or estimated the impacts of fixed entangling nets on the habitat utilised by grey seal. Therefore, indirect evidence based on the life history of grey seals and the habitats they utilise is considered. During the UK breeding season, September to December, grey seals stay close to shore or on shore at haul out sites (Matthiopoulos *et al*., 2004). When not ashore, grey seals spend time feeding during short foraging trips generally focussed in areas within 30-40km of a haul out site during the breeding period (McConnell *et al.,* 1999; Vincent *et al*., 2016), and usually lasting 1-5 days in duration (Hall and Thompson, 2009).

	Although it is known that seals rely on haul out sites to rest, breed, moult and give birth, and require suitable foraging areas to feed, the exact habitat requirements of grey seals are not well understood (Pomeroy *et al.,* 2000b). There is no impact pathway linking the operation of fixed entangling nets to damage or disturbance of grey seals whilst they are hauled-out on land, therefore only at-sea habitats are considered within this assessment. The interaction between fixed entangling nets and the benthic habitats of grey seal prey is considered in Impact Pathway 4. Grey seal activities, other than benthic feeding, tend to occur within the water column or on land and are not known to be dependent on the seabed habitat. The impacts from nets, weights or anchors are not likely to affect the integrity of the water column habitats utilised by grey seal.
Assessment of impact pathway 3	**3. Removal of prey species of a designated species feature** No studies were found that directly measured or estimated the impacts of fixed entangling nets removing the prey species of grey seal. Therefore, indirect evidence from other fixed net fisheries that catch the prey of grey seal is considered. Grey seals are marine predators and opportunistic feeders of fish and invertebrates with a diet that varies both geographically and seasonally (Hammond and Wilson, 2016). They are largely demersal or benthic feeders, foraging in coastal waters where diets include a range of commercial and non-commercial fish species (Strong, 1996; Hammond and Wilson, 2016). Common UK prey species include sandeels, gadoids e.g. cod, whiting, haddock, saithe and ling, and flatfish such as plaice and sole (Evans and Hintner, 2012; Hammond and Wilson, 2016). The diet of grey seals in Pembrokeshire in the 1990s was reported as whiting, solenid species, *Trisopterus* species, dragonet, plaice and herring being the most common prey species in Wales at that time, with the notable absence of sandeels in the diet of Welsh grey seals studied (Strong, 1996). Although forming only a small part of the diet, grey seals also eat cephalopods (Evans and Hintner, 2012; Hammond and Wilson, 2016). UK inshore fixed entangling net fisheries target demersal species such as dover sole, plaice, other flatfish, spider crabs, crawfish and monkfish (Seafish, 2011; Seafish, 2019). In Wales, Walmsley & Pawson (2007) describe fixed entangling nets and trammel nets being used to target sole, plaice, dab and flounder with mesh sizes of 100-120mm, and rays, turbot, monkfish and brill with larger net sizes of 200-300mm. Some of the fixed entangling net target species are also prey species for grey seals, therefore some competition is likely to occur between this fishery and foraging grey seals.

	The Maximum Sustainable Yield (MSY) for a fish stock is the maximum level at which a fish stock can be routinely exploited without long-term depletion. In the pursuit of MSY for fish stocks, the International Council for the Exploration of the Seas (ICES) incorporates both fishing and natural fish mortality in their stock assessment models and Total Allowable Catch (TAC) advice. Natural mortality is defined as “all sources of mortality of a fish stock outside of that caused by fishing” (Walmsley, 2018). Specifically, this includes predation by other fish, birds and marine mammals, and mortality from biotic and abiotic factors such as temperature, disease and other anthropogenic activities, excluding fishing (Walmsley, 2018). ICES have recently developed a multi-species model for the North Sea, including cod, haddock, herring, whiting, sprat, Norway pout and sandeel (Walmsley, 2018). A similar multi-species assessment model is being developed for the Irish Sea. This multi-species approach specifically incorporates predator prey interactions (Walmsley, 2018) e.g. foraging grey seals, and reflects changes in abundance of different ecosystem components. Better estimates of natural mortality should lead to more realistic TAC advice, improved fisheries management in line with MSY and adequate allocation of food resources to predator species such as grey seals. Importantly it should be noted that commercially fished non-TAC species forming part of the grey seal diet would not be subject to the same stock assessments. Depending on the intensity of fishing activity, it is possible that the removal of prey species by fixed gill nets could affect grey seals. However, evidence suggests that grey seal will readily switch prey, but it is not known if dependency on alternative prey availability and quality is detrimental at the population level in the long term

