Offshore Wind in Coastal North Carolina:
A Feasibility Study

by

Jessica E. Regan

Masters project submitted in partial fulfillment of the
requirements for the Master of Environmental Management degree in
the Nicholas School of the Environment and Earth Sciences of
Duke University

2004

Date:________________

Approved:

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Dr. Joseph Bonaventura, Advisor

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Dr. William H. Schlesinger, Dean

I. INTRODUCTION

"Energy resource use is one of the most important and contentious issues of our time (Pelc 2002)." In the United States, we have become increasingly dependent on energy sources as our technology has increased and our standards of living have been elevated. In 1999, North Carolina ranked eighth in the nation with electricity expenditures of over seven billion dollars. Over 90 percent of the energy generated in North Carolina utilizes resources purchased from other states, such that almost one third of energy expenditures leaves the state economy (Environmental Defense 2003). This reliance on outside coal, natural gas, and oil could be eliminated by utilizing renewable energy sources.

Renewable energy sources, while providing the same electricity as fossil fuels, exist in an infinite supply and are much cleaner than the fuels we currently use. In light of global warming and especially the current conflict in Iraq, many feel it is essential to refocus our energy pursuits and begin to rely more heavily on renewable sources that are more reliable in the long run.

Wind energy has recently received a greater amount of attention than many other renewable sources due to highly controversial projects like that being proposed in the Nantucket Sound. Generating electricity from wind is considered "one of the most promising and economically feasible technologies for clean power generation (Pelc 2002)." The lack of suitable sites for such facilities has led to the development of several offshore wind facilities in Europe. Such a facility could contribute to energy generation in North Carolina.

The objective of this study is to evaluate and analyze data related to the construction of an offshore wind facility located in coastal North Carolina in order to determine whether or not a renewable energy project of this scope and magnitude would be feasible. In order to determine how feasible such a development would be for coastal North Carolina, several different aspects of the project will be analyzed: Ecological impacts, including potential changes in coastal geology and climate patterns; regulations and legal issues; economic issues; and the public's perception of wind energy. Based on these analyses, recommendations will be made as to whether a project of this scope would be a reasonable undertaking.

II. ENERGY IN THE UNITED STATES

As stated in the National Energy Policy, created by the National Energy Policy Development Group in 2001, our "current energy challenges can be met with rapidly improving technology, dedicated leadership, and a comprehensive approach to our energy needs (Breslow 2002)." In the United States, we have seen prices for our most used sources of energy (gasoline, heating oil, and natural gas) dramatically increase while our consumption has also increased, as shown in Figure 1. These high energy prices are causing fears of uncertainty among U.S. citizens, as they are facing rolling blackouts, financial instability, and foreign conflicts.

In the year 2002, energy use in the United States was primarily provided by the use of petroleum products, coal, and natural gas, as shown in Figure 2 (doe http://www.eia.doe.gov/emeu/aer/overview.html). Use of solar, geothermal, and wind energies were negligible at less than 0.5 Quadrillion Btu. Energy consumption far exceeds energy production in the U.S. (Figure 3), causing our dependence on outside sources of energy.

III. ENERGY IN NORTH CAROLINA

The state of North Carolina suffers from a lack of natural resources that can be utilized to provide energy to its citizens. The state imports virtually all of its fuel resources representing annual expenditures of approximately 7 billion dollars. These funds could make a significant impact on the state's economy, if not being funneled out to pay for energy sources (North Carolina State Energy Office 2003).

The natural environment in North Carolina also faces some challenges, as air pollution and other forms of air and water pollution have been seen to affect not only visibility in the mountains, but also sparked the need to recognize "ozone alert" days in several of our cities (North Carolina State Energy Office 2003).

Energy consumption in North Carolina has increased rapidly; Between 1977 and 2000, the population grew by 1.7% annually as energy use grew by 2.3%. In 2000, energy use in the state was mostly provided by petroleum (38%). Coal was used for 29% of energy use while nuclear power consisted of 16% of energy use. Natural gas contributed 9% of the state's energy use while renewable energy sources (mostly hydroelectric and wood waste burning) provided only 5%. These contributions are depicted in Figure 4. (North Carolina State Energy Office 2003)

Environmental concerns coupled with the lack of renewable energy sources used in North Carolina has led to a push towards developing some of the state's renewable energy sources. The most promising source to be utilized is wind energy.

IV. WIND ENERGY

Wind has been harnessed for our use for thousands of years, for everything from grinding grain to creating electricity. In the United States, windmills were used widely in the rural economy until cheap fossil fuelled engines and electrification of rural areas occurred. With the drastic increase in oil prices, unease over decreasing supplies of fossil fuels, and increasing environmental concerns surrounding their use, energy development in the 1970s shifted back towards cleaner renewable forms of energy (Burton et al. 2001). With an average annual growth rate of over 30% each year since 1995, wind power is the fastest growing energy sector in the United States (Environmental Defense 2003).

TURBINE DESIGN

Wind turbines used in offshore projects are very similar to those used inland, with the exception of the foundation. The current trends in turbine construction are 1.5 – 2.0 MW machines (Byrne O Cleirigh Ltd 2000), however, GE has produced a new 3.6 MW offshore wind turbine (GE Wind Energy 2003). Tower height for the average turbine varies from 60 m to over 120 m (Krohn 2003). The height of the tower is site specific, depending on the predicted navigation needs in the area. Rotor diameters can vary from 30 m to over 100 m. From the rotor tip (in a vertical position) to the surface of the ocean can range from just a few meters up to almost 50 meters, depending on the site (Tingley 2003). A typical GE Offshore 3.6 MW wind turbine has a rotor tip height of approximately 27 m as shown in Figure 5. This height allows for safe navigation by recreational and commercial vessels. A height comparison is shown as Figure 6 (note heights are not metric).

PRODUCING POWER FROM THE WIND

Converting wind to energy using wind turbines begins with the force winds exert on the rotor blades. This amount of energy transferred to the rotor by the wind is dependent on wind speeds, the rotor area, and also the density of the air (Parkinson 2003). As the wind turns the blades of the turbine, the kinetic energy is converted into electrical energy by a generator located within the turbine. This electricity can then by fed into pre-existing electricity grids and used by consumers like any other source of energy.

TYPES OF OFFSHORE FOUNDATIONS

There are several foundation types available for use, each having its own advantages and disadvantages. The foundations are commonly made of either concrete or steel and can take several forms such as a concrete or steel caisson, monopile, or tripod. In order to decide which of these foundation types will be used for a site, several different aspects are evaluated, including sediment type, water depth, and distance from shore. I will evaluate each of these foundation types with respect to the benthic composition of continental shelf of North Carolina in order to determine which would be most feasible and economic to install and least environmentally degrading to use.

The concrete caisson foundation is made of concrete and must be very large to support the large turbines so they are especially heavy and difficult to transport. The caissons are built onshore and transported onsite to be filled with sand and gravel and sunk to the sea floor. An advantage of this method is the lack of seabed preparation necessary. Since the supports are so heavy, gravitational forces are able to maintain stability in the turbines. A disadvantage of this method is the cost and weight of the caissons. At water depths of greater than 10 m, these foundations are prohibitively expensive and heavy. In areas of high erosion, rocks or boulders must surround this type of foundation in order to prevent shifting over time. (Krohn 2003).

This has led to a similar design in the steel gravitation foundations that are cheaper and easier to transport than concrete. Instead of a large concrete structure, this method uses a large, flat steel box that is sunk and filled with olivine, a heavy mineral. The low weight compared to concrete structures allows for much easier transportation and can be used up to water depths of 10 m. Unfortunately, seabed preparations prior to installation are necessary with this type of foundation. Sediment must be removed and a smooth layer of shingles must be laid before installation. Like the concrete foundation, in areas susceptible to erosion, the foundation will have to be protected using rocks or boulders. (Krohn 2003).

Monopile foundations were used at a recently established facility in Denmark. This simple method calls for a longer turbine tower that is embedded (by drilling or simply ramming) into the sea floor. This method requires no preparation of the seafloor before installation but requires the use of heavy machinery and is not suitable for all seabed types. (Krohn 2003). If large boulders and outcroppings are present, this foundation cannot be used.

In areas where access to the sea floor is not practical and bed preparation is not ideal, steel tripod foundations have been developed. This method uses lightweight three legged steel structures similar to those used in the offshore oil industry. This foundation is ideal for use in deeper waters (but not any shallower than 7 m) and is not affected by erosion. (Krohn 2003).

POTENTIAL IN NORTH CAROLINA

Wind Map

By utilizing wind speed and intensity maps (Figure 7), it is clear that there are two regions in North Carolina that have the potential to supply a consistent flow of wind generated electricity. These two areas are the mountains in western Carolina or the coastal areas along the Outer Banks. Due to the North Carolina Ridge Law, no development of wind facilities can be initiated in the mountains (Environmental Defense 2003). Several European nations have begun successfully erecting wind farms offshore, which is a possibility for coastal North Carolina. Offshore development attracts many developers not only due to a lack of land sites available for wind farms, but also because ocean winds are usually at higher speeds, are less turbulent, and are not obstructed by any landforms (Pelc 2002).

The Wind Energy Resource Atlas for the United States, developed for the U.S. Department of Energy states:

> Areas designated class 3 or greater are suitable for most utility-scale wind turbine applications, whereas class 2 areas are marginal for utility-scale applications but may be suitable for rural applications. Class 1 areas are generally not suitable, although a few locations (e.g., exposed hilltops not shown on the maps) with adequate wind resource for wind turbine applications may exist in some class 1 areas (National Renewable Energy Laboratory 2004).

It is clear from the wind resource map of North Carolina (Figure 7), that the areas along the Outer Banks are all a class 3 or higher (including the sounds) making them suitable sites for a utility scale wind farm. Wind speeds required for categorization into each class are also shown on Figure 7.

Location

The coast of North Carolina is considered a passive continental margin, meaning that it is currently not tectonically active (Anderson 1999). The coast is comprised of a diverse collection of estuaries and sounds most of which are encased by a series of barrier islands, referred to as the outer banks. Seaward of these barrier islands is the continental shelf, which deepens to approximately 50 – 60 meters at the shelf break off the coast of North Carolina (Mallin et al. 2000). The shoreline has a shallow slope and high wave energy, which provides for abundant sediment supply and transport (Anderson 1999). An offshore wind facility could be located either within the fringe of the Outer Banks in

Pamlico Sound or on the continental shelf. Both of these scenarios are depicted as Figures 8 and 9.

V. ECOLOGICAL IMPACTS

The construction of an offshore wind facility in coastal North Carolina has the potential to drastically effect the ecology of the area, spanning from the benthic habitats to pelagic species, especially those protected species that call the waters around the state home. Since these structures extend above the water as well, the effects on animals and activities on and above the surface must also be taken into consideration. These effects will range from acute, or immediate impacts, to chronic impacts, which will persist over time.

SURFACE

Birds

One of the few noted environmental downsides to wind power is the potential for impacting bird populations (Pelc 2002). These impacts can range from collisions to disturbance to habitat loss (Parkinson 2003). Facilities in the late 1980s and early 1990s were cited as the cause of several hundred raptor deaths, generating bad media coverage for the wind industry as a whole. This publicity has led to a poor public perception of these “Cuisinarts of the sky” which is often the deciding factor in whether or not these projects succeed (Tingley 2003). The impact of offshore wind farms has been shown to be much less significant than land based facilities, however, the potential for detrimental effects still exists (Krohn 2003).

Collisions

Collisions with wind turbines can occur in one of three ways:

- Contact with non-moving parts of the turbine (e.g. the hub, tower, or motor box),
- Contact with the rotor blades, or
- Being caught in the pressure wave or "wake" of the spinning blades (Tingley 2003).

Stationary collisions have been shown to be affected by several attributes of towers, including a larger number of collisions with increased height and certain illumination heights. Towers greater that 150 m tall have been associated with higher mortality rates. These collisions become more serious and cause greater mortality rates due to the location offshore. Many impacts on land cause momentary unconsciousness, but some animals are able to recover. However, impacts over open water do not give the birds time to recover before they drown (Tingley 2003).

Rotor and wake collision frequencies and risk potential vary according to the speed and size of the turbine. Original turbines had a rotor diameter of 34 m, while the most recent technologies have produced turbines with rotor diameters of 100 m. This increase in rotor diameter is coupled with a decrease in rotor speed. This slower speed has been cited as the basis for arguments that collisions are less likely with these modern turbines (Tingley 2003).

In order to quantify the actual impact of these structures, we need to evaluate other sources of avian mortality. In comparison to the 60 to 80 million birds that are killed each year due to collisions with motor vehicles, the 10,000 to 40,000 birds killed from impacts with wind turbines seems almost negligible. A wind facility in California that operates over 5,000 turbines completed a study that found only 0.15 bird fatalities per turbine per year (0.06 for raptors) (Tingley 2003).

Disturbance

Disturbance of bird populations occurs primarily during the construction phase of the process due to the presence of large machinery and construction teams (Parkinson 2003), but also due to noise created in the daily operation of such a facility. These noises may displace populations from using areas consistently or may discourage birds from flying through the area (Tingley 2003).

This disturbance can cause indirect habitat loss as well as creating a barrier to normal flight patterns (Tingley 2003), which may alter migratory routes. Indirect habitat loss would occur when resources are patchy, and the noise annoyance prevents birds from utilizing resources within the wind farm. The habitat loss would be considered indirect as the birds are not excluded from the area, but the area is made less desirable, and is therefore not used.

A barrier to movement due to a wind facility occurs when birds choose to fly around a wind farm instead of through it. While this seems logical due to the collisions discussed earlier, for migratory species, this change in pathway could be detrimental. Migration around a wind facility could incur additional stress or energy to be exerted by the animal. It has been shown that migrating birds have unusually high blood pressures due to the strenuous nature of the migration (Tingley 2003). As these offshore facilities are sometimes a considerable distance from land, this barrier to migration could cause high mortality rates if too much extra effort is required of the birds.

