17 Noise

17.1 Introduction

This chapter on noise deals with the effects that the introduction of marine renewables can bring to the ambient noise levels, both above and below water. The potential effects of noise are based on the effect of receptors, be they flora, fauna or geological and this makes noise different to most of the other chapters. As such the impacts of this chapter will not only look at relative ambient noise but also what the effects of this are on receptors which are covered in other chapters.

It is important to note that while there are, in some cases, a relative abundance of information on noise and its impacts, it is not always in directly comparable formats and the information is not in consistent levels of detail. There is also not a consistency in the amount of data available for different sources and receptors, with until recently mammals being the only focus of study, due to a legal obligation, and fish not being considered. This has led to less of an understanding with regards to the hearing of fish.

17.2 Baseline Environment

The baseline environment for ambient levels of noise occurs in two places. Firstly the noise levels above the water which affect the human environment as well as bird life, other terrestrial and terrestrial based animals and, to a lesser extent, fully marine mammals. Secondly the underwater noise levels which affect the marine environment including the pelagic and benthic ecosystems. For the needs of this report “ambient” or “background” noise refers to noise levels that are already present in the study area, not necessarily ones that are constantly present.

In the UK there are currently no national measurements of ambient noise available. In 2003 a rural white paper was produced to develop an Ambient Noise Strategy in England. As yet no data is available from this, with only limited modelled data on areas in the UK in Major cities focussing on major roads, railway lines and airports, which is not applicable to Guernsey. This information is available from DEFRA from the following website - http://www.defra.gov.uk/environment/quality/noise/environment/mapping/index.htm. They have used computer modelling rather than actual measurements because of the time and cost required to take a suitable number of samples at each location and because the European Commission recommend using modelling and only looking at transport. The difficulty in establishing noise source from real readings mean they would not be able to reliably report the noise from transport as opposed to other sources. This apparent lack of empirical information contrasts with the underwater environment where there has been a relatively high level of study in the past few years.

It is also important to remember that at any location the amount of noise, in both magnitude and frequency, may change considerably over the course of a day, week, month or year. A good terrestrial example of this is the noise on roads increases during rush hour, but will be relatively quite in the interim times.

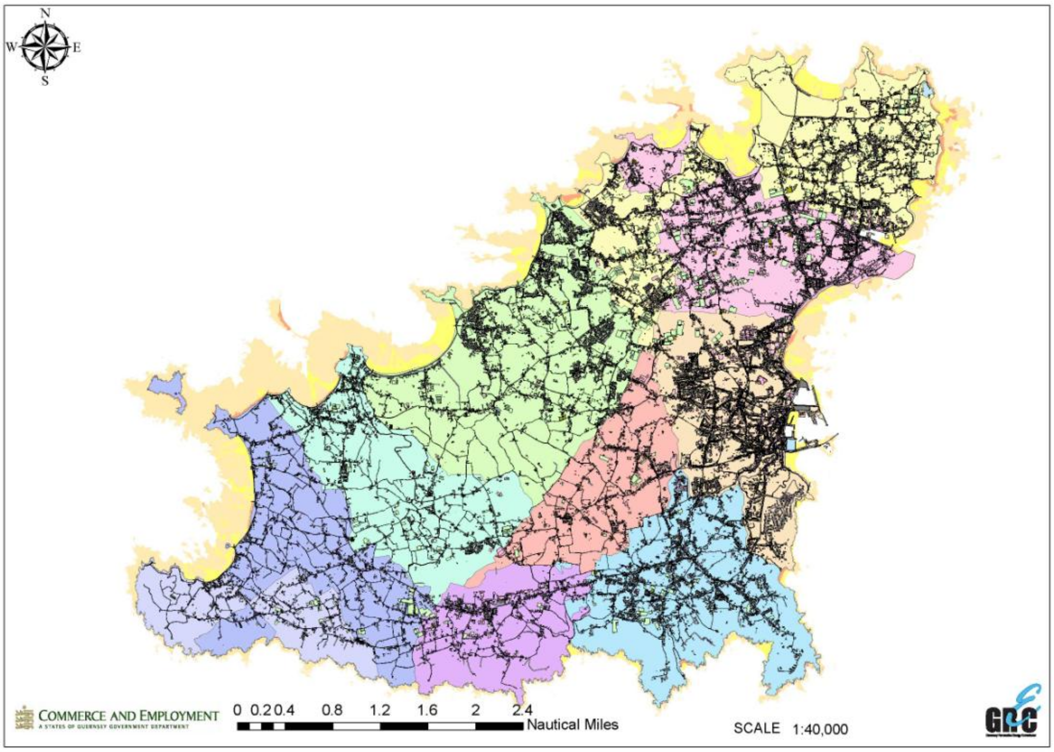
17.2.1 Noise Sources Above Water

There are many sources of noise in the human environment, mainly on land, and the above water environment. The study area, while mainly looking at offshore, also considers any affects onshore, and also effects relating from the shore. As such potentially terrestrial noise sources can affect the ambient noise levels out at sea. There are two main sources of noise above water, "naturally" occurring sources including biological and geological, and anthropogenic sources including shipping and other industry. If the study area is divided up into two parts, ambient noise over land and ambient noise over water, there are some small differences.