Assessment of impact pathway 4	**4. Damage to habitat of prey species** No studies were found that directly measured or estimated the impacts of fixed entangling nets on the habitats of prey species of grey seals. Therefore, indirect evidence on the impacts from other fixed net fisheries on the habitats utilised by grey seal prey species is considered. Prey species of grey seals include sandeels; gadoids e.g. cod, whiting, haddock, saithe, ling and *Trisopterus* species; dragonet; herring; flatfish such as plaice and sole; and to a lesser extent, cephalopods (Evans and Hintner, 2012; Hammond and Wilson, 2016; Strong, 1996). The habitat of these prey species vary but can be broadly characterised as pelagic and benthic in nature and includes sediments such as sands, gravels and reefs. Sandbanks are important environments with a range of sediment mobilisation varying from relatively static (usually finer muddier sediments) to active mobile sandbanks (JNCC, 2017). Due to enhanced levels of primary and secondary productivity on or around sandbanks, a range of fish species use this habitat as feeding and nursery grounds; including sandeel, goby and common dab (Daunt *et al*., 2008; Scott *et al*., 2010; Camphuysen *et al*., 2011), several of which are prey species for grey seals. The anchors or weights that fix the entangling nets to the seabed have a potential to penetrate finer sediments. However, in exposed areas the mobile nature of the sediments is likely to negate any long-term influence on seabed composition or habitat condition (Hinz *et al*., 2010). Reef habitats are potentially at risk of abrasion or crushing by fixed net anchors or weights, nets can also become entangled on seabed structures causing fragmentation, tearing or abrasion of the habitat, leading to deterioration and the removal of long-lived fragile and emergent epifauna (Brown and Macfadyen, 2007). However, most fishers with nets tend to avoid reef habitats to prevent losing or damaging their nets, and so the risk to these habitats may be lower than anticipated. Factors affecting the integrity of pelagic fish habitats e.g. water quality are not likely to be affected by fishing with fixed entangling nets. These factors are not considered further in this assessment. Depending on the footprint and the intensity of the activity it is possible the impacts from nets, weights or anchors could cause damage to the habitat of the prey species of grey seals. However, these are large scale habitat features and there is no evidence to suggest that the impacts from fixed entangling net fisheries on the habitats of grey seal prey species would affect the grey seal at a population level.

6. SACs designated for grey seal

Grey seals are listed as protected species in three Welsh SACs, but due to their mobile nature, impacts from activities must be considered throughout their wider management unit.

Cardigan Bay SAC	Grey seals are known to range throughout Cardigan Bay and beyond, and there are a significant number of pupping sites in south-western Ceredigion (NRW, 2018c). Moulting and resting haul-out sites are scattered along the site. None are used as haul-outs by large numbers of seals, instead they generally haul-out singly or in small groups in undisturbed locations throughout the site (NRW, 2018c). Grey seals were assessed to be in favourable condition during the 2018 indicative site level feature condition assessment for the Cardigan Bay SAC (NRW, 2018d). The grey seals present Cardigan Bay SAC do not form a discrete population but are part of a much wider population shared among UK, Ireland, France and the Isle of Man (NRW 2020).
Lleyn Peninsula and the Sarnau SAC	Grey seals range throughout the open coast areas of the site and beyond, with Bardsey Island identified as the most important breeding colony in north Wales (NRW, 2018e). Grey seals are commonly observed within the SAC around the Lleyn Peninsula, Bardsey Island and the islands along the south Lleyn coast. Recent tracking studies showed wide ranges for individual seals from Northern Irish Sea to south-west England and beyond (NRW, 2018e). Grey seals were assessed to be in favourable condition during the 2018 indicative site level feature condition assessment for the Lleyn Peninsula and Sarnau SAC (NRW, 2018f). The grey seals present in this SAC do not form a discrete population but are part of a much wider population shared among UK Ireland, France and the Isle of Man (NRW, 2020).
Pembrokeshire Marine SAC	Grey seals range throughout the open coast areas of the site but use the Milford Haven waterway less frequently and are predominantly confined to few favoured locations, such as Stack Rock. Pupping takes place throughout the site on open coast in suitable habitat, which includes physically accessible, remote and/or undisturbed rocky coast beaches, coves and caves. The high proportional use of sea-caves by the south-west Wales population is a particularly unusual variation in breeding behaviour (NRW, 2018a).