Habitat loss

While habitat loss is a consideration for onshore wind facilities, offshore facilities do not have a significant of an impact on habitat, as the only habitat directly "lost" is the sea floor used to house the turbine foundations (Tingley 2003), which is not directly utilized by seabirds.

Recommendations

The most effective way to minimize these impacts on birds is the careful siting of facilities. Migration pathways and areas that are essential to the life cycle of shorebirds should be avoided when the site selection process occurs. The size, shape, and configuration of the wind farm can also have significant impacts on bird populations. While these characteristics are most often shaped by the energy goals of the developer (Tingley 2003), a compromise must be made in order to lessen impacts on avian populations.

Noise

A commonly cited problem with wind farms is the creation of noise, as older wind turbines were often known to disturb human beings living in close vicinity. New technologies have minimized the propagation of noise and vibration from these structures, however, neither has been totally eliminated. Due to the nature of offshore wind facilities, no human habitations will be bothered by the noise as it usually only extends for a few rotor diameters from the turbine (Krohn 2003), however, the impacts on wildlife may be more significant.

Noise, which can be defined as simply unwanted sound, is a sensation caused by pressure variations in the fluid surrounding an organism's ear or hearing mechanism. Sound waves are characterized by their wavelength, frequency (Hz), and velocity. Wavelength and frequency are not affected by the medium in which the sound travels, however, the velocity of sound waves is dependent on the medium. The velocity of sound in air is approximately 330 m/s while the velocity of sound propagation in water is approximately 1500 m/s (Both of these values varies depending on temperature, pressure, humidity and/or salinity) (Vella et al 2001). The common measurement of sound intensity is the decibel (dB). This scale measures sound over the entire range of audible frequencies and uses a weighting scheme to account for sensitivities of the human ear. The decibel scale is logarithmic, therefore with increasing distance from the turbine, the sound level will decrease with the square of the distance (Krohn 2003).

In shallow waters, underwater sound may be "channeled by the seabed and water surface" thereby limiting the sound propagation to only two dimensions, which will cause a decrease in sound levels with increasing distance from the source. Absorption of sound waves may also occur, the rate of which depends on a number of factors, including temperature, pressure, salinity, and the frequency of the sound waves. This absorption may be increased by air bubbles or suspended sediments in the water column. This finding has led to the use of "bubble curtains," especially during construction, to minimize noise (Vella et al 2001).

The actual impact of the added noise of a wind farm must be looked at as an addition to the ambient noise already present and other sources of anthropogenic noise that has already been introduced into the system. Ambient sources of noise already present in the ecosystem include that caused by wind and waves, rain, the movement of seabed materials, and natural seismic activity. Anthropogenic noises already present include noise from shipping vessels, seismic surveying, offshore construction, airborne noise, sonar, and explosions (Vella et al 2001). These sources of noise are shown in Table 1 with average frequencies (Hz) and source levels on the decibel scale (dB).

Noises from offshore wind facilities can occur not only in the day-to-day operation, but also during installation and decommissioning.

Installation

Noise caused during installation of these structures varies depending on the type of foundation chosen. The largest audible impact due to construction will most likely occur as a result of any dredging or piling that must occur to prepare the seabed for the foundations. Vessel traffic will also contribute as a source of noise during the construction phase, as vessels will be used to transport the parts of the turbine. As these activities are short term, their impact is thought to be minimal, however, actions can be taken, such as the use of “bubble curtains” or other structures that minimize the propagation of sound through the water column (Vella et al 2001).

Normal Operation

Very little data regarding the audible impacts of offshore wind farms has been collected to date. Measurements from the first offshore wind turbine in 1994 recorded underwater sound levels at varying distances from the turbine, focusing on sound frequencies below 100 Hz. Using the measurements found in that study and accounting for attenuation loss over a further distance, the source level of wind turbines was estimated to be approximately 115 dB (Vella et al 2001). As shown in Figure 10 most anthropogenic sources of noise have a greater intensity than wind turbines.

No data have been collected regarding the vibrations emitted from operating offshore wind turbines. It can be assumed that such vibrations would occur, however further studies would be required to determine the impacts, if any.

Decommissioning

As offshore wind farms are fairly recent developments and the typical lifespan of such a structure is between 20 and 50 years, the actual noise impacts of the decommissioning of these structures is largely unknown (Vella et al 2001).

Potential impacts on wildlife

Hearing in marine wildlife is a function of several different characteristics and processes, however, for the purposes of this study, we will focus on frequency and intensity discrimination. Frequency and intensity discrimination refers to "the ability to discriminate sounds of different frequencies and levels, particularly over ambient noise levels (Vella et al 2001)."

Organisms of concern in North Carolina waters include: marine mammals, sea turtles, and fish. While there is little data available on most species, Table 2 shows several organisms of concern and their associated frequency range (Hz) and their most sensitive frequency (Hz). As found by Vella et al. (2001), most turbines emit frequencies of lower than 100 Hz. As shown in Table 2, many of the species of concern are most sensitive to frequencies above that emitted by turbines.

Recommendations

Due to the nature of the frequency of sound emitted by wind turbines, impacts from noise can largely be prevented or minimized. During the construction phase, extra precautions, like using a bubble curtain, should be used in order to reduce the impacts of the activities. Once the turbines are in operation, it appears that their presence should have minimal effects on wildlife in the area. Monitoring must be conducted in order to ensure that no organisms are being disturbed by this increased noise level.

Navigation

The presence of wind turbines on the continental shelf will certain hinder navigation and may increase the potential for collisions in the area (Parkinson 2003). The coast of North Carolina is used extensively not only by fishermen and commercial shipping, but also extensively by the United States military. This high vessel traffic would necessitate the clear marking of these structures on all charts and the lighting and marking of each turbine (Parkinson 2003). Wind turbines are usually equipped with a 500 m safety buffer, in which vessels are discouraged to travel in (Krohn 2003). The rotor tip height above the water varies depending on the site so that vessel traffic is not impacted.

Recommendations

It is essential that turbines are clearly marked and appear on all maps and charts so that their presence is clear. In order to place the hub and rotor at an appropriate height for the vessel traffic that does occur in the area, additional research must be done to quantify a minimum rotor tip height.

Recreation

Presence of wind turbines in the coastal waters of North Carolina would inhibit the recreational boating in the area, as navigation through the wind field will be more difficult. However, this limitation of boating could have positive ecological impacts on the system as a whole, as the area will become a safe haven for fish and marine creatures such as sea turtles and marine mammals. The allure of these structures could increase public interest and create larger amounts of traffic in the area, thereby increasing the chance for collisions (Parkinson 2003). Increased boat traffic around the wind field could lead to greater amounts of boat strikes to marine mammals and sea turtles, which inhabit the waters in which a wind farm would be located.

Recommendations

Again, it is essential that turbines are clearly marked and appear on all maps and charts. The public and tourists to the area should also be educated about the facility, as heightened awareness will eliminate some of the curiosity surrounding the turbines, thereby eliminating the chance for boating accidents.

Fisheries

While one of the major impacts on fisheries in North Carolina due to a wind facility would be economic, the ecological effects on populations of commercially viable species could also be significant.

The presence of turbines in an area will eliminate the ability of fishermen to trawl or drop large nets in that area, as the spacing or turbines will not allow for such large scale fishing operations. The wind field will then become a sort of marine protected area, or safe haven for fish stocks. This protection could increase the stocks of fish commercially used. This potential increase would provide additional recruitment to areas outside of the wind field thereby increasing commercial takes.

This increase in large predatory marine fishes could also have significant impacts on lower trophic levels that may be depleted as higher up predators increase. This top-down control could drastically alter the composition of the communities in the area.

Recommendations

The impacts of a wind farm on the populations of commercially viable finfish and shellfish species is largely unknown. Monitoring and additional studies must be performed after such an installation in order to determine and mitigate any detrimental impacts caused to fish populations.

BENTHIC

The benthic habitats of the continental shelf vary from soft-bottomed sediments to hard-bottomed outcrops, both of which support a variety of benthic algae, invertebrate communities, and fishes (Mallin et al. 2000). Hard bottomed areas of the shelf have varying levels of diversity and depending on the degree of relief of the substrate. In areas with a high slope, you will see a different assemblage of organism that in a low slope area. Low relief hard bottom areas are subject to sand scour and even burial, so they tend to support lower species diversity. These areas are usually dominated by sessile octocorals and sponges. Hard bottoms with a greater slope are commonly dominated by microalgae, sponges, bryozoans, hydrozoans, and tunicates. Further offshore, in waters of depths greater than 35-40m, influences of the Gulf Stream are more evident and a greater variety of tropical and subtropical taxa are frequently found (Mallin et al. 2000).

Soft sediment communities are much more diverse. A survey of the North Carolina coast in 1999 found that over 500 taxa are present in soft-bottomed areas. These areas are dominated by polychaetes and small bivalves, but also support economically important fisheries including those of the blue crab and shrimp (Mallin et al. 2000). These soft-bottomed areas, like the Pamlico Sound, with greater sediment abundance are more susceptible to burial and the suffocation of sessile and filter feeding organisms with increases in water turbidity.

The coast of North Carolina is also the home to a diverse population of fish ranging from those that exclusively use estuarine areas to pelagic fishes. Populations include migratory marine fishes (mackerels and bluefish), rock/reef associated fishes (snapper, grouper and sea bass), and large pelagic fishes (wahoo, swordfish, marlins and shark). (Mallin et al. 2000). The North Carolina coast is also the home to several species of marine mammals and sea turtles. While none of these species are benthic, their food sources depend on the benthic communities. Therefore any detrimental impacts on the benthic communities will indirectly hard these commercially valuable and protected species.

Construction of offshore wind facilities has the potential for detrimental environmental impacts despite their temporary and short-lived nature. This construction process includes not only the installation of each turbine, but also the running of cables back onshore to connect back into the power grid. The potential impacts of these activities are described below. These impacts include sedimentation, disturbance, and burial of organisms, which can directly affect food sources for predators in the area. Also, presence of the turbine foundations could potentially disturb behavior and migration patterns of fish, marine mammals, and sea turtles, which could have large impacts on benthic assemblages (Parkinson 2003).

In reference to the benthic communities, the laying of cables back onshore to connect to the existing electricity grid will have a great impact over a potentially large area. Cables can be laid in one of two ways, through trenching or tunneling. The impacts of both of these methods are shown in Figure 11.

Recommendations

In order to minimize the impacts on the benthic community, caution must be taken to minimize the disturbance of additional sediments into the water column. This would include utilizing foundation types that are most suited to the site chosen so that additional seabed preparation is not necessary. The laying of cables to transmit electricity generated will certainly have detrimental impacts initially, however, once the action is performed, the community will be able to recolonize, as only a small area of habitat will be disturbed.

PELAGIC

Impacts on the pelagic environment and the species that utilize the open ocean is much less straightforward. Inserting a structure into the ocean that does not naturally exist there could impact many facets of the lives of flora and fauna that depend on that resource. Much study has been done regarding the impacts of offshore oil and gas drilling on marine mammals and sea turtles, as well as highly migratory fish species, however little study has focused on offshore wind, although impacts could be similar.

Marine Mammals

Marine mammals, including dolphins, porpoises, toothed whales, and balaenid whales are known to inhabit the waters off of North Carolina, however not all inhabit the waters of the coastal shelf on which an offshore wind facility would be located. Therefore this analysis will focus primarily on those species that inhabit coastal waters. As they are protected by the Endangered Species Act, impacts of offshore wind must be considered. The most pressing issue in relation to marine mammals is the potential for increased underwater noise due to the turbines. The initial construction will produce noise pollution, however, the long-term effects will probably have a greater effect as the movement of the blades could produce noise that may be transmitted through the tower and into the water. It has been proven that these marine mammals rely highly on sound not only for communication, but also for foraging and navigation. This increased noise could negatively impact these creatures and their behaviors, however, the actual impacts are unknown.

Communication

Marine mammals are known to produce a wide variety of sounds, ranging from whistles and tones to clicks and pulses used for echolocation. The addition of noise into their environment could mask communication with conspecifics or mask other noises of biological importance that they depend on while in the environment (Vella et al 2001). However, there is little conclusive evidence whether or not noise causes any adverse behavioral reactions. The range of frequencies emitted by marine mammals is shown in Figure 12. Clearly, very few of the species shown will be affected by the frequency emitted by wind turbines (100 Hz) (National Research Council et al 2003).

Behavior

Increases in anthropogenic noise may displace marine mammals from their normal migratory or foraging routes, due mainly to the disturbance or annoyance from the additional noise. This indirect habitat loss may impact behavior, however, there are no conclusive studies. There are several cases that appear to show habituation and tolerance for anthropogenic noise, but also studies that appear to show avoidance (Vella et al 2001).

Recommendations

Due to the lack of knowledge on the effects of such structures on marine mammals, it is vital that after the construction of such a facility, monitoring and additional research be done in order to acknowledge and mitigate any impacts that may be seen.

Sea turtles

The coast of North Carolina is home to several species of sea turtle, including the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and Kemp's ridley sea turtle (*Lepidochelys kempii*). Leatherback (*Dermochelys coriacea*) and hawksbill (*Eretmochelys umbricate*) turtles have also been observed in coastal waters, however, their presence is much more infrequent.

These marine turtles have a distinctive life history that, for some species, may begin on the beaches of North Carolina. The turtles then migrate offshore and spend a large majority of their lives at sea, until they migrate back to their original nesting beach to lay eggs. The Gulf Stream and other large warm water currents in the Atlantic Ocean play a large role in these migrations. If the presence of wind turbines were to affect the circulation of ocean currents, the migratory patterns of these marine turtles could be altered (Eckert 2004). However, several environmental impact assessments have found these changes in hydrologic regimes to be negligible (amec 2004).