17.2.1.1 Noise Sources Over Land

For ambient noise over land there is tends to be a divide between rural an urban areas with regards to the sources of noise. Guernsey's urbanisation is mainly to the North and East of the island; however there is development over most of the island as Illustrated in figure 17.2.1 below. As such, there is a large amount of noise produced from motor travel, mainly cars, due to the relatively high numbers of cars to people ratio, but also busses, bikes and lorries, and this tends to be the major contributor to noise in urban areas. While Guernsey has a large amount of foliage, this will have little effect on dampening the noise as the majority of traffic tends to be over the main roads which are not generally surrounded by large amounts of foliage. It is also important to remember that there will be generally 3 peaks a day for transport noise, before 9am, between 12 and 2 and after 5pm due to commuter traffic.

Figure 17.2.1 – Illustration of the Development on Guernsey



There is also, for the case of this study, an ambient noise associated with air travel, in Guernsey especially, as much of the island is affected by aircraft noise. However, this noise is actually very difficult to quantify, as while at the airport it is significant for small periods of time, when taken across the whole island over the course of the whole day it could have a very small overall impact. There is also to a lesser and localised extent noise produced from boats. This would tend to be focused around the coastal regions and specifically the ports on the east coast. The other main cause of anthropogenic noise is construction and demolition of buildings and industry, including the shipping industry. Again these would be focussed in certain areas and so the overall effect on the Islands 24 hour ambient noise levels are hard to predict, and would also vary from day to day.

Sark and Herm are comparatively more rural than Guernsey, and this means that there are likely to be lower levels of ambient anthropogenic noise, especially related to motor vehicles, as for example on Herm there are no cars and only a handful of quad bikes and a tractor.

There are also many natural causes of background noise and on land these include:

- Wind;
- Precipitation;
- Biological;
  - Birds;
  - Terrestrial Mammals;
  - Insects;
- Tides;
- Waves.

Wind is an almost ever present source of background noise and the Bailiwick of Guernsey is exposed to winds coming from the West as there is little land shelter. This means that there is a relatively large amount of noise caused by wind. Tidal and wave noise can be heard at all times of day around the coasts of Guernsey, Herm and Sark. However, due to the localised area this noise source could have a relatively low effect on overall ambient noise levels. The Biological noise factors can include a number of behavioural functions within the animal kingdom. From birds the main source of noise is likely to be from their calls, where as for mammals and insects it could be that more noise comes from movement. Again these are hard to quantify, and while bird song can be almost ever present, other animal noises can be very rare.

17.2.1.2 Noise Sources Over Water

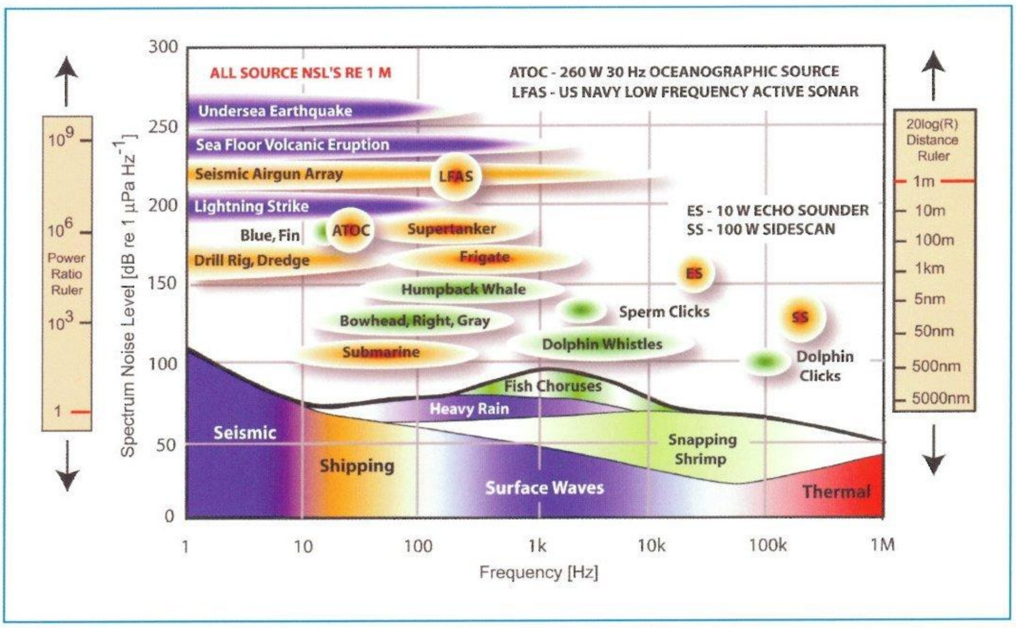
The air above the water in the Bailiwick does not have any large infrastructure such as rigs and so the anthropogenic impacts are limited. The major noise source would come from boats, with a major shipping lane a little way outside of the 12nm Guernsey fishing limits. There is also an inshore traffic zone affecting the north and east of Guernsey (see chapter 15) with the main shipping lane for entering into the islands being the Big and Little Russel. There is a fishing industry in the Bailiwick (see chapter 11) which causes further shipping noise. Other than this, as over land, there is noise created by aircraft flying over Bailiwick waters, but as mentioned over land, this is infrequent and spread out over the course of the day. Also in the coastal regions of Guernsey there would also be an expected noise to be coming from land, with automobiles contributing largely to this.