	The Welsh grey seal population is estimated to represent about 2.5% of the UK population (SCOS, 2018) and the Pembrokeshire coast includes the largest breeding colonies and greatest concentration of grey seals in Wales (NRW, 2018a). Grey seals were assessed to be in favourable condition during the 2018 indicative site level feature condition assessment for the Pembrokeshire Marine SAC (NRW, 2018b). The grey seals present Pembrokeshire Marine SAC do not form a discrete population but are part of a much wider population shared among UK, Ireland, France and the Isle of Man (NRW 2020).

7. Evidence Gaps

- Direct studies to measure the impacts from fixed entangling nets on grey seals
- Studies to measure noise pollution of Welsh fishing fleet on grey seals
- Studies to measure behaviour change of grey seals towards pingers
- Monitoring of grey seals population status and structure
- Studies on vision of grey seals and how this relates to interaction with fishing gear

8. Confidence assessment

The confidence score is the sum of scores from three evidence components: quality, applicability and agreement. These are qualitatively assessed as high, medium or low using the most appropriate statements in the table below, and these are numerically represented as scores of 3, 2, or 1 respectively.

A total confidence score of 3 – 4 represents low confidence, 5 – 7 shows medium confidence and 8 – 9 demonstrates high confidence in the evidence used in the assessment.

This assessment scores 8, representing high confidence in the evidence.

	Evidence quality	Evidence applicability	Evidence agreement
High	**Based on more than 3 recent and relevant peer reviewed papers or grey literature from established agencies.** **Score 3.**	Based on the fishing gear acting on the feature in the UK.	**Strong agreement between multiple (>3) evidence sources.** **Score 3.**
Medium	Based on either relevant but older peer reviewed papers or grey literature from less established agencies; or based on only 2-3 recent and relevant peer reviewed evidence sources.	**Based on similar fishing gears, or other activities with a similar impact, acting on the feature in the UK.** **Score 2.**	Some disagreement but majority of evidence agrees. Or fewer than 3 evidence sources used.
Low	Based on either less relevant or older grey literature from less established agencies; or based on only 1 recent and relevant peer reviewed evidence source.	Based on dissimilar fishing gears acting upon the feature in other areas.	Little agreement between evidence.

N.B. When evidence is indirect the evidence quality and applicability will be capped to medium, to ensure that direct evidence gaps are captured in this approach.

9. References

Asselin, S., Hammill, M.O. & Barrette, C. (1993). Underwater vocalisations of ice breeding grey seals. Canadian Journal of Zoology. 71, 2211-2219.

Baines, M.E., Earl, S.J., Pierpoint, C.J.L. & Poole, J. (1995). The west Wales grey seal census. CCW Contract Science Report No. 131. Countryside Council for Wales, Bangor.

Bjørge, A., Øien, N., Hartvedt, S. & Bøthun, G. (2002). Dispersal and bycatch mortality in Grey, *Halichoerus grypus*, and Harbour, *Phoca vituline*, seals tagged at the Norwegian coast. Marine Mammal Science, 18(4):963-976.

Brown, J. and Macfadyen, G. (2007). Ghost fishing in European waters: Impacts and management responses. Marine Policy, Elsevier, vol. 31(4), pages 488-504. Brown, S.L., Bearhop, S., Harrod, C. & McDonald, R.A. (2012). A review of spatial and temporal variation in grey and common seal diet in the United Kingdom and Ireland. Journal of the Marine Biological Association of the United Kingdom, 92(8), 1711-1722.