It was historically thought that sea turtles were unable to hear, as they exhibit no vocalizations or auditory communication. Limited behavioral actions were recorded in response to sound, however, there was little proof. However, in the 1950s and 60s, proof that turtles do indeed have a sense of hearing was discovered. It was found that turtles can hear the best between 200 and 700 Hz, while the maximum sensitivity is around 400 Hz (Eckert 2004). Wind turbines have been demonstrated to emit frequencies of less than 100 Hz (Vella et al 2001).

Recommendations

As wind turbines have been shown to have to insignificant effects on ocean currents, impacts on migration patterns appear to be minimal. The sensory biology of turtles also appears to not be affected by such structures, as the range of hearing for most marine turtles is higher than the frequency emitted by wind turbines. The impacts on sea turtles seem to be minimal.

Artificial Reefs

Artificial reefs, which have been defined as "submerged structures deliberately placed on the seabed to mimic some characteristics of a natural reef (Parkinson 2003),' can easily be constructed as a part of the design of an offshore wind farm (Byrne O Cleirigh Ltd 2000). Artificial reefs have been widely used as a popular coastal zone management tool for several purposes including:

- Improving the quality and quantity of fishing events,
- Providing additional spawning areas,
- Providing refugia for juvenile fish,
- Protecting natural stocks of shellfish and finfish,
- Preventing trawlers from utilizing certain areas,
- Protecting the shore and reduce rates of erosion (breakwaters),
- Restoration of degraded habitats,
- Nutrient recycling,
- Reducing fishing areas by excluding fishermen, and
- For scientific experiments (Byrne O Cleirigh Ltd 2000).

These artificial reefs are often constructed of waste materials that are submerged (Byrne O Cleirigh Ltd 2000). This not only disposes of the waste, but also provides the above listed benefits to the ecosystem. In North Carolina artificial reefs have been utilized along the coast, and also in the sounds for such purposes.

Studies have shown that artificial reefs near oil rigs no longer in use attract fish very rapidly, with some achieving a climax population after only several month of being in place (Parkinson 2003). The base of offshore wind turbines could serve this same purpose and enhance fisheries in the area of the wind farm. While fishing will be inhibited due to more difficult navigation, the wind farm and artificial reefs could serve as a "protected area" of sorts that will protect fish stock and allow populations to increase. As the commercial fishing industry in North Carolina is substantial, this increased ability to support species could positively benefit the economy.

Recommendations

The construction of artificial reefs around the base of wind turbines may positively impact fisheries and ecological communities in the area. These structures do not impact the effectiveness of energy production. The use of turbine foundations to support artificial reefs may be a way to further the benefits of using wind energy.

VI. GEOLOGICAL AND HYDROLOGICAL IMPACTS

Several proposed offshore wind facilities have begun the initial phases of environmental impact statements to determine what effects, if any, the presence of wind turbines would have on geological and hydrologic conditions. A major concern to communities of the Outer Banks would be the threat of increased beach erosion. While these coastal communities are already dealing with this problem, if the addition of these offshore structures would contribute to the occurrence of shoreline erosion, serious consideration would need to be taken before proceeding.

Geologically, the coastal plain surrounding North Carolina deepens to approximately 50 to 60 meters at the shelf break and consists of shallow relic sediments (fine, medium, and coarse sands) which overly sedimentary and calcareous layers which sometimes form hard-bottom outcrops. The Gulf Stream, which occurs at approximately the shelf break mentioned above is a dynamic current of warm water from the Gulf of Mexico that drives circulation and contributes new nutrients into the shelf ecosystem (Mallin et al 2000).

SUBSTRATUM CHANGES

There is currently little known about the impacts of offshore wind turbines on the geology of the seabed or the potential impacts on hydrologic regimes (Parkinson 2003). Changes in the currents that normally flow over the seabed could disturb current bedforms and features that are in balance with the normal current regime. If a structure disrupts water flow and changes the speed of the current, scouring or other processes could occur, depending primarily on the change in water speed. Figure 13 shows that with decreasing current speeds, less dramatic bedforms are created (Parkinson 2003). While there is the potential for wind turbines to have an impact on seabed features, it is thought that those impacts would be negligible.

HYDROLOGIC REGIME CHANGES

As mentioned above, the presence of an obstruction can alter the energy of currents flowing towards shore. The presence of structures on the shelf could not only alter oceanic currents, but may also influence wind currents, which ultimately affect oceanic currents as well. The Gulf Stream is essential to many species and highly influences many climates, therefore any possible alterations to this warm water currents could have large impacts (aric 2001). Fortunately, the influence of wind turbines is expected to be negligible in relation to the many processes that maintain the Gulf Stream (amec 2004). The impact of an offshore wind farm on the hydrologic regime is not of concern.

BEACH EROSION

Wave action controls the transport of sediment to and from the beaches along the coast. Therefore, any process that changes the shape or magnitude of the waves, can have significant impacts on the shape of the shoreline. This is abundantly clear in the case of hurricanes or large nor'easters that frequently impact the Carolina coast. These meterological occurrences alter normal wave patterns and are usually associated with periods of beach erosion. Changes in wave activity can also result in increased accretion on the beach. The addition of wind turbines to the coastal plain could potentially impact wave amplitude, as the structures could provide a partial obstruction to the incoming waves, which may reduce wave heights. An Irish impact assessment determined that while there could be changes in wave action in the immediate area of the wind farm, those changes would be negligible and localized. These negligible impacts are not expected to significantly change wave and current regimes, or overall seabed processes (amec 2004).

VII. POLICY

The development of an offshore wind facility has not yet been proposed in North Carolina; however, the addition of green power to the electric grid could be very beneficial to the state. However, the permitting and regulatory processes necessary for approval of such a facility could also be a major obstacle as there are no clear regulations governing such a facility, several federal and state policies that would regulate coastal development and no specific regulatory body to oversee the process. This unclear regulatory structure and burden of responsibility poses a challenge for any proposed development. This analysis will attempt to evaluate the process necessary for an offshore wind facility to be constructed in North Carolina and which state and federal statutes and laws apply as well as how such a facility would impact the human ecology of the area.

FEDERAL GOVERNING AUTHORITIES

National Environmental Policy Act of 1969 (42 U.S.C. §4341) – The National Environmental Policy Act (NEPA), in order to minimize damage to the environment while still allowing for development for the welfare of man, requires that any projects proposed must be evaluated in light of any alternatives available. NEPA also established guidelines for the preparation of an Environmental Impact Statement (EIS) for projects that have the potential to produce detrimental impacts on the environment (42 U.S.C. §4341).

Coastal Zone Management Act of 1972 (16 U.S.C. §1456 et seq.) – The Coastal Zone Management Act (CZMA) mandates that all federal activities (which includes permitting) be consistent with any state coastal zone management plans in place and encourages the development of such plans (16 U.S.C. §1456 et seq.). In North Carolina the Coastal Areas Management Act (CAMA) serves as the decisive management authority.

Marine Mammal Protection Act of 1972 (16 U.S.C. §1361 et seq.) – The Marine Mammal Protection Act (MMPA) was established to maintain "optimum sustainable populations" of marine mammals. In order to achieve this goal, the MMPA prohibits the taking or harassment of marine mammals. Harassment, as defined in the MMPA includes "any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal… or disrupt behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (16 U.S.C. §1361 et seq.)." The coast of North Carolina is the home to several different species that are protected under the MMPA; this causes the potential for "harassment" to occur, especially during initial construction activities. It is unknown how the permanent structures will affect marine mammal stocks, however current evidence suggests that there will be no effect.

Endangered Species Act of 1973 (16 U.S.C. §1531) – The Endangered Species Act (ESA) serves to protect threatened and endangered species by prohibiting actions that jeopardize the existence of listed species or detrimentally effects habitats critical to their reproduction. In order to avoid interactions with any listed species, and as required by Section 7(a), a consultation with the Secretary of the Interior will occur (16 U.S.C. §1531). If it is determined that there may be detrimental impacts of the wind facility on protected species, the site should be relocated (Freedman 2001).

Magnuson-Stevens Fishery Conservation and Management Act (P.L. 94-265) – The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) exists to provide for the "conservation and management" of fisheries, with special focus on continental shelf fishery resources, highly migratory fish species, and the protection of essential fish habitats (P.L. 94-265). While the MSFCMA deals primarily on fisheries themselves, the construction of an offshore wind facility could potentially threaten fisheries resources and habitats in the vicinity of the project.

Clean Water Act of 1977 (33 U.S.C. §1251 et seq.*)* – Section 404 of the Clean Water Act (CWA) states that a permit from the United States Army Corps of Engineers (USACE) is required for any projects that require the "discharge of dredged or fill material into navigable waters." While the construction of an offshore wind facility will not directly involve any dredging or filling activities, preparation of the seafloor for turbines may involve some excavation. Any excavated materials are considered dredged material for the purposes of this section. 33 C.F.R. §323.2(d)(1)(iii). In 1997, *American Mining Congress v. USACE* concluded that a permit was not required for this incidental dredging and filling; therefore it is not clear whether or not permitting would be required.

Rivers and Harbors Acts of 1890/1899 (33 U.S.C. §401) – Section 10 of the Rivers and Harbors Act prohibits the obstruction of any navigable waters of the United States. Any potential obstruction must first obtain a permit from the USACE. As a wind facility on the coast of North Carolina will certainly be located in navigable waters and the construction of wind turbine structures could be considered an obstruction. The USCAE will have final jurisdiction (33 U.S.C. §401).

Navigation and Navigable Waters (33 C.F.R. Parts 62,64,66) – These regulations give the United States Coast Guard the authority to determine whether or not the facility would obstruct or create a hazard to navigation. The Coast Guard also will provide recommendations on required markings, lights, or other navigational tools (Freedman 2001). As turbines located in open water would certainly be considered an obstruction to navigation, a consultation with the District Commander of the Coast Guard would be vital.

Federal Aviation Administration (Objects Affecting Navigable Airspace, 14 C.F.R. § 77) – These regulations serve to "ensure the safety of air navigation, and the efficient utilization of navigable airspace by aircraft." Notice of a project is required to the regional FAA office for any "construction or alteration of more than 200 feet in height above the ground level at its site." For a waterway "an amount equal to the height of the highest mobile object that would normally transverse it (14 C.F.R. §77.13(a))." It would seem that this would include offshore wind turbines, so the regional FAA office would be directly involved in the approval and would designate lighting requirements for visibility purposes.

National Historic Preservation Act of 1966 (16 U.S.C. §470 et seq.) – The National Historic Preservation Act established a National Register of Historic Places, which is composed of "districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, engineering, and culture (16 U.S.C. §470 et seq.)." Although an offshore wind facility would not directly impact any historic places, the presence of such large structures could compromise the integrity of historic areas located on the coast. Any designated places near the location of the facility should be examined in order to minimize any impacts. A meeting with the State or local Historic Preservation Officer may be necessary.

Fish and Wildlife Coordination Act of 1958 (16 U.S.C. §661) – This act mandates that a consultation with the U.S. Fish and Wildlife Service (USFWS), Department of the Interior, and a representative from the North Carolina Department of Environment and Natural Resources (NCDENR) is required "whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified (16 U.S.C. §661).". Since this project is marine, consultation with the National Marine Fisheries Service (NMFS) would also be beneficial. These consultations serve to provide recommendations to minimize impacts on fisheries and promote wildlife conservation (Freedman 2001).

Migratory Bird Treaty Act of 1918 (16 U.S.C. §703-712) – The Migratory Bird Treaty Act established guidelines that prohibit the capture, kill, or harm of any migratory bird. While the harming of birds happens very infrequently due to collisions with wind turbines, siting of the facility would have to take into consideration migratory paths of these migratory birds (16 U.S.C. §703-712). In order to reduce the incidental take or harm of these species and avoid possible fines and penalties, developers should work closely with the United States Fish and Wildlife Service (USFWS).

Abandoned Shipwrecks Act (43 U.S.C. §39) - The coast of North Carolina is often referred to as the "graveyard of the Atlantic" due to the large numbers of shipwrecks that surround the Outer Banks. The Abandoned Shipwrecks Act gives states the authority to manage these "irreplaceable State resources for tourism, biological sanctuaries, and historical research (43 U.S.C. §39)." States are given ownership rights to shipwrecks that are: (1) embedded in submerged lands of a State, (2) embedded in coralline formations protected by a State on submerged lands of a State, or (3) on submerged lands of a State and is included in or determined eligible for inclusion in the National Register (43 U.S.C. §39). Since there are a great number of shipwrecks off the coast of North Carolina, siting for a wind facility would have to take into consideration the location of these shipwrecks. A consultation with the State Historic Preservation Officer may be necessary.

STATE GOVERNING AUTHORITIES

North Carolina Environmental Policy Act (NCEPA) (G.S. 113A-1 et seq.) – The NCEPA, written in 1971 serves as a regulatory document to

> "…encourage the wise, productive, and beneficial use of the natural resources of the State without damage to the environment, maintain a healthy and pleasant environment, and preserve the natural beauty of the State; …to require agencies of the State to consider and report upon environmental aspects and consequences of their actions involving the expenditure of public moneys or use of public land; and to provide means to implement these purposes."

This Act mandates that state agencies review any proposed projects that fall meet certain criteria. These criteria include the use of public funds, involvement of a state agency, and possible detrimental environmental effects. If all three of these criteria are met, an environmental assessment (EA) must be produced. If the EA results in a 'Finding of No Significant Impact" (FONSI), no additional assessment is necessary. However, if a FONSI is not achieved, a more rigorous Environmental Impact Statement (EIS) should be completed (G.S. 113A-1 et seq.).