There are similar weather effects as over land, with wind and precipitation being the major causes of ambient noise. Equally tidal flows and the waves, especially when they break, cause noise in the environment. Biological noise will not be contributed to by terrestrial mammals, but aquatic mammals will have an effect through communication and breaching, however both of these are likely to have very little effect when compared to engine noise and even the lifting of trawl gear. Seabirds will add to ambient noise through feeding, which can include calls as well as varying levels of diving. Additionally occasional breaching of fish can add to the background noise.

17.2.2 Noise Sources Under Water

There have been a number of studies in recent years into underwater noise, both the ambient levels and the hearing thresholds of various animals. Figure 17.2.2 below illustrates some of the different frequencies and noise levels that are generally found in the sea. Some of the noise sources are endemic background noises such as surface waves, rain and the anthropogenic source, shipping. As well as this there are noise source which are not always present but still contribute to the ambient conditions. These include animal calls such as dolphin clicks and whistles, whale calls and fish noises.

Figure 17.2.2 – Marine Noise Sources (image – SCAR report on Marine Acoustic Technology and the Antarctic Environment. Information Paper IP078.ATCM XXVII.)



Anthropogenic sources of underwater noise primarily come from the shipping industry in the waters of the Bailiwick, with large vessels such as the Condor car ferry using the waters daily, so there is a large amount of noise coming from this. There is also noise from the fishing industry, as well as recreational fishers and boaters. Generally speaking, the sound level and frequency of the sound in water of boats is roughly correlated to the size of the boat and its speed. However, there are considerable variations between various classes of boats (Richardson et al.

1995). Sound emissions of boats, aside from the obvious engine noise, derive from cavitation (the formation of bubbles and their collapse due to changes in pressure, causing a hissing sound) and the sound of the hull's passage through the water. Noise travels well in water, with studies showing that whale calls can travel many miles, and so it is likely that boat noise also travels long distances.

In some areas of the Bailiwick there is demersal trawling taking place and part of this fishing effort falls within the study area, adding to background noise levels, however there are no published studies on the noise effect of fishing gear. Sonar noises are also associated with both the shipping and fishing industries as for the fishing industry sonar has become a useful tool for locating schools of fish. The frequencies of sonar and other anthropogenic sources and brief summaries are listed in table 17.2.1 below.

Natural sources of noise emissions in the underwater environment come from the movement and communication of aquatic animals, be they mammal, fish, invertebrate or bird. It is well known that the low frequency whale calls can travel for many miles through the ocean, when there are no other major noise sources to overpower them. These days however it is far more likely that long distance whale calls will be drowned out by boating activity and so only localised calls and sounds are likely to contribute to background noise. As well as animal communication and movement, there are noises associated with feeding. Away from animal noises there are other natural sources; rainfall on the surface of the water is a major cause of background noise, as are waves and sediment transport. A brief summary of the major contributors to the natural underwater ambient noise is listed in table 17.2.1 below.

Table 17.2.1: Table outlining the potential contributors to underwater ambient noise

Source	Indicative Frequency Range	Comments
Wind-sea noise	500Hz – 25kHz	Noise levels are dependent upon local wind speed.
Precipitation noise	1 – 100kHZ	In the winter months precipitation is likely to be a significant contributor to ambient noise.
Shore and surf noise	1 Hz – 1000kHz	Shore and surf noise is likely to be a major contributor to ambient noise in coastal areas in the REA study area - particularly at coastlines that are exposed to large waves such as the west coast
Sediment transport noise	Mostly above 10kHz	Sediment transport mainly occurs in the intertidal zone but can also occur away from the coastline.
Commercial Shipping	50 – 300 Hz for large ships	Shipping noise is typically the dominant contributor to ambient noise in shallow water areas and close to shipping lanes in the study area. At higher frequencies than 300 Hz, the sounds of individual ships merge into a background continuum. At higher frequencies the dominant noise source is likely to be wind generated noise. In the shallower waters (e.g. tens of metres) of the REA study area the water is too shallow to support long-range propagation of the very low frequencies. Different types of ships give different noise contributions from different sources.
Leisure craft	Various	In the summer months it can be a dominant source of sound through the study area.
Industrial noise: Offshore	Various	Includes noise generated from offshore wind farms, construction and oil and gas developments. There are no such developments in the REA study at present.
Industrial noise: Onshore	<100Hz	Potential sources include traffic noise from roads. Coupling through the substrate into the marine environment will generally only occur at low frequencies (i.e. less than 100 Hz).
Military noise	Various	The REA study area does not contain any military activity areas, however there are occasional military ships in