Bull, J.C., Börger, L., Banga, R., Franconi, N., Lock, K., Morris, C., Newman, P. & Stringell, T. (2017a). Temporal trends and phenology in grey seal (*Halichoerus grypus*) pup counts at Marloes Peninsula, Wales. NRW Evidence Report No: 155, Natural Resources Wales, Bangor.

Bull, J.C., Börger, L., Franconi, N., Banga, R., Lock, K.M., Morris, C.W., Newman, P.B. & Stringell, T.B. (2017b). Temporal trends and phenology in grey seal (*Halichoerus grypus*) pup counts at Skomer, Wales. NRW Evidence Report No: 217, 23pp. Natural Resources Wales, Bangor.

Cameron, A. (2009). Seasonal movements and diurnal activity rhythms of the Grey seal (*Halichoerus grypus*). Journal of Zoology. 161(1):15 - 23. DOI: 10.1111/j.1469-7998.1970.tb02166.x.

Camphuysen, K., Scott, B. & Wanless, S. (2011). Distribution and foraging interactions of seabirds and marine mammals in the North Sea: a metapopulation analysis. Available online from: http://www.abdn.ac.uk/staffpages/uploads/nhi635/ZSLpaper-kees.pdf.

Carter, M.I.D., Russell, D.J.F., Embling, C.B., Blight, C.J., Thompson, D., Hosegood, P.J. & Bennett, K.A. (2017). Intrinsic and extrinsic factors drive ontogeny of early-life at-sea behaviour in a marine top predator. Scientific Reports 7, Article number: 15505 https://www.nature.com/articles/s41598-017-15859-8.

Robinson, G.J., Clarke, L.J., Banga, R., Griffin R.A., Porter J., Morris, C.W., Lindenbaum, C.P., & Stringell, T.B. (2020). Grey Seal (*Halichoerus grypus*) Pup Production and Distribution in North Wales, 2017. NRW Evidence Report No. 293. 54pp. Natural Resources Wales, Bangor.

Cosgrove, R., Cronin, M., Reid, D., Gosch, M., Sheridan, M., Chopin, N. & Jessopp, M. (2013). Seal depredation and bycatch in set net fisheries in Irish waters. Fisheries Resource Series Vol. 10.

Cosgrove, R., Gosch, M., Reid, D., Sheridan, M., Chopin, N., Jessopp, M. & Cronin, M. (2015). Seal depredation in bottom-set gillnet and entangling net fisheries in Irish waters. Fisheries Research 172 335–344.

Cosgrove, R., Gosch, M., Reid, D., Sheridan, M., Chopin, N., Jessopp, M. & Cronin, M. (2016). Seal bycatch in gillnet and entangling net fisheries in Irish waters. Fisheries Research 183, 192-199. http://www.sciencedirect.com/science/article/pii/S0165783616301965.

Cronin, M., Jessopp, M., Houle, J. & Reid, D. (2014). Fishery-seal interactions in Irish waters: Current perspectives and future research priorities. Marine Policy 44 120–130.

Daunt, F., Wanless, S., Greenstreet, S.P.R., Jensen, H., Hamer, K.C. & Harris, M.P. (2008). The impact of the sandeel fishery on seabird food consumption, distribution and productivity in the northwestern North Sea. Canadian Journal of Fisheries and Aquatic Science 65: 362-81.

Duck, C.D. (2009). Grey seal pup production in Great Britain and Ireland in 2008. In Special Committee on Seals (Ed.), Scientific advice on matters related to the management of seal populations: 2009 (Briefing Paper 09/1). St Andrews: Sea Mammal Research Unit. 12pp.

European Council. (2013). Council Regulation (EC) No 227/2013 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31998R0850.

Evans, P.G.H. & Hintner, K. (2012). A review of the direct and indirect impacts of fishing activities on marine mammals in Welsh waters. CCW Policy Research Report No. 12/5: 1-172.

FAO. (2019). Fishing Gear types. Gillnets and entangling nets. Fisheries and Aquaculture Department Technology Fact Sheets. [Accessed 12th December 2019]. http://www.fao.org/fishery/geartype/107/en.