Coastal Area Management Act (CAMA) (G.S. § 113A-100 et seq.) – CAMA was developed by the state of North Carolina in 1974 in order to protect the state's "most valuable resources" which are "its coastal lands and waters (G.S. § 113A-100 et seq.)." This act has four main goals which are:

(1) To provide a management system;
(2) To insure that the development of the coastal area occurs in a way that does not destroy the environment;
(3) To insure the equitable utilization of the states coastal resources; and to
(4) To establish policies, guidelines, and standards for:
    a. Protection, preservation, and conservation of natural resources;
    b. The economic development of the coastal area;
    c. Recreation and tourist facilities and parklands;
    d. Transportation in the coastal area;

e. Preservation and enhancement of the historic, cultural, and scientific aspects of the coastal area;
f. Protection of common-law and statutory public rights in the lands and waters of the coastal area;
g. Any other purposes deemed necessary or appropriate to effectuate the policy of this Article (G.S. § 113A-100 et seq.).

With respect to an offshore wind facility, CAMA designates several areas of environmental concern that must be taken into account when the siting for this project occurs. These areas that could be impacted by such a facility include, but are not limited to: Sand dunes and shorelines, areas that support rare or endangered species, unique geologic formations (as designated by the state geologist), historic places, and navigable waters (G.S. § 113A-100 et seq.).

CAMA states "every person before undertaking any development in any area of environmental concern shall obtain a permit pursuant to the provisions of this Part (G.S. § 113A-100 et seq.)." Development could fall into one of two categories: major or minor. A major development is considered any development that meets any of the following criteria:

(1) requires permission, licensing, approval, certification or authorization in any form from the Environmental Management Commission, the Department of Environment and Natural Resources (DENR), the Department of Administration, the North Carolina Mining Commission, the North Carolina Pesticides Board, the North Carolina Sedimentation Control Board, or any federal agency or authority; or
(2) occupies a land or water area in excess of 20 acres;
(3) contemplates drilling for or excavating natural resources on land or under water;
(4) occupies on a single parcel a structure or structures in excess of a ground area of 60,000 square feet (G.S. § 113A-100 et seq.).

This designation as a major development would certainly apply to an offshore wind facility, as it would meet several of these criteria, if not all.

CONCLUSION

An offshore wind facility in coastal North Carolina has the potential to increase the flow of clean, green power into the grid while not only improving environmental quality and public health in the area, but also to providing more jobs for coastal residents. However, since a project of this magnitude and scope has never been completed in the U.S., the approval and construction will prove to be a major obstacle. It is unclear who would be ‘in charge’ of such a project, both in the initial permitting and approval process, but also as a regulatory body. There is legislation in place that encompasses development on our coast; however, there is no structure in place to adequately manage the development of offshore wind energy. In North Carolina, I believe that CAMA would have to be amended or adapted to be able to adequately assess the impacts of such a facility. I believe that adding wind energy to the supply of energy used in North Carolina would be very beneficial, however, we need to have a structure in place not only to set a precedent for other states, but also to ensure that the integrity of our coastal environment is maintained.

IIX. ECONOMICS

Economic considerations must be evaluated before installation of an offshore wind facility. While these structures offer energy from a free resource, the start-up costs can sometimes be daunting. Fisheries in coastal North Carolina are a large source of income for its residents. The potential impacts of the presence of wind turbines are especially of concern to fishermen. The crystal coast of North Carolina is a huge draw for tourists each year. It has been suggested that tourism may be impacted by the presence of a wind facility in the waters of popular vacation spots, such as Cape Cod. Another concern of local residents is the potential for decreased land values as a result of the "tainting" of the landscape by wind turbines.

COSTS

Wind energy has been cited as one of the fastest growing energy sources. Between 1990 and 2000, wind energy generated in the world grew from approximately 2,000 MW to approximately 18,500 MW. Figure 14 displays this increase in wind energy production. This rapid growth is the result of not only increased technologies that lead to greater efficiency, but also due to a decline in cost. This reduced cost of production and installation has made wind energy much more competitive in the energy market (Marafia 2003).

Installation costs

Installation costs of wind turbines vary according to the size of generator, height of tower, and diameter of the rotors (Krohn 2003). Costs of installation offshore have been reduced from approximately $2000/kWh for the first Danish offshore wind farms, to an estimated $1490/kWh for more recent projects (Renewable Energy World 2002). These costs include the cost of the foundation, cost to transport the turbines offshore, cost of a transformer to convert the energy to be compatible with the local grid, and the cost of laying cables back to the local energy grid. In the past, the cost of offshore foundations held back the progress of offshore facilities, however the cost of foundations has decreased dramatically (Krohn 2003).

Maintenance costs

Past studies have shown that operation and maintenance costs of wind farms are usually very low, especially during the period immediately following installation. However, as turbines age, their need for maintenance increases (Krohn 2003). It has been found that newer generations of wind turbines require significantly less maintenance than those produced in the past. Danish wind turbines produced using older technologies have seen maintenance costs around 3 % of the original turbine investment. Newer machines have been seen to only require 1.5 – 2 % of the original cost in maintenance (Krohn 2003).

Lifetime

Onshore wind turbines are generally designed to last for approximately 20 years. However, due to the lower turbulence subjected to offshore turbines, their lifespan is predicted to be around 50 years, as new technologies have produced components that are predicted to last significantly longer. When this increased lifespan is considered, offshore wind farms become comparable to their onshore counterparts (Krohn 2003).

Cost comparison

In light of these advances, wind turbines have become more cost effective and competitive with widely used and inexpensive fossil fuels. Since wind energy eliminates the need to purchase fuel, this additional cost also help to make wind energy more affordable. In addition to the comparable costs of fossil fuels and wind energy as energy sources, we also have to consider the externalities that occur as a result of these energy sources. The cost of environmental remediation due to the burning of fossil fuels is an external cost that must be figured into economic analyses, making wind energy even more cost competitive, if not cheaper (Marafia 2003). The costs of offshore wind production are expected to drop by another 50 percent in the next 10 years, thereby making it even more competitive (Pelc 2002).

IMPACTS ON FISHERIES

Landings in North Carolina accounted for 70% of the total weight landed in the southeastern United States in 2001. This portion of landings accounted for 51% of the total value of fisheries in the southeast. Several very important fisheries, such as the blue crab and summer flounder, have resulted in over 350 million dollars in revenue in the period from 1994 – 2001. This industry is a very important part of the socioeconomy of the state, employing over 570 people in 2001 and producing over $144 million (Bianchi 2003). Any potential impacts of a wind facility must be seriously considered before construction in order to protect those who depend on the fishing industry.

Historically, landings in North Carolina have gone through fluctuations. These fluctuations can be due to ecological changes such as habitat destruction, which can be due to hurricanes and nor' easters; improvement of habitat and/or water quality; or other alterations in community structure due to both natural and anthropogenic occurrences

(Bianchi 2003). Figure 15 shows the fluctuations in statewide commercial landings from 1972–2001.

These landings are comprised of two categories of fisheries, finfish and shellfish. Finfish are considered any fish that have fins, including flounders, sharks, and tuna. Shellfish fisheries include all bivalves, such as clams and oysters, as well as crustaceans and other finless species. Eight major gear types accounted for the majority of landings between 1994 and 2001. These gears include purse seines, pots, gill nets, trawls, pound nets, haul seines, longlines, and rod and reel (Bianchi 2003). The percentages of landings from 1994-2001 acquired by each of these gear types is shown in Table 3, along with the potential for a wind field to interfere with such gear, as is detailed below.

Towed fishing gear such as purse seines, gill nets, trawls, and longlines may be negatively impacted by a wind facility, as the presence of turbines will restrict their navigation and ability to use large towed gear. In most situations, a 500 m safety zone is implemented around each structure, creating obstacles to fishermen (Byrne O Cleirigh Ltd 2000). However, stationary fishing gear and those used in close proximity to shore will not be directly negatively impacted.

Impacted Gears

Gill nets, while outlawed in several states, are still legal in North Carolina. These nets are anchored at both ends and sometimes left for extended periods of time. Fish that swim into the net are trapped by their gills. A diagram of such a net is shown as Figure

16 (European Cetacean Bycatch Campaign 2004). Gill nets of up to 3000 yards (2743 m) are allowable in some parts of state waters (North Carolina Division of Marine Fisheries 1999). Gill nets of such length would not be feasible to use in a wind field, as turbines will not be spaced that far apart.

Trawls are fishing gear used to collect not only bottom dwelling species, but also those in the water column. Figure 17 displays a typical otter trawl, which disturbs bottom sediments so that organisms are trapped within the net (Stolpe 1998). These trawls are often very large and dragged along the seabed for considerable distances. The presence of wind turbines in an area where trawling usually occurs would inhibit the ability to use such a trawl net.

Longline fishing is a technique used to catch fish in open waters, where wind turbines would be located. This method utilizes a main fishing line up to 100 kilometers in length, with secondary lines branching off it, each set with hundreds or thousands of barbed, baited hooks (Humane Society 2004). Figure 18 is an illustration of such gear. Due to restricted navigation through a wind field and the large nature of longline fishing gear, fishermen using this technique will not be able to use waters surrounding wind turbines.

Rod and reel fishing occurs primarily through the recreational fishery in North Carolina. This industry could be impacted by inhibited navigation, however, the spacing of wind turbines would still allow for such fishing to occur.

Unaffected Gears

The purse seine fishery in North Carolina is restricted to the menhaden fishery, which is located less than a mile from shore (Orbach 2004). This close proximity to shore will ensure no inhibitions to the fishery due to the presence of wind turbines.

Crab pots are used primarily within the Pamlico and Albermarle sounds in the blue crab fishery. As these pots are stationary and located within the waters of the sound, wind turbines will have no affect on the blue crab fishery.

Pound nets are stationary gear types used in shallow water (12-20ft) along shore to catch live finfish species (Luisi 2004). As this gear is stationary and closer to shore than an offshore wind facility would be, this fishery will not be directly affected by its presence.

Haul seines are used in shallow coastal waters (within wading depth) to collect specimens (Foltz 2003). This proximity to shore eliminates any direct impacts from a wind facility.

IMPACTS ON TOURISM

Tourism is a vital part of the economy of the outer banks of North Carolina. Annually, over 44 million visitors vacation in North Carolina spending over 12 billion dollars (North Carolina Department of Commerce 2004). Tourists visiting the coast totaled 11 million in 1999 (TIA Travelscope 1999). The impacts of a wind farm in the waters off of the state would play a major role in whether or not such a project would be accepted, as so many depend on the tourism dollars being brought into the area.

A similar tourist locale, Cape Cod, is currently being faced with the decision to make use of their offshore wind resource. A study by the Beacon Hill Institute at Suffolk University conducted a study in 2003 to evaluate the impacts of such a facility on the economy of the area (Haughton et al 2003). A survey was conducted of 497 tourists and 501 home owners over an eight week period in the summer of 2003. Respondents were shown computer-generated images of the area with and without wind turbines. They were then questioned regarding their willingness to visit the cape if a wind facility were present. These valuations were used to discern the impact on the local tourism economy.

The survey found that while the windmills would attract additional tourists (0.6%), 3.2 % of respondents would spend an average of 2.9 days fewer on the cape if wind turbines were installed (Haughton et al 2003). 1.8% of respondents reported that they would no longer visit Cape Cod. Only 1.0% reported that they would extend their stay, staying an extra 13 days on average. By using these changes in time spent, the study was able to estimate an average reduction in spending by approximately $44.67 per respondent per year.

When willingness to pay for lodging was surveyed, 9.6% of respondents (who spend an average of 5.5 days per visit) would pay 48 dollars less per night and visit just as often. Those respondents who would visit less often (1.4%) would pay 100 dollars per night less for lodging. 1.1% of visitors would be willing to pay an additional 10 per night, on average. By using these responses, an estimation of the reduction of spending for lodging was calculate to be $30.48.

The summation of these two effects results in an average decrease in spending of $75.15 per respondent per year.

If these figures are applied to the average number of tourists that visit the coast of North Carolina each year (11 million), it appears that a significant decrease in tourism dollars coming into the state would occur with the construction of a wind facility. However, of the 11 million visitors to the coast in 1999, only 24% required nightly lodging in a hotel, motel, or bed and breakfast (TIA Travelscope 1999). 68% of visitors either stayed in their private home or condo or did not stay overnight.   This would make the impact of a wind farm on lodging dollars much less than expected. However, there may still be losses in other sectors due to a potential reduction in the number of visitors.

IMPACTS ON LAND VALUES

The above-mentioned Cape Cod survey also estimated expected changes in land property values if an offshore wind farm were constructed. Opinions of homeowners in regards to aesthetic changes due to windmills are shown in Table 4. Homeowners expect the project to decrease property values by 4.0%. Those homeowners on the waterfront expect to lose 10.9% of its value (Haughton et al 2003).

If property values decrease, property tax revenues will also fall. This will reduce tax monies being funneled back into local communities. This reduction in funding would cause communities to raise tax rates in order to compensate for the loss (Haughton et al 2003).

Local realtors were surveyed to validate the opinions of homeowners. 45 real estate professionals in the area of Nantucket Sound responded to the survey. 49% of realtors expect property values to fall, however, 38 % of those realtors expect no impact on the local real estate market (Haughton et al 2003).

Impacts on the real estate market and property values in North Carolina are unknown, however, there is the potential for the area to see a decrease in revenue due to the construction of an offshore wind energy development.

IX. PUBLIC PERCEPTION

The construction of offshore wind facilities is highly controversial, as many of the impacts are not yet known due to the recent development of the technology. The use of a public asset, such as the waters off of the coast of North Carolina, is a process that must be supported by the public in order to succeed. A similar project proposed in the Nantucket sound has come upon strong opposition to the use of a public resource. This public outcry has slowed the process and questions whether or not such a use is reasonable (Haughton et al 2003). A similar outcry could be expected in coastal North Carolina.