Source	Indicative Frequency Range	Comments
		the area.
Sonar	Echosounder: 26 kHz – 300kHz	Used by small leisure craft up to the largest commercial ships. The higher frequencies are attenuated over short distances by absorption but their contribution to ambient noise is significant due to the numbers of units.
	Fishing sonar: Lower frequencies than those for general echosounders noted above.	Their contribution is mainly restricted to fishing grounds, which can also be sensitive areas where there is a high density of fish and cetaceans, and these cover most of the REA study area in one form or another.
	Air guns: Centre frequency between 50 – 100 Hz	Used for seabed geological/geo physical survey work
	Military sonar: 1 – 300kHz	High frequencies above 80 kHz are used by mine hunters and the high acoustic absorption coefficient of seawater at such frequencies means that any impact is limited to a very small area around the ship, typically less than 3 km. Lower frequencies (<3 kHz) are used in the deeper waters and can fill a whole ocean basin with sound.
Aircraft noise	Various	Aircraft noise from Guernsey airport may be locally significant
Fishing Activity	Vessel: Less than 1 kHz	Noise can come from vessel, sonar or gear noise (e.g. trawl noise). No published information is available on noise levels/frequency ranges for fishing gear.
Biological Noise	Sperm whale echolocation: 2-40 kHz	Fish, cetaceans and seals can all produce sound. Cetacean sounds are either tonal whistles in the range 2 to 25 kHz, or wideband echolocation clicks with maximum energy in the 40 to 140 kHz region. Seals can make a significant contribution to ambient noise at certain times of the year, particularly during the breeding season.
	Bottle nose dolphin echolocation: 80 – 120 kHz	
	Cetacean tonals: 2 – 25 kHz	
	Harbour porpoise echolocation: 130 kHz	
Thermal Noise	More than 100kHz	Caused by thermal motion of molecules. This sound source is only relevant in the absence of all other sound sources.

Table taken and adapted from the Scottish Marine Renewables SEA, Chapter 17 (www.seaenergyscotland.net).

17.2.3 Noise Modifiers

Propagation – The way sound travels through water is affected by the salinity, temperature and pressure of the water as well as the substrate type. Within the study area the variation in salinity is going to be extremely small as there are no major river mouths to affect salinity. Pressure variations are almost entirely related with depth so this may have a small effect on the sound propagation in water, but the main factor will be changes in temperature. Under certain conditions a mixed layer forms close to the surface of the sea due to mixing caused by waves and turbulence. The existence of this layer, and its thickness, depend upon atmospheric factors and on fresh water exchange. This mixed layer acts as a boundary which can trap sounds within it, as the layer tends to refract sound upwards while the surface reflects sound back.

As sound can interact with the seabed, the substrate and bottom morphology can affect noise propagation loss, with hard, flat, sediment free sea beds reflecting noise effectively while muddy sea beds will absorb much more noise. In addition to this the waves on the surface can scatter sound rather than just reflecting it. Sediment suspension and other water impurities can increase propagation loss as can bubbles.

Multiple Path Effects – Because of reflection from the seabed and surface, sound travels between a source (such as pile driving) and a receptor (such as a fish) by a number of paths. This has the knock on effect of giving dispersed sound arrival time. This is particularly relevant for noise sources over a large frequency range such as pile driving, and other impulsive sounds. There is also the possibility of frequency dispersion where the propagation effects are frequency sensitive. Time dispersion reduces the upper limit of the energy that is received by the receptor, while the overall energy levels reaching the receptor remain the same the peak levels can be significantly lower than without time dispersion.

17.3 Potential Effects

There are numerous potential effects on the receptors to increased noise levels, in this case marine organisms and, to a far lesser extent, terrestrial organisms. There is a large probability that there will be different effects throughout the stages of the lifecycle of the machines. There will also be different effects depending upon whether the device is wave or tidal and whether they are surface piercing. At a basic level, throughout the entire development there is the possibility of displacement of species, of damage or death to marine organisms and of behavioural change.

One major problem of identifying potential effects is that three questions need to be answered:

- Is wildlife affected by noise?
- Are any effects biologically significant (relating to populations not individuals)?
- Can the effects be mitigated?