Fjälling, A., Kleiner, J. & Beszczyńska, M. (2007). Evidence that grey seals (*Halichoerus grypus*) use above-water vision to locate baited buoys. The North Atlantic Marine Mammal Commission (NAMMCO) Scientific Publications. Volume 6.

Götz, T. and Janik, V.M. (2010). Aversiveness of sounds in phocid seals: psychophysiological factors, learning processes and motivation. Journal of Experimental Biology, 213, 1536-1548.

Götz, T. & Janik, V.M. (2011). Repeated elicitation of the acoustic startle reflex leads to sensitisation in subsequent avoidance behaviour and induces fear conditioning. BMC Neuroscience, 12, 30.

Götz, T. & Janik, V.M. (2013). Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. Marine Ecology Progress Series, 492, 285-302.

Hall, A.J. & Thompson, D. (2009). Grey Seal *Halichoerus grypus*. In: *Encyclopedia of Marine Mammals*. Pp 500-503. Academic Press.

Hammond, P.S. and Wilson, L.J. (2016). Grey seal diet composition and prey consumption. Scottish Marine and Freshwater Science Vol 7 No 20. Scottish Government. http://www.gov.scot/Topics/marine/Publications/stats/Science/SMFS/2016/0720.

Hanke, F.D., Hanke, W., Scholtyssek, C. & Dehnhardt, G. (2009). Basic mechanisms in pinniped vision. Experimental Brain Research. 199:299–311. DOI 10.1007/s00221-009-1793-6.

Harwood, J. & Walton, M. (2002). Interactions between seals and commercial fisheries in the north-east Atlantic. European Parliament. Directorate-General for Research Working Paper. Fisheries Series. Fish 110 EN.

He, P. (2006). Gill nets: gear design, fishing performance and conservation challenges. Marine Technology Society Journal 40(3):12-19.

Hinz, H., Scriberras, M., Murray, L.G., Benell, J.D. & Kaiser, M.J. (2010). Assessment of offshore habitats in the Cardigan Bay SAC (June 2010 survey). Fisheries & Conservation report, (14), p.30.

JNCC. (2007). European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) Second Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2001 to December 2006 Conservation status assessment for Species: S1364 – Grey Seal (*Halichoerus grypus*). http://jncc.defra.gov.uk/pdf/Article17/FCS2007-S1364-Final.pdf.

JNCC. (2013). European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2007 to December 2012 Conservation status assessment for Species: S1364 – Grey Seal (*Halichoerus grypus*). http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/S1364_UK.pdf.

JNCC. (2017). Annex 1 Sandbanks in offshore waters. [Viewed 21/08/2017]. http://jncc.defra.gov.uk/page-1452.

JNCC. (2019). European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) Fourth Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2013 to December 2018 Conservation status assessment for Species: S1364 – Grey Seal (*Halichoerus grypus*). https://jncc.gov.uk/jncc-assets/Art17/S1364-UK-Habitats-Directive-Art17-2019.pdf.

Kalaycı, F. and Yeşilçiçek, T. (2012). Investigation of the selectivity of trammel nets used in red mullet (*Mullus barbatus*) fishery in the eastern Black Sea, Turkey. Turkish Journal of Fisheries and Aquatic Sciences, *12*(4).

Königson, S., Lövgren, J., Hjelm, J., Ovegård, M., Ljunghager, F. ven-Gunnar Lunneryd, v-G. (2015). Seal exclusion devices in cod pots prevent seal bycatch and affect their catchability of cod. Fisheries Research 167 114–122.

MarLIN. (2019). Grey seal (*Halichoerus grypus*). Marine Life Information Network [Viewed 13 February 2019]. https://www.marlin.ac.uk/species/detail/1995.

Matthiopoulos, J., Mcconnell, B., Duck, C. & Fedak, M. (2004). Using satellite telemetry and aerial counts to estimate space use by grey seals around the British Isles. Journal of Applied Ecology. 41, 476–491.

McConnell, B.J., Fedak, M.A., Lovell, P. & Hammond, P.S. (1999). Movements and foraging areas of grey seals in the North Sea. Journal of Applied Ecology, 36, 573-590.