PURPOSE

The purpose of this analysis is to discern how residents of coastal North Carolina perceive wind energy facilities and how that perception might affect the development of such a facility in the region. It has been found that over 42 percent of Americans are in favor of increasing sources of renewable energy, however the "Not In My Backyard" or NIMBY syndrome can negate this enthusiasm (Damborg 2003). Due to this syndrome and the overwhelming and largely publicized opposition to a similar project in the Nantucket Sound, I hypothesize that residents of coastal North Carolina will have an overall negative opinion of wind turbines.

METHODS

In order to discern public opinion on a subject that may not be common knowledge to all residents of the region, a content analysis of newspapers articles regarding wind energy was conducted. Newspapers selected to be included in the analysis originated in coastal counties, as designated by CAMA (see Figure 19) and were available electronically, either through their own website, or through lexisnexis.com. Also included in the analysis were articles acquired from The Associated Press State and Local Wire through lexisnexis.com. Newspapers used are shown in Table 5.

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Articles published within the last five years were located using a predetermined sequence of search terms. Those search terms are included as Table 5 . All results were analyzed for content, and only articles which specifically referenced utilizing wind to produce electricity were included. Forty-two articles met those standards and were included in the content analysis. Each article was formatted and imported into NVivo, a qualitative analysis program, for coding.

A coding scheme was developed prior to coding including the variables shown in Table 6. During coding it became evident that the current situation in Iraq may have some effect on the perception of wind energy; therefore an additional category (War/Foreign Dependence) was added to analyze that relationship, if any. Articles were coded using NVivo. Statements that fit into a broad category (eg., General) but had no evident demonstration of a positive or negative position were categorized into that broad category. If a statement fit into more than one category, it was coded as both.

ANALYSIS

The coded articles were analyzed using NVivo and Microsoft Excel in order to better quantify the number and frequency of references made regarding wind energy in each category. Analyses were conducted on the entire collection of articles as well as on a subset of documents that included only those editorials written by local residents. This was done primarily to discern whether the general public had a different opinion than that being portrayed by the media.

The percentage of the working set of documents (42) coded by each category was calculated. The percentage of total characters (130,358) of all documents coded by each category was also calculated in order to account for the length of statements coded, as some statements were significantly longer than others.

A similar analysis was conducted using only those dichotomous (positive and negative) variables that directly referenced wind energy (general, environmental, economic, and aesthetics). The percentage of all documents coded into each category was calculated. In order to better decipher positive and negative opinions, positive and negative references were summed and compared over both sets of documents. The percentage of total characters coded by each positive and negative category was calculated and graphed for both the editorials and all documents. A t-test was run to analyze whether the difference in characters coded (negative and positive) was statistically significant.

RESULTS

Analysis of the data showed that the category that included the most documents coded was the "General" category (62% of documents), which included statements that showed no clear viewpoint of pessimism or optimism towards wind power. 55 percent of the articles were coded into the category of general positive statements about wind energy. The negative category that included the most documents was "Economic-negative" which included 52% of all documents. Positive environmental impacts were referenced in 33 % of documents while 31% of documents referenced general negative statements and negative statements regarding our current use and/or energy system. These results are shown in Figure 20.

Percentage of total characters coded by each category was also calculated to account for the length of statements coded, if relevant. That analysis did slightly adjust the ranking of most referenced categories. Percentages of total characters coded are shown in Figure 21 while changes in rank are depicted in Figure 22. "General" maintained the most references with 4.70 % of all characters. 3.51% of characters were coded as "Economic-negative" while 3.18% of characters were coded as "General-Positive." In the initial analysis, it appeared that more documents were coded as "General-Positive." 2.45% of characters were coded as negative statements towards the current usage of energy, while 1.97% of characters were coded as negative regarding wind energy in general.

The percentage of total characters coded for each of the dichotomous categories was calculated. Positive references accounted for 5.51% of all characters coded, while negative references accounted for 7.81% of all characters coded within the entire set of documents. A t-test was conducted to determine whether this difference was significant. We were unable to reject the hypothesis that the two means were the same with a probability of 0.005. Therefore, we cannot say that there is a significant tendency toward negative opinions.

The percentage of total characters coded for each of the dichotomous categories in the subset of editorials was also calculated. Positive references accounted for 4.85% of total characters coded, while negative references accounted for 8.86% of characters coded. This difference was also unable to be proven as statistically significant with a probability of 0.005.

Sentiments regarding our current usage of energy or the system that regulates that usage were expressed in 32% of documents. Positive references were only coded in 2% of total documents, while negative statements were coded in 31%. 0.09% of all characters were coded as supporting our current usage/system while 2.45% of total characters were coded as having finding our current system objectionable.

Statements regarding the war in Iraq or our foreign dependence on oil were coded in 14% of documents, resulting in 1.73% of total characters. This amount of characters is greater than the number of characters coded into any of the environmental categories (negative or positive).

DISCUSSION

The public can often have a dramatic impact on local politics and development, however, the source of their strong opinions is not always founded in factual knowledge. We, as scientists, sometimes have to rely on the media communicating scientific facts and occurrences to the public in a clear and straightforward way. The media is typically the way that most Americans receive their information regarding energy projects, specifically wind energy (Damborg 2003). The results of this analysis show that the data were unable to confirm a difference between the number of positive and negative references made regarding wind energy, therefore, is appears the public is getting an impartial and unbiased introduction to wind power and the benefits and drawbacks that have been associated with it. The largest proportion of characters and documents made specific references to wind energy in general, not displaying a clear attitude as to whether it is a positive or negative venture.

The high initial costs of these wind facilities seem to be the negative point most stressed by the media. This short-sided opinion could be one of the main reasons wind power has seen so much opposition. In the long run, wind energy has the potential to be a cost effective investment, however, the overwhelming initial costs can be discouraging.

Our current usage and the regulation of the current energy system is clearly viewed in a negative light in the region. This could be a reflection on the current administration or merely a sign that the public is aware of the predicament we have gotten into by relying so heavily on nonrenewable sources of energy. This indicates that residents of coastal North Carolina may be more likely to support an offshore wind farm as a catalyst to change in energy policy.

The current conflict in Iraq and our dependency on foreign oil obviously has made an impact on how we think about energy and energy policy, as it was referenced more often than several other categories coded. This implies that Americans, and more specifically residents of North Carolina are currently more concerned about our energy use's effect on war and foreign politics than the environment.

CONCLUSIONS

Contrary to the original hypothesis, it appears that residents of coastal North Carolina do not have an overall negative opinion of wind farms. It appears that the media portrays the advantages and disadvantages in an unbiased way that allows the public to make their own decisions. This, however, does not indicate that local residents will be in support of such a facility. In order to determine willingness, a survey of coastal residents should be conducted.

X. CONCLUSIONS

This study clearly describes some of the many potential impacts of an offshore wind farm in North Carolina. While many of the potential impacts are positive, there are concerns that stem from the newness of this technology that has not been in operation long enough to have substantial data sources.

The potential for wind energy to reduce our dependence on fossil fuels and foreign oil alone makes this source of energy a good choice for the future. While studies have been conducted that show potential detrimental environmental impacts, there is also the possibility that ecological communities could benefit from such a project. It appears that affects on hydrologic regimes and geologic features will be negligible. The political system surrounding the approval of an offshore wind facility will prove to be problematic, as there is no clear jurisdictional body. Economically, the largest impact will be the initial startup costs of the installation process. Public perception of the project by local residents could have a great effect on the approval of an offshore wind energy project. In order to ensure public support, education and public involvement is crucial. Additional studies into the potential impacts should be conducted as well as monitoring of such impacts if such a project is proposed or approved.

The potential benefits seem to outweigh the unknown disadvantages of offshore wind energy. I believe that it is a feasible energy source for the future of coastal North Carolina.

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16 U.S.C. §470 et seq.

16 U.S.C. §661

16 U.S.C. §703-712

16 U.S.C. §1361 et seq.

16 U.S.C. §1456 et seq.

16 U.S.C. §1531

33 U.S.C. §401

33 U.S.C. §1251 et seq.

43 U.S.C. §39

42 U.S.C. §4341

14 C.F.R. § 77

33 C.F.R. Parts 62,64,66

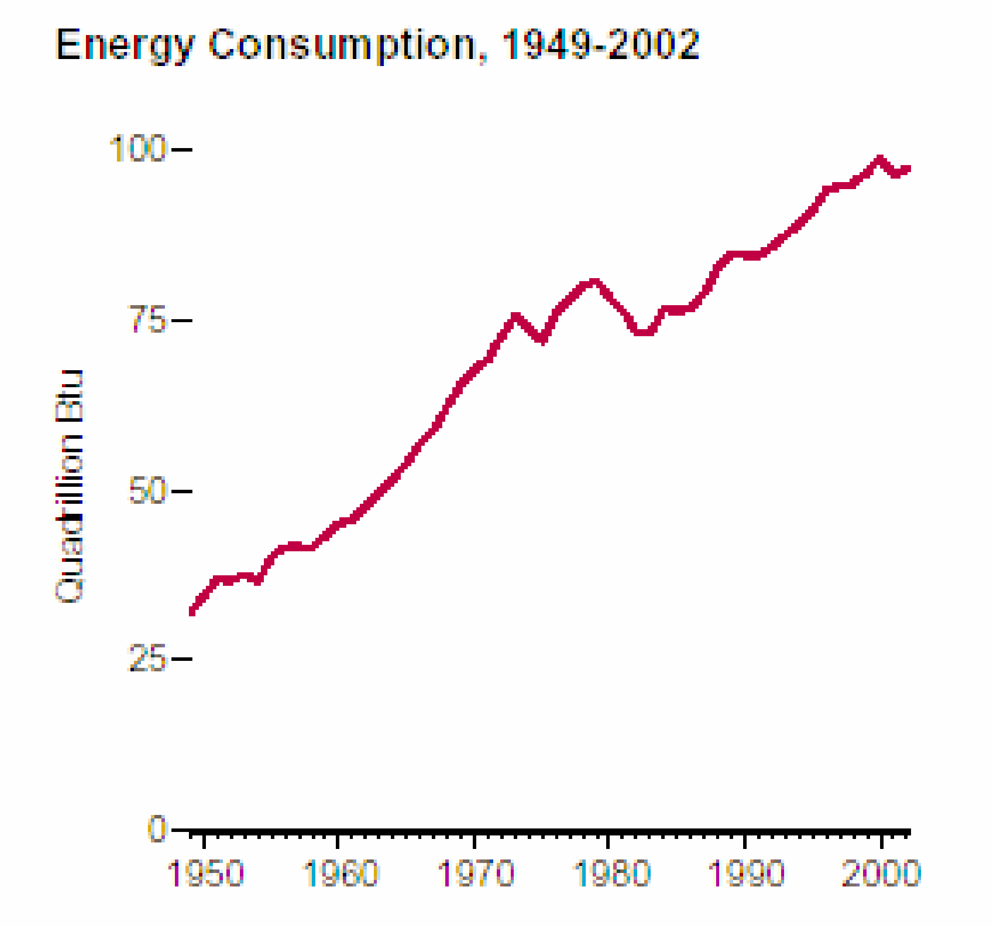
P.L. 94-265

North Carolina General Statutes

G.S. 113A-1 et seq.

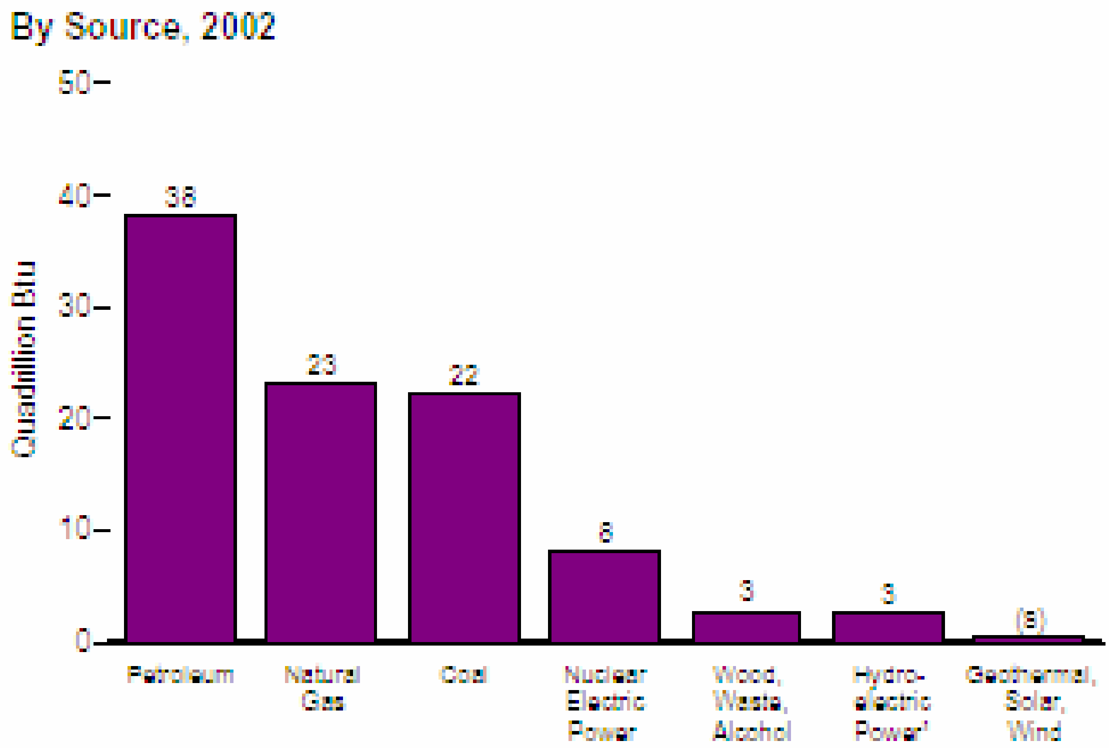
G.S. § 113A-100 et seq.