The first question is easily answered, many studies have identified that fish, mammals and other species can hear sounds and are affected by them, such as beaching of whales due to sonar. The second question is where much of the problems arise, as there is not sufficient research done to confirm that there is a problem, let alone if it is detectable and matters. Part of the problem in this respect is the ability of most organisms to remove themselves from areas of high stress for periods of time. This leads at least to temporary displacement, but this in itself is not necessarily biologically significant. The third question relies on being able to assess the significance of effects, and so this poses a further problem.

17.3.1 Deployment

The major noise impact would be expected to come from the installation of the devices, especially tidal devices, due to the mooring systems likely to be used. Potential methods of installation include piling, drilling and gravity foundations. Currently it is unknown how most devices are to be deployed. As well as the installation method, the other sources of noise during the deployment phase are increased shipping and machinery use and dredging for cable laying.

Piling – Piling can be large mono piles such as they currently use in the wind industry, or they can be smaller multiple piles that moor the structure at certain points. There are many factors that affect the noise levels produced from piling, and these include:

- Hammer energy and material,
- Seabed penetration,
- Seabed and sediment properties,
- Pile dimensions and material,
- Water depth.

Generally the potential effects on organisms from piling are likely to be divided into two receptor categories, mobile species and immobile species. Mobile species include marine mammals and many species of fish, which have the ability to move away from the source quickly. Immobile species include crustaceans which are slow moving and will not be able to move quickly from the source.

For mobile species the potential effects are:

- Temporary or permanent threshold shift affecting the hearing of the species due to exposure to the source reducing the survival potential of individual organisms.
- Internal damage cause by the sound pulses leading to
    - Death
    - Permanent injury
    - Temporary injury (any compromise of fitness is likely to affect survival)
- There is likely to only be little intermittent masking
- Behavioural effects
    - Temporary displacement due to short term noise
    - Permanent displacement due to moving to other areas
    - Affects on breeding success if at breeding time of year

Studies have shown that fish and marine mammals do move away from noise sources, although the methods of movement are not the same, with cod for example freezing first and then moving while sole move without freezing. For immobile species, the potential effects are likely to be more significant to those in the immediate area. Additionally, if there are multiple piles being placed at the same time there may well be an increased impact due to cumulative effects.

It is important to note that piling is an intermittent source of noise, and that it is industry practice now to "soft start" piling, delivering a number of reduced power, longer interval strokes prior to commencing full piling. This will potentially allow for mobile animals to leave the area.

Drilling – There have been studies on Cetaceans and fish with tapes playing back drilling sounds. Both cetaceans and fish avoid areas where the sound levels are higher. Results for an individual tidal device drilling predicted negligible effects, however this may be different for a full array.

Gravity Base – There are no relevant sound measurements for gravity bases, however it is likely that the effects of this method of deployment will have negligible effects.

Shipping Noise – There is likely to be an increase in the amount of shipping in the areas of deployment, which may have an effect on the species normally present. This may lead to a temporary displacement of species during deployment. As mentioned above the amount and frequency of noise will depend upon the type of ships present.

Trenching and Cabling – Typically noise levels for trenching and cabling are below any thresholds that a behavioural or physiological change would be expected.

17.3.2 Operation

The potential sources of underwater noise from the operation of devices are:

- Rotating Machinery;
- Flexing Joints;
- Structural Noise;
- Moving air;
- Moving water;
- Moorings;
- Electrical Noise;
- Instrumentation Noise;

There is the potential for temporary or permanent threshold shift for organisms within certain distances of the devices over a period of time, however this is very hard to predict due to the uncertainty or the devices which will be deployed and the noise levels that they will produce. Also it is more likely that organisms would move away from a noise source that would cause them irreparable damage. This leads to the potential of displacement from areas surrounding device arrays. It is also unknown what difference there will be in noise levels between single devices and multi megawatt deployments.

There is also a potential for masking while in the vicinity of the arrays for various species. In addition to this there is the possibility that the receptors may take avoidance action of areas of noise even below the damage threshold to them. This may in turn make some areas separated by a barrier, possibly restricting them from important areas, even though there appears to be ample room to negotiate past the arrays without suffering damage.

17.3.3 Maintenance

The main noise source attributed to maintenance comes from the use of ships between the harbour and the arrays.