Merchant, N.D., Brookes, K.L., Faulkner, R.C., Bicknell, A.W.J., Godley, B.J. & Witt, M.J. (2016). Underwater noise levels in UK waters. Scientific Reports 6, Article Number: 36942.

Morgan, L.H, Morris, C.W. & Stringell, T.B. (2018). Grey Seal Pupping Phenology on Ynys Dewi / Ramsey Island, Pembrokeshire. NRW Evidence Report No: 156, 22 pp, Natural Resources Wales, Bangor.

NOAA. (2019). Fishing Gear: Gillnets. NOAA Fisheries. [Accessed 05th March 2019]. https://www.fisheries.noaa.gov/national/bycatch/fishing-gear-gillnets.

Northridge, S., Sanderson, D., Mackay, A., & Hammond, P. (2003). Analysis and mitigation of cetacean bycatch in UK fisheries: final report to DEFRA Project MF0726. *Sea Mammal Research Unit, St. Andrews*.

Northridge, S., Kingston, A. & Thomas, L. (2012). Annual report on the implementation of Council Regulation (EC) No 812/2004 during 2011.

Northridge, S., Kingston, A. & Thomas, L. (2013). Annual report on the implementation of Council Regulation (EC) No 812/2004 during 2012.

Northridge, S., Kingston, A. & Thomas, L. (2014). Annual report on the implementation of Council Regulation (EC) No 812/2004 during 2013.

Northridge, S., Kingston, A. & Thomas, L. (2015). Annual report on the implementation of Council Regulation (EC) No 812/2004 during 2014.

Northridge, S., Kingston, A. & Thomas, L. (2016). Annual report on the implementation of Council Regulation (EC) No 812/2004 during 2015.

Northridge, S., Kingston, A. & Thomas, L. (2017). Annual report on the implementation of Council Regulation (EC) No 812/2004 during 2016.

Northridge, S., Kingston, A. & Thomas, L. (2018). Annual report on the implementation of Council Regulation (EC) No 812/2004 during 2017.

NRW. (2018a). Pembrokeshire Marine / Sir Benfro Forol Special Area of Conservation. Advice provided by Natural Resources Wales in fulfilment of Regulation 37 of the Conservation of Habitats and Species Regulations 2017. Natural Resources Wales, Bangor pp 131.

NRW. (2018b). Pembrokeshire Marine / Sir Benfro Forol Special Area of Conservation: Indicative site level feature condition assessments 2018. NRW Evidence Report Series, Report No: 233, 67pp, NRW, Bangor.

NRW. (2018c). Cardigan Bay/ Bae Ceredigion Special Area of Conservation. Advice provided by Natural Resources Wales in fulfilment of Regulation 37 of the Conservation of Habitats and Species Regulations 2017. Natural Resources Wales, Bangor pp 87.

NRW. (2018d). Cardigan Bay / Bae Ceredigion Special Area of Conservation: Indicative site level feature condition assessments 2018. NRW Evidence Report Series, Report No: 226, 39pp, NRW, Bangor.

NRW. (2018e). Pen Llŷn a'r Sarnau/Lleyn Peninsula and the Sarnau Special Area of Conservation Advice provided by Natural Resources Wales in fulfilment of Regulation 37 of the Conservation of Habitats and Species Regulations 2017. Natural Resources Wales, Bangor pp 143.

NRW. (2018f). Pen Llŷn a`r Sarnau / Lleyn Peninsula and the Sarnau Special Area of Conservation: Indicative site level feature condition assessments 2018. NRW Evidence Report Series, Report No: 234, 58pp, NRW, Bangor.

Pomeroy, P.P., Twiss, S.D. & Redman, P. (2000a). Philopatry, site fidelity and local kin associations within grey seal breeding colonies. *Ethology,* vol 106, pp. 899-919.

Pomeroy, P.P., Twiss, S.D. & Duck, C.D. (2000b). Expansion of a grey seal *(Halichoerus grypus)* breeding colony: Changes in pupping site at the Isle of May, Scotland. Journal of Zoology 250:1-12.

Potter, E.C.E. & Pawson, M.G. (1991). Gill netting. Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research.