Figure 1- Energy consumption in the United States from 1949-2002 in Quadrillion Btu



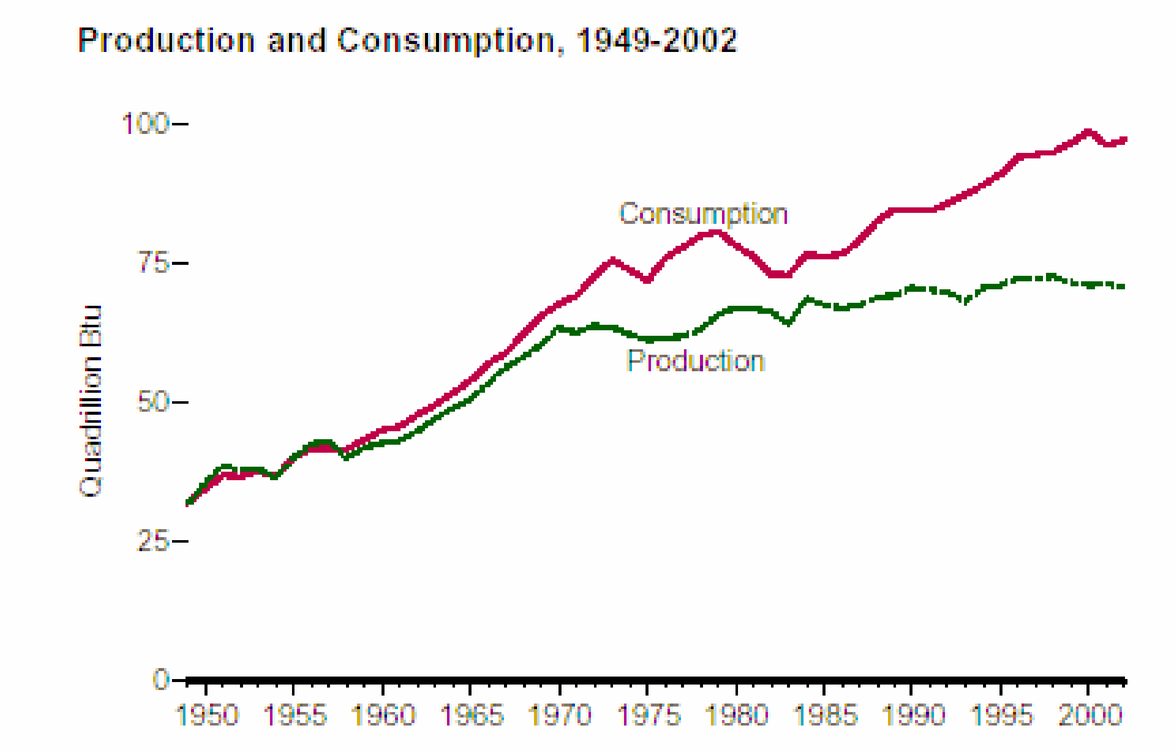
(NREL 2004)

Figure 2 - Energy consumption in the United States by source in 2002



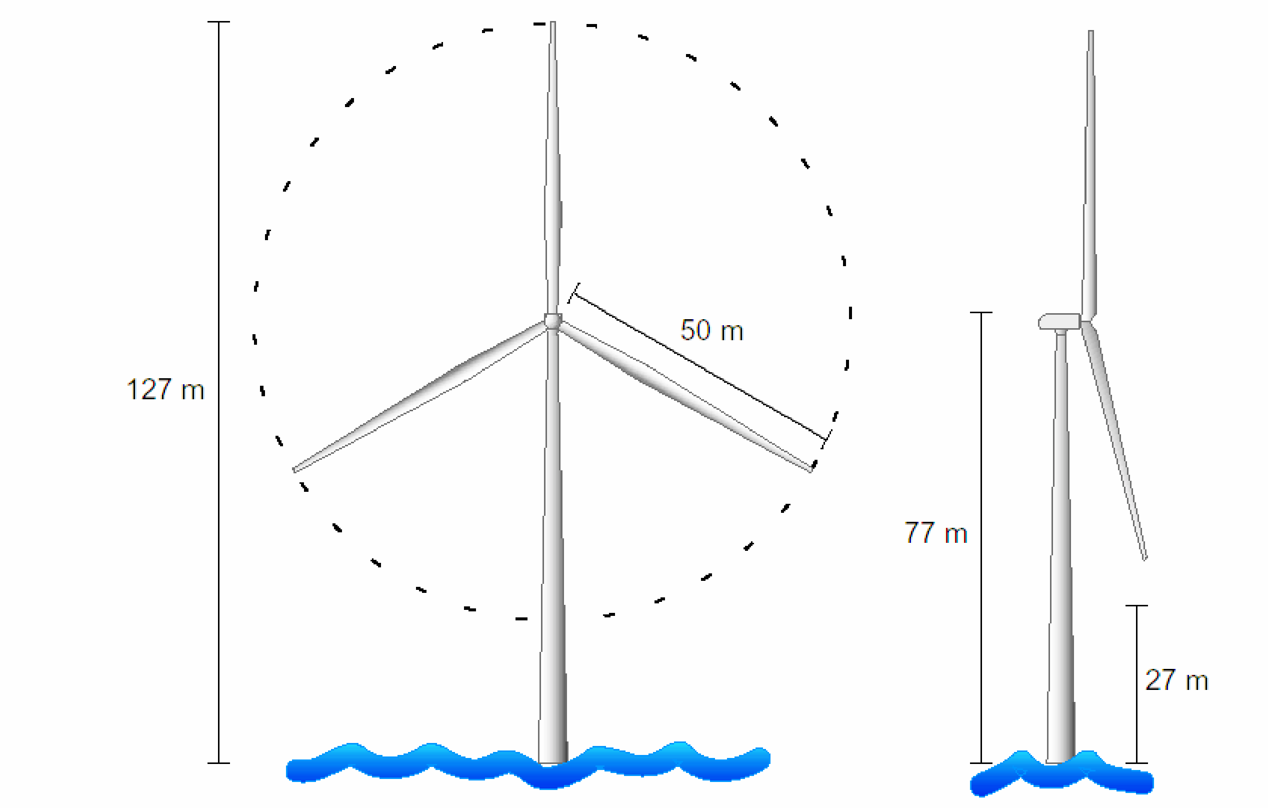
(NREL 2004)

Figure 3 - Energy production and consumption in the United States 1949-2002



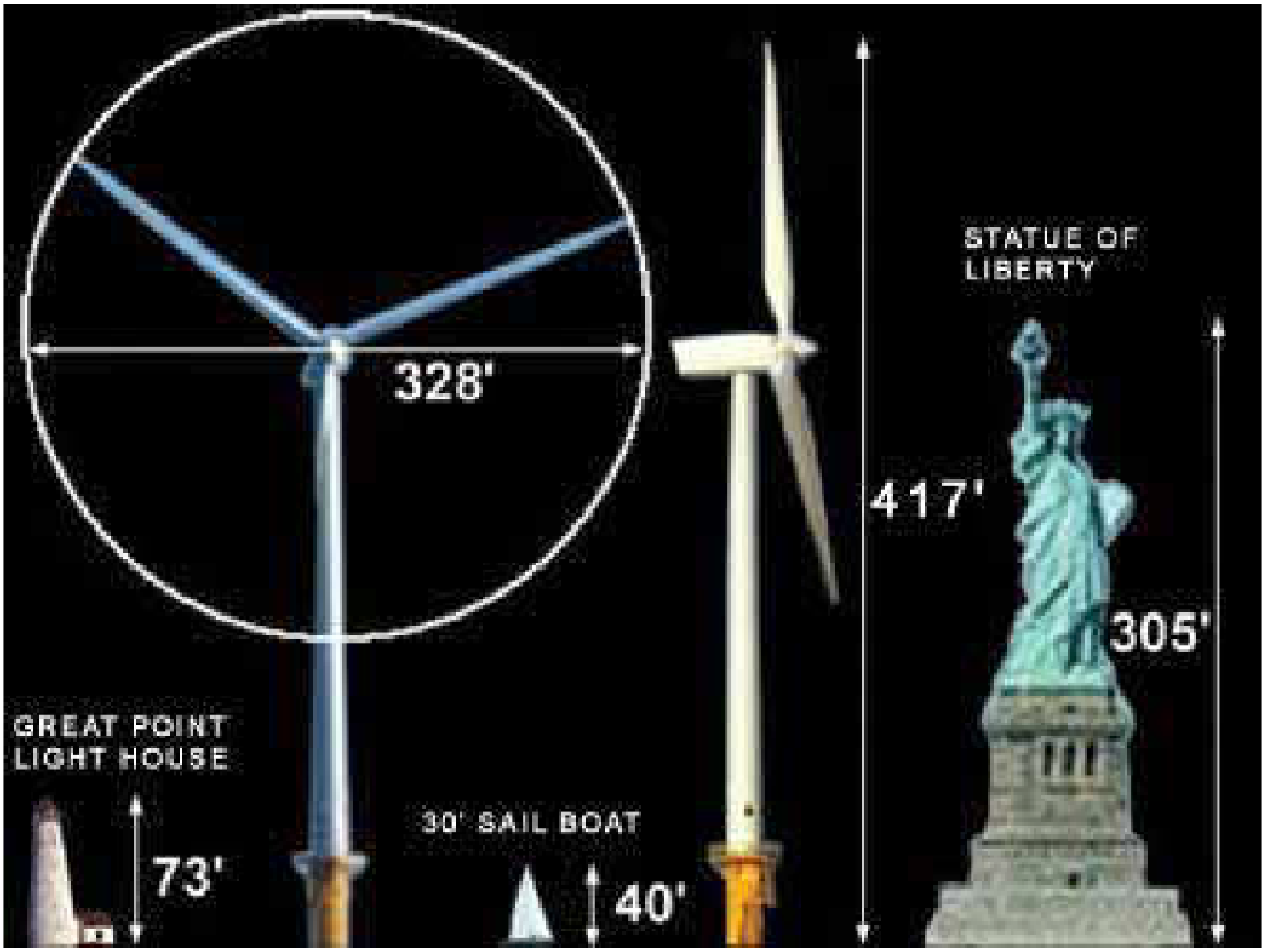
(NREL 2004)

Figure 4 - Dimensions of the 3.5 MW GE offshore turbine



(GE Wind Energy 2003)

Figure 5 - Dimensions of a typical offshore wind turbine in comparison to other coastal landmarks



(Tingley 2003)

Figure 6 - Wind resource map of North Carolina at 50 m above sea surface

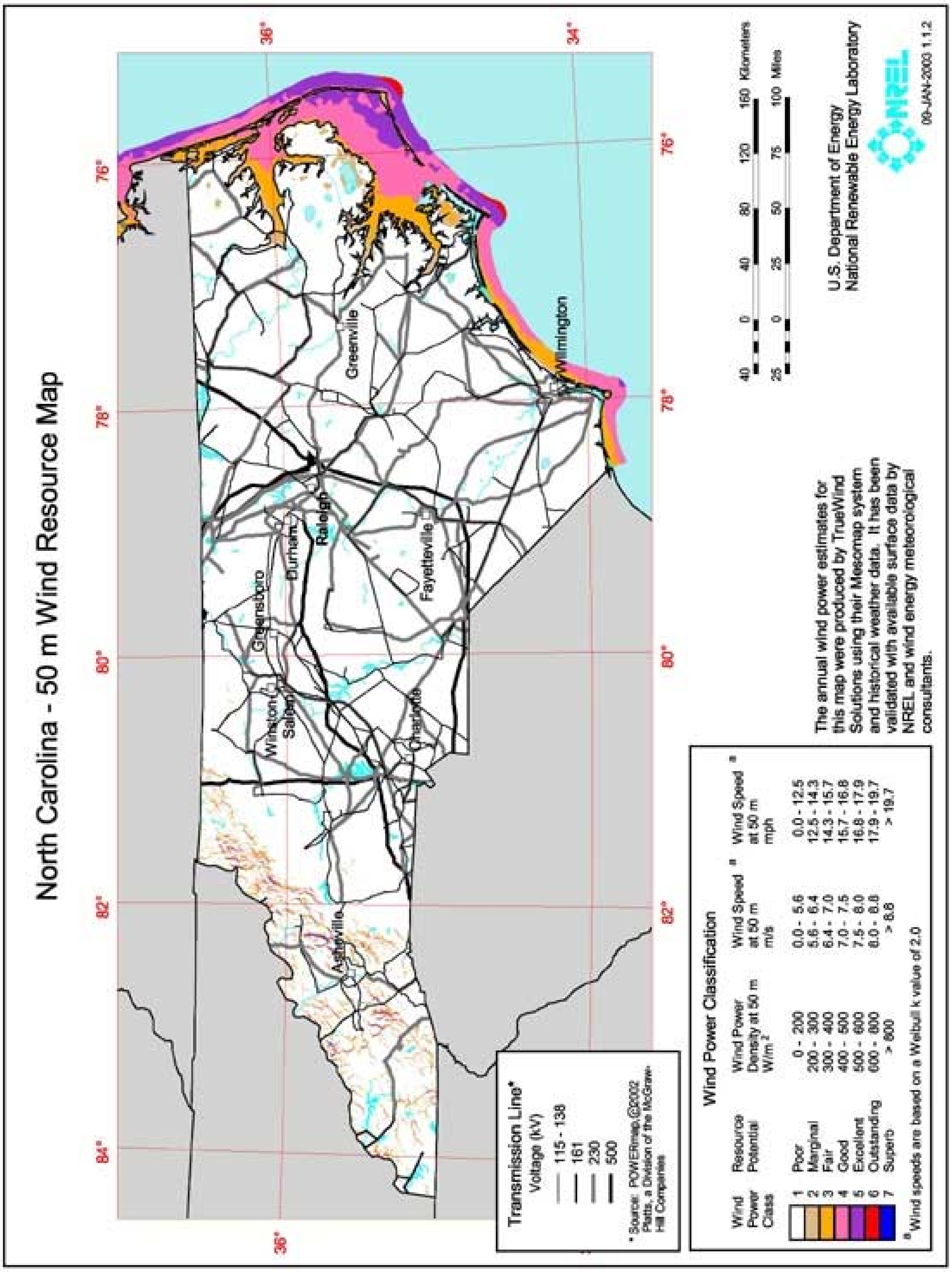


Figure 7 - Schematic of an offshore wind turbine located within a North Carolina sound