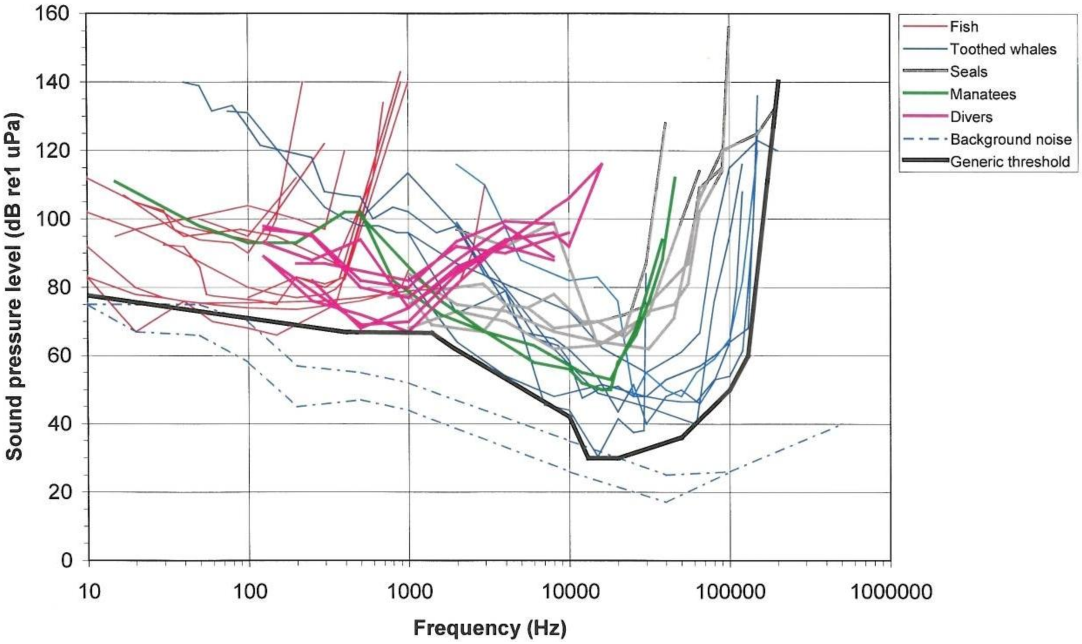
17.3.4 Decommissioning

There is the potential for explosives to be used as part of the decommissioning process. This could have severe effects on the receptors, with the same potential impacts as piling. Other methods of decommissioning have potentially less severe effects, with the possibility that structures could be left would lead to no effect.

17.4 Sensitivity of receptors

Figure 17.4.1 below gives some examples of the hearing limits of certain receptors of noise in the underwater environment. The potential for impacts on certain species depends partially upon their hearing threshold related to the source noise. However if an organism cannot hear it there is still the possibility of internal damage due to the pressure and this is especially true of pile driving.

Figure 17.4.1 – General Threshold Curves (Image - Environmental Impact Assessment (EIA) in support of the procurement of Sonar 2087. QINETIQ/S&E/SPS/CR020850/1.0. October 2002)



There is a difference between how mammals and fish are affected by noise, but there are also differences between how different species of fish and mammal react.

17.4.1 Fish

There has historically been very little research done on the hearing of fish for a number of reasons. These include that there was little demand for it as they are not as appealing animals as mammals, that they were thought to only have very primitive hearing, and basically that they just were not important. In recent years that has started to change, and it is now known that not only do most fish hear very well at low frequencies, but there are a number of ways that fish detect sound. The otoliths can detect sound and sound direction and this forms the basis for fish hearing. Fish with gas bladders can detect sound pressure which improves hearing, and the nearer the gas bladder is to the ear the better the hearing.

Fish can hear very well at low frequencies and so loud low frequency noises can affect the hearing of fish. The pressure of a noise can also do internal damage to fish, potentially rupturing internal organs, and in fish with gas bladders rupturing the bladder rendering them unable to regulate buoyancy. Generally speaking the smaller the fish, or fish larvae, the larger the amount of damage they are likely to sustain. This means for loud pulsing noises such as pile driving there is the possibility of major damage to fish that are too close. For less loud noise sources, such as the running of the devices, fish will likely move in and out of the area and so will be relatively unaffected.

17.4.2 Mammals

As can be seen in figure 17.4.1, mammals can hear noises at higher frequencies, but also many species have good low frequency hearing as well. This means that there is a wider range at which mammals can suffer auditory damage, but also a wider range at which they can detect sounds and move away. With regards to pile driving studies have shown that if fleeing, the predicted response according to Borsani et al, then mammals are only over the damage threshold for a couple of kilometres. However if the mammal is static the threshold extends out to 10’s of kilometres.

During the operation phase of the arrays, mammals are likely to fall into two categories, those which are localise around Guernsey, Herm and Sark, and those which travel through Guernsey waters (see chapter 10 for more information). Those which are localised to Guernsey will have higher susceptibility to being affected, with potential to have calls masked and prey sounds masked. They may also be in the area for sufficient time to suffer temporary or permanent auditory damage, however limited dive times may restrict this. The increased noise in the area may also be a driver for the marine mammals based on shore in the Bailiwick (see Marine Mammals, chapter 10) to relocate to other areas. For mammals that pass through the waters in the REA there may be some alteration to migration routes to avoid the main sources of noise, but their susceptibility to other problems is low, save if they breed in bailiwick waters.