Robinson, G. J., Clarke, L. J., Banga, R., Griffin, R. A., Porter, J., Morris, C. W., Lindenbaum, C. P. & Stringell, T. B. (2020). Grey seal (Halichoerus grypus) pup production and distribution in North Wales during 2017. NRW Evidence Report No. 293. 54pp. Natural Resources Wales, Bangor.

SCOS. (2016). Scientific Advice on Matters Related to the Management of Seal Populations: 2016. Special Committee on Seals, SMRU, University of St Andrews.

SCOS. (2017). Scientific Advice on Matters Related to the Management of Seal Populations: 2017. Special Committee on Seals, SMRU, University of St Andrews.

SCOS. (2018). Scientific Advice on Matters Related to the Management of Seal Populations: 2018. Special Committee on Seals, SMRU, University of St Andrews.

Scott, B.E., Sharples, J., Ross, O.N., Wang, J., Pierce, G.J. & Camphuysen, C.J. (2010). Sub-surface hotspots in shallow seas: fine-scale limited locations of top predator foraging habitat indicated by tidal mixing and sub-surface chlorophyll. Marine Ecology Progress Series 408: 207-26.

Seafish. (2019). Fishing Gear Database: Gill Nets. [Accessed 12th December 2019]. https://seafish.org/gear-database/gear/gill-nets/.

Sjöberg, M.,Fedak, M. & Mcconnell, J. (1995). Movements and diurnal behavior patterns in a Baltic gray seal (*Halichoerus grypus*). Polar Biology 15(8):593-595. DOI: 10.1007/BF00239652.

Stringell, T.B., Millar, C.P., Sanderson, W.G., Westcott, S.M. & McMath, M.J. (2014). When aerial surveys will not do: grey seal pup production in cryptic habitats of Wales. Journal of the Marine Biological Association of the United Kingdom. 94 (6): 1155-1159.

Strong, P.G. (1996). The West Wales Grey Seal Diet Study. CCW Science Report 132.

Strong, P.G., Lerwill, J., Morris, S.R. & Stringell, T.B. (2006). Pembrokeshire marine SAC grey seal monitoring 2005 (CCW Marine Monitoring Report No. 26). Bangor: CCW. 51pp.

The Mammal Society. (2017). Species Fact Sheet: Grey Seal (*Halichoerus grypus*). [Viewed 11 September 2017]. http://www.mammal.org.uk/sites/default/files/factsheets/grey_seal.pdf.

Thompson, D., Hammond, P.S., Nicholas, K.S. & Fedak, M.A. (1991). Movements, diving and foraging behaviour of grey seals (*Halichoerus grypus*). Journal of Zoology, London. 224, 223-232.

Vincent, C., Ridoux, V., Fedak, M.A., McConnell, B.J., Sparling, E.E., Leaute, J.-P., Jouma'a, J., Spitz, J. (2016). Foraging behaviour and prey consumption by grey seals (*Halichoerus grypus*)—spatial and trophic overlaps with fisheries in a marine protected area. ICES Journal of Marine Science, doi:10.1093/icesjms/fsw102.

Walmsley, S.A. & Pawson, M.G. (2007). The coastal fisheries of England and Wales, Part V: a review of their status 2005-6. Sci. Ser. Tech Rep., Cefas Lowestoft, 140: 83pp.

Walmsley, S.F. (2018). Marine Fish Mortality Considerations as part of Maximum Sustainable Yield Calculations NRW Report No: 267, 37pp, Natural Resources Wales, Bangor.

Welsh Government. (2011a). Inshore Fishery Legislation: South Wales 0-6 nautical miles. Text of the saved Byelaws of the former South Wales Sea Fisheries Committee.

Welsh Government. (2011b). Inshore Fishery Legislation: North Wales 0-6 nautical miles. Text of the saved Byelaws of the former North Western and North Wales Sea Fisheries Committee.

Wilson, S.C. (2003). Seal-fisheries interactions, Problems, Science and Solutions. British Divers Marine Life Rescue. http://www.bdmlr.org.uk/uploads/documents/reports/seal-fisheriesinteractions.pdf.