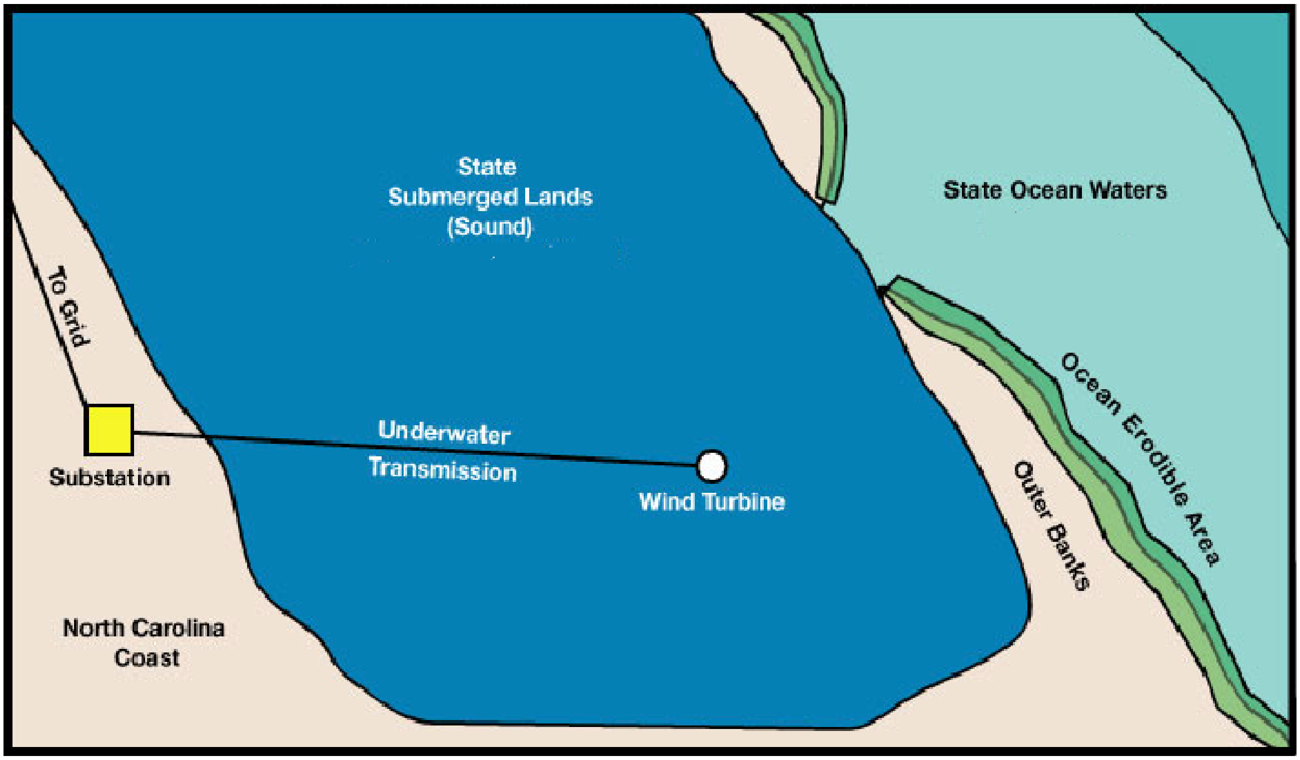


Figure 8 - Schematic of an offshore wind turbine located on the continental shelf

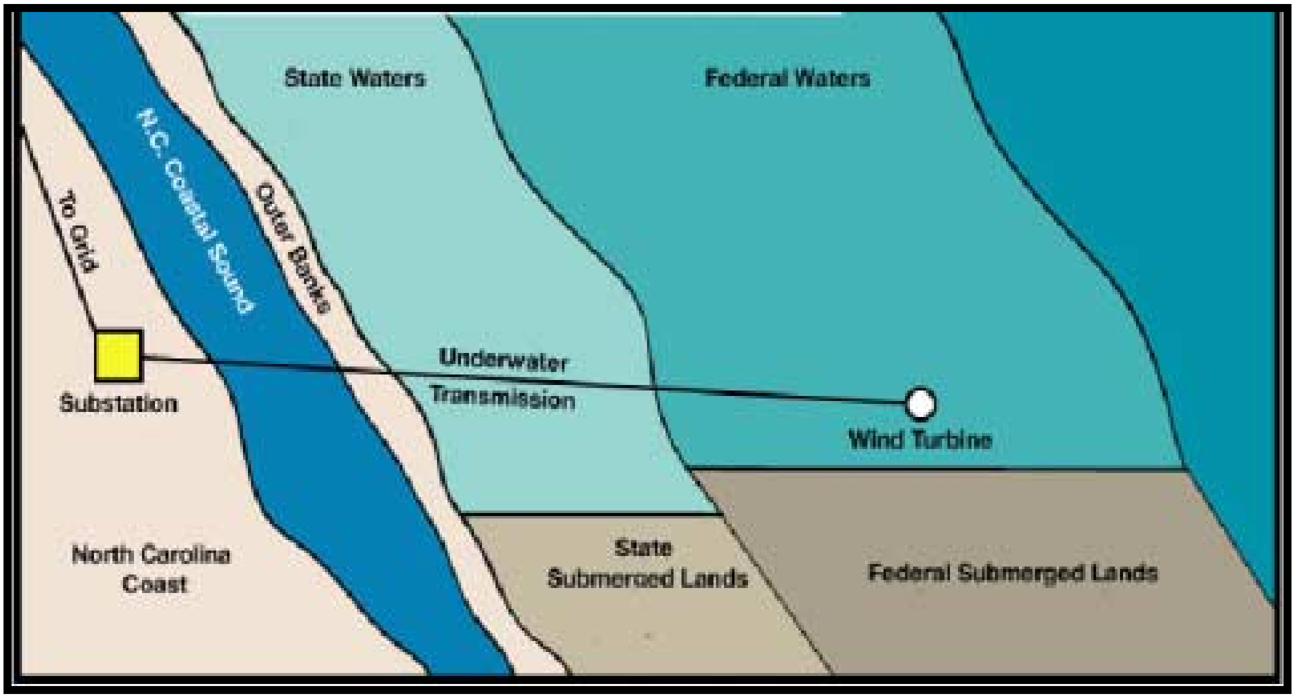
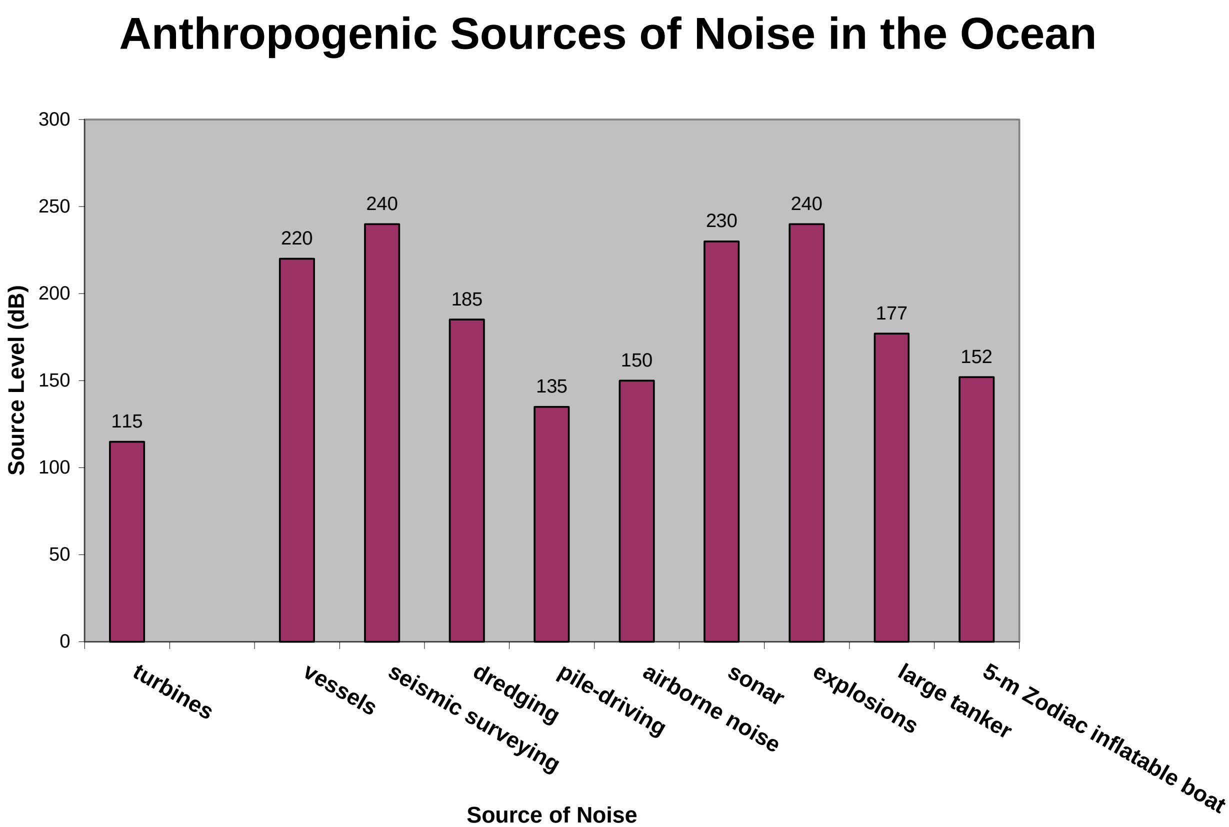


Figure 9 - Source levels of anthropogenic sources of noise in the ocean (dB)



(Adapted from NRC 2003)

Figure 10 - Environmental impacts associated with laying of cables and benthic communities