Human sensitivity to increased marine noise would be relatively low to specific noise below the water. Divers would be affected at the frequencies highlighted in figure 17.4.1, however diving is unlikely to take place close to devices for safety reasons. For land dwelling mammals, humans included, it is most likely that effects will be felt from the installation, with disruption on land during the installation of cables, as well as potential noise from piling. During operation humans and other land based mammals are likely to be sensitive to the “nuisance factor” of maintenance noise and also the localised buzzing off the substations, which would especially affect rural areas as there would be constant buzzing.

17.4.3 Other Organisms

There is little available research on how other organisms will be affected by the increased noise from marine renewables. There is some anecdotal evidence to suggest that during the operation phase of the turbines large crustaceans such as lobsters and crabs will not be adversely affected by noise. For all slow moving or sedentary organisms during installation there is the likely hood that they will be very susceptible to damage from activities such as piling.

The Bailiwick of Guernsey is home to a large and diverse selection of birds (see Birds, chapter 9) with a large selection of gulls and also resident puffins off some of the cliff areas. As well as this there are some small terrestrial birds on the islands. During the construction phases there is likely to be some adverse effects on sea bird species from piling in areas where they would normally feed. This would interfere with calling, but could also cause severe damage to any birds diving at the time in the vicinity. Also any noise disruption around the nesting sites of birds could lead to reductions in the populations in the bailiwick through reduced breeding effort. During operation the main noise issue is likely to come from the constant buzzing of the substations, should they be located near nesting sites.

17.5 Potential Significance of Effects

Table 17.5.1 below illustrates the potential significance on the receptors of the different possible effects listed above. There are 4 categories the effect can fall into; Major, Moderate, Minor or None. This relates to the impact that the effect would have on populations of organisms and is calculated by working out the value of the receptor – based on how far reaching the effects are: local, regional or international – and the perceived magnitude of the impact on the receptor.

Some of the receptors of noise impacts are internationally protected species. Therefore, the Value of noise receptors is 'International', as described in chapter 20.

Table 17.5.1 – Significance of Effects

Potential Effect	Device Type	Development phase	Receptor	Significance of effects
Temporary Threshold Shift (TTS) in Auditory Functions	All	Installation Decommissioning Operation	Fish Mammals Other organisms	Moderate Moderate Moderate
Permanent Threshold Shift (PTS) in Auditory Functions	All	Installation Operation Decommissioning	Fish Mammals Other organisms	Major Major Major
Internal Damage	All	Installation Operation Decommissioning	Fish Mammals Other organisms	Major Moderate/Major Moderate/Major
Masking of Calls/Sounds	All	Installation, Operation, Decommissioning	Fish Mammals Other Organisms	Moderate/Minor Moderate/Minor Moderate/Minor

Potential Effect	Device Type	Development phase	Receptor	Significance of effects
Temporary Displacement	All	Installation Decommissioning	Fish Mammals Other Organisms	Minor Minor Minor
Permanent Displacement	Tidal Devices	Operation	Fish Mammals Other Organisms	Moderate Moderate Major
Disruption to migration	All	Installation Decommissioning	Fish Mammals Other Organisms	Minor Minor Moderate
		Operation	Fish Mammals Other Organisms	None None Unknown
Barrier to Feeding/ Breeding Grounds	All	Operation	Fish Mammals Other Organisms	Moderate Moderate/Minor None/Minor

17.6 Likelihood of Occurrence

There will doubtlessly be noise generated during installation, operation and decommissioning and so there will be some impacts from noise within the vicinity of development. However noise emissions will be dependent on the methods used during installation, as yet unknown, and the device types, also unknown. If the marine renewables industry follows the offshore wind industry then it is likely that piles of some description will be the deployment method of choice. The site characteristics will also affect the probability of effects occurring, with the local environmental conditions of the area affecting the area of influence the noise will have.

17.7 Mitigation Measures

There are a number of potential mitigation measures that could be implemented, depending on the method of deployment and the types of devices that will be used.

Deployment

During the deployment phase there is the most like chance of disturbance due to noise. There are ways to reduce the impact on the receptors, as outlined below.

- Avoid using piling. Failing this the following are mitigation for piling;
  - Soft start – current best practice already
  - Use bubble curtain – although this is best at removing noise at high frequencies and fish are especially aurally sensitive in the low frequencies, high frequency noise may cause greater tissue damage.
  - Use vibration piling
  - Use resilient pads to reduce sound – may require more force/strokes to compensate
- Use of deterrents such as acoustic avoidance devices prior to starting work.
- Time the development to not interfere with known migration/breeding.

Operation

During the operation phase of the development there are only very limited options for mitigation. Ensuring that the device is well sound insulated is one option, as well as ensuring there is regular maintenance. The other possible mitigation is to ensure the devices are only sited in areas that will not cause a barrier to known feeding or breeding grounds.

Decommissioning

The major mitigation measure is to avoid the use of explosives during decommissioning.