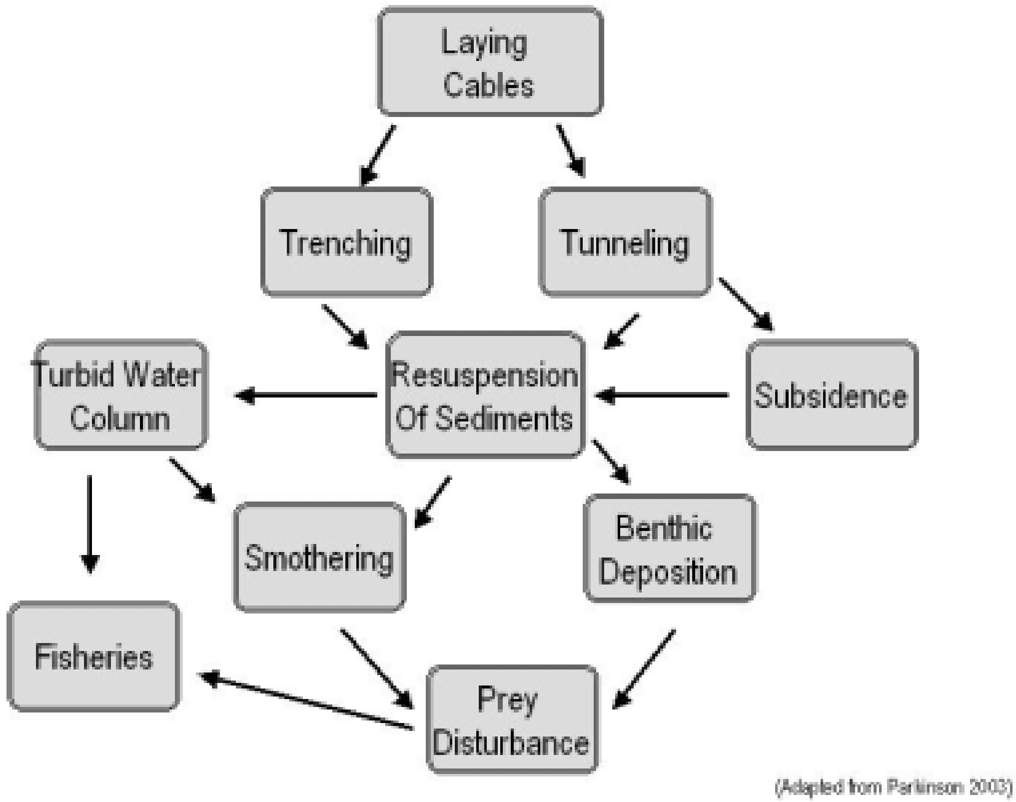
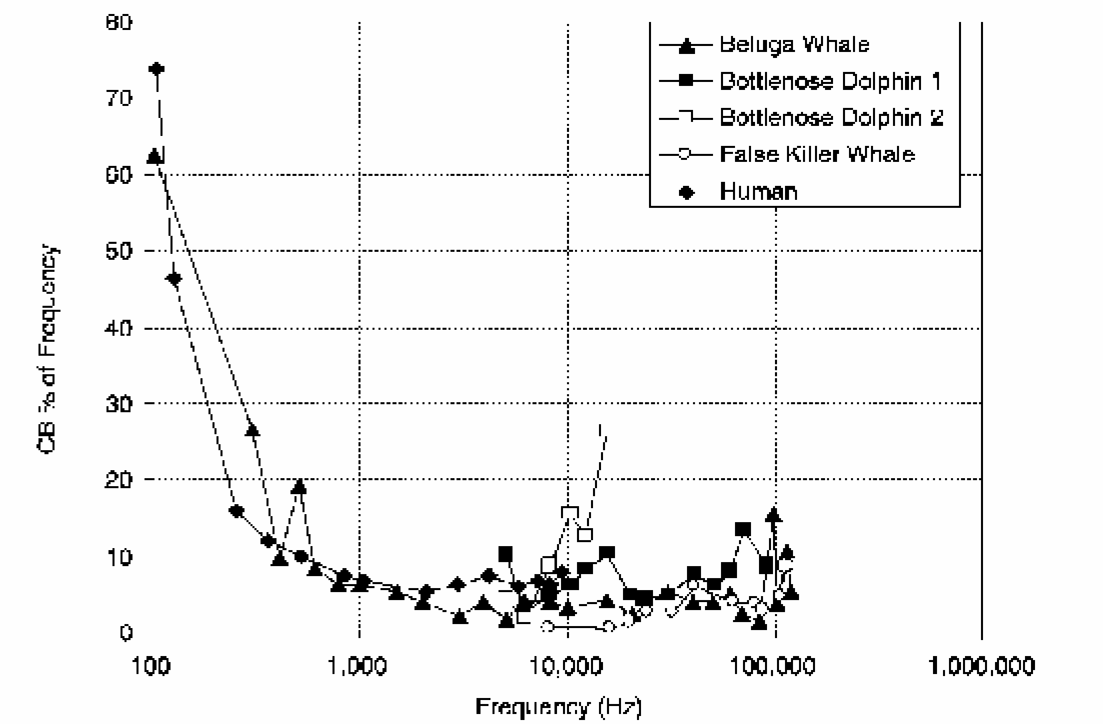
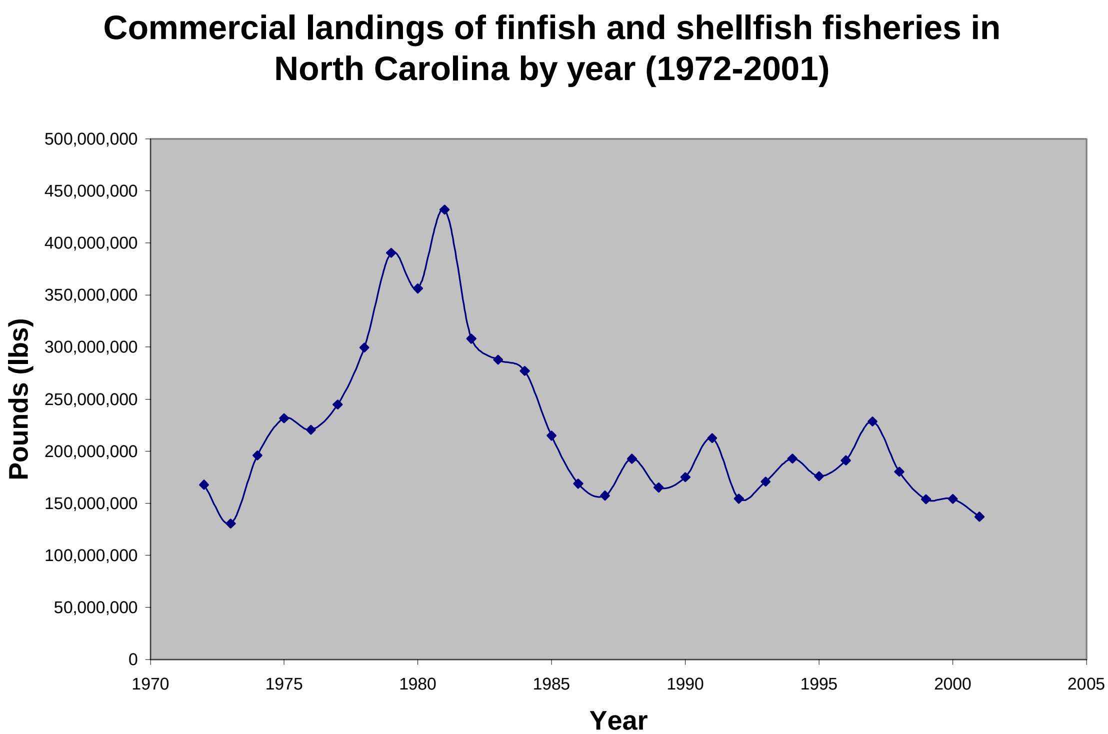


Figure 11 - Critical frequencies of odontocetes as a proportion of frequency vs. frequency



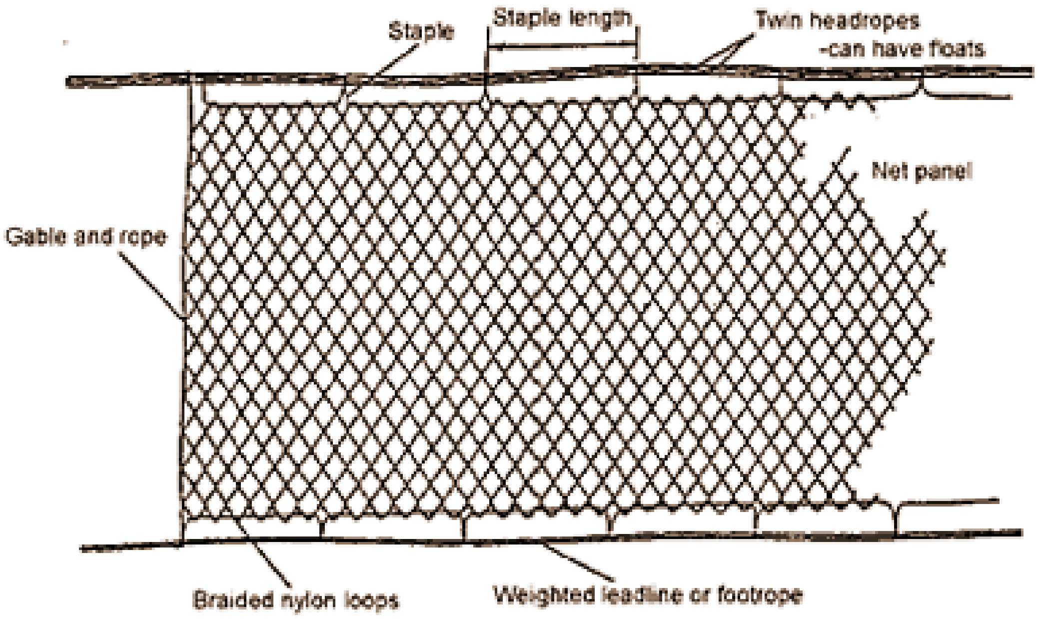
(NRC 2003)

Figure 12 - Commercial landings of fisheries in North Carolina in pounds from 1972-2001



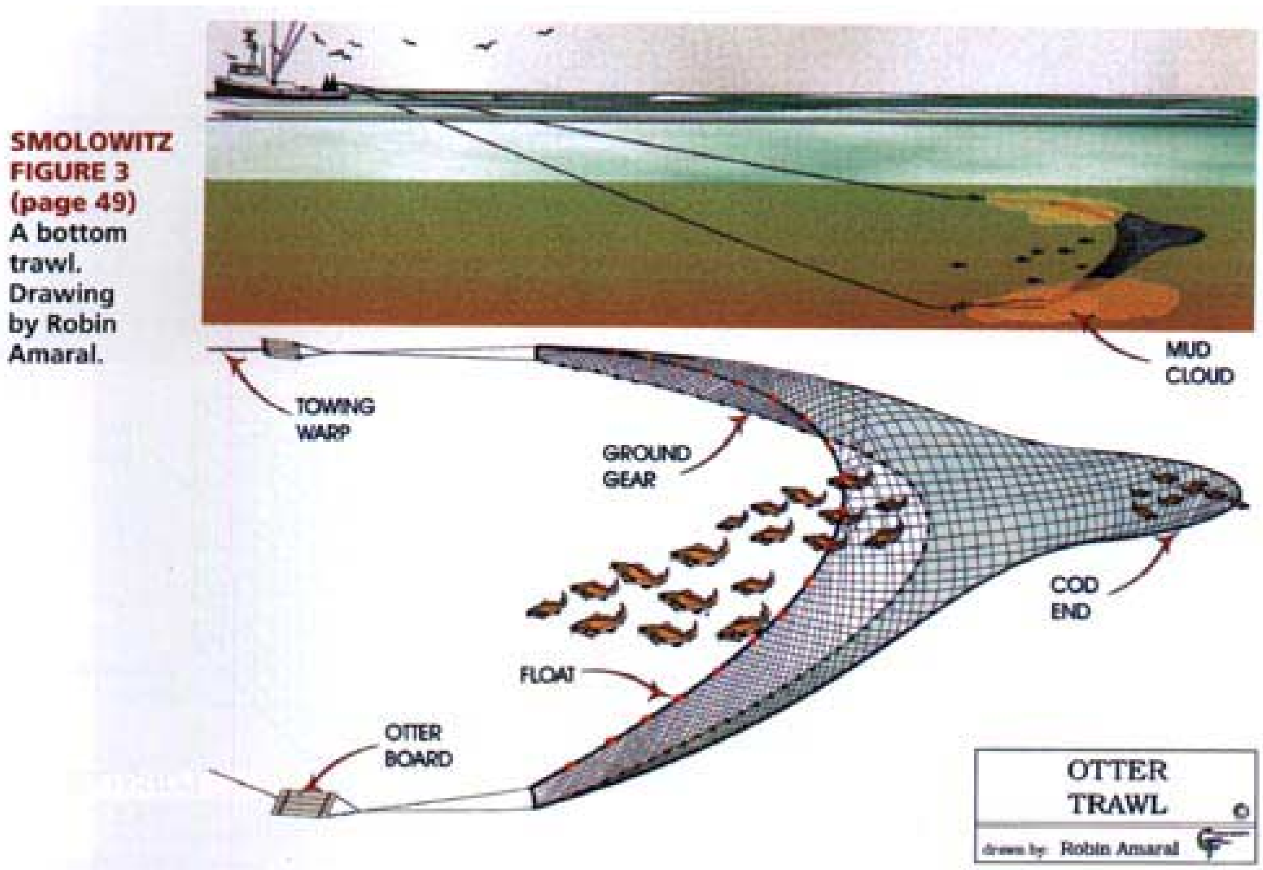
(Adapted from Bianchi 2003)

Figure 13 - Schematic of a typical gill net



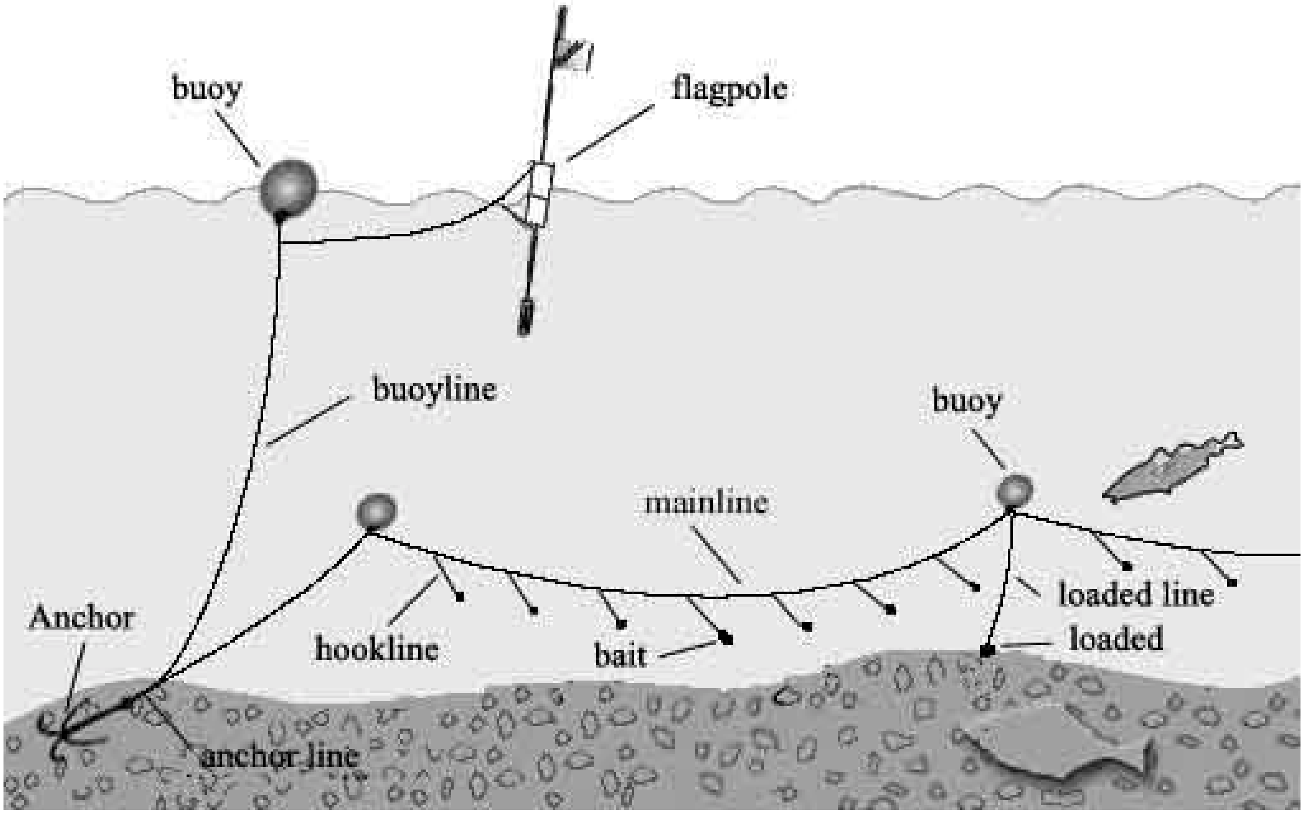
(ECBC 2004)

Figure 14 - Schematic of a typical otter trawl