17.8 Confidence and Knowledge Gaps

There is a lack of research into the effects of various different noise sources and levels on most species in the marine environment. This means that the confidence associated with most of the predictions on the potential effects and the effect that mitigation methods will have is low. In relation to the baseline data there is no real data relating to the Bailiwick of Guernsey, and so all baseline data is using information used in the UK.

In addition to this, there is lack of certainty over much of the marine renewable industry with regards to methods of deployments of arrays of devices and the types of devices to be deployed in the REA area. This, combined with very little information on the noise levels associated with different devices, does not help the confidence in predictions.

Further problems relate to the recording of noise data in the marine environment. There is no standard method of measuring source level data, for activities such as piling, at either national or international levels. This can lead to different figures being reached for the same activities.

There has been no work on identifying any directionality of noise emitted from devices and only minimal on single device emissions. As such there has been no work done at all on the cumulative effects of devices in an array. This is mainly due to the fact that at present there are not two devices or more in place in an array anywhere in the world. As well as this noise levels have not been extensively studied and so there have been no attempts to model this either.

Currently the scale of the proposed operations are not known, for example there could be multiple 10MW or one large array, and the number of devices that make up an array are unknown. This means that, aside from the fact that there is a lack of research into the effects on organisms and cumulative effects, there is no known in the equation, and so there can be no confidence in predictions.

There is also the issue of location of the devices; the areas of likely development are identified in chapter 5 for wave and tidal devices, however these are not specific locations. This affects the confidence of the effects on specific species as some species may be more adversely affected by operations in one area more than another.

17.9 Residual Effects

Table 17.9.1 below shows how the mitigation measures relate to the effects identified in section 17.7. It also demonstrates the potential reduction on any adverse effects that mitigation might have. However, as was stated in section 17.8, there are many knowledge gaps and confidence is generally low and so the subsequent predicted effect of mitigation confidence is also low.

Table 17.9.1 below shows how the mitigation measures

Table 17.9.1 – Residual Significance of Effects Following Mitigation

Effect	Device Type	Development phase	Receptor	Significance of effects	Mitigation measure	Residual Significance of effects
Temporary Threshold Shift (TTS) in Auditory Functions	All	Installation Decommissioning Operation	Fish Mammals Other organisms	Moderate Moderate Unknown	Use of Acoustic avoidance devices Noise reductions (as mention above)	Unknown
Permanent Threshold Shift (PTS) in Auditory Functions	All	Installation Operation Decommissioning	Fish Mammals Other organisms	Major Major Major	Use of Acoustic avoidance devices Noise reductions (as mention above)	Unknown
Internal Damage	All	Installation Decommissioning	Fish Mammals Other organisms	Major Moderate/Major Moderate/Major	Use of Acoustic avoidance devices	Unknown
		Operation	All	Negligible		
Masking of Calls/ Sounds	All	Installation, Decommissioning	Fish Mammals Other Organisms	Minor Minor Minor	Noise reductions (as mention above)	Minor Minor Minor
		Operation,	All	Moderate	Improved sound insulation	

Effect	Device Type	Development phase	Receptor	Significance of effects	Mitigation measure	Residual Significance of effects
Temporary Displacement	All	Installation Decommissioning	Fish Mammals Other Organisms	Minor Minor Minor	Avoid installation at important times in life cycles	Minor Minor Minor
Permanent Displacement	Tidal Devices	Operation	Fish Mammals Other Organisms	Moderate/Minor Moderate/Minor Unknown	Improved sound insulation Avoid sensitive areas	Unknown
Disruption to migration	All	Installation Decommissioning	Fish Mammals Other Organisms	Minor Minor Moderate	Avoid installation at important times in life cycles	Negligible
		Operation	Fish Mammals Other Organisms	Negligible Negligible Unknown	Improved sound insulation Avoid sensitive areas	
Barrier to Feeding/ Breeding Grounds	All	Operation	Fish Mammals Other Organisms	Moderate Moderate/Minor Unknown	Improved sound insulation Avoid sensitive areas	

17.10 Recommendations for Survey and Monitoring

As has been identified there are many gaps in our knowledge as to how sound affects marine life for many reasons. As such the following are recommendations for future work that should be done in order to increase confidence levels.

- Device specific noise studies – to include cumulative effects of devices in arrays. This would need to be completed by every developer wishing to deploy their devices.
- Baseline noise level survey – this would need to be completed prior to any development. This would give a good indication of the noise levels in Bailiwick waters.
- Monitoring of noise levels – following on from the baseline survey, post installation monitoring of noise could help to reduce potential harm to receptors. This could be incorporated as part of the licence.
- Wildlife studies – further research needs to be done one animals in order to get a better understanding of how they responds to noise stimulus and whether noise acts as a barrier.
- Acoustic Avoidance Device Surveys – to identify whether they are an actual deterrent, or just a shock initially and whether they do any harm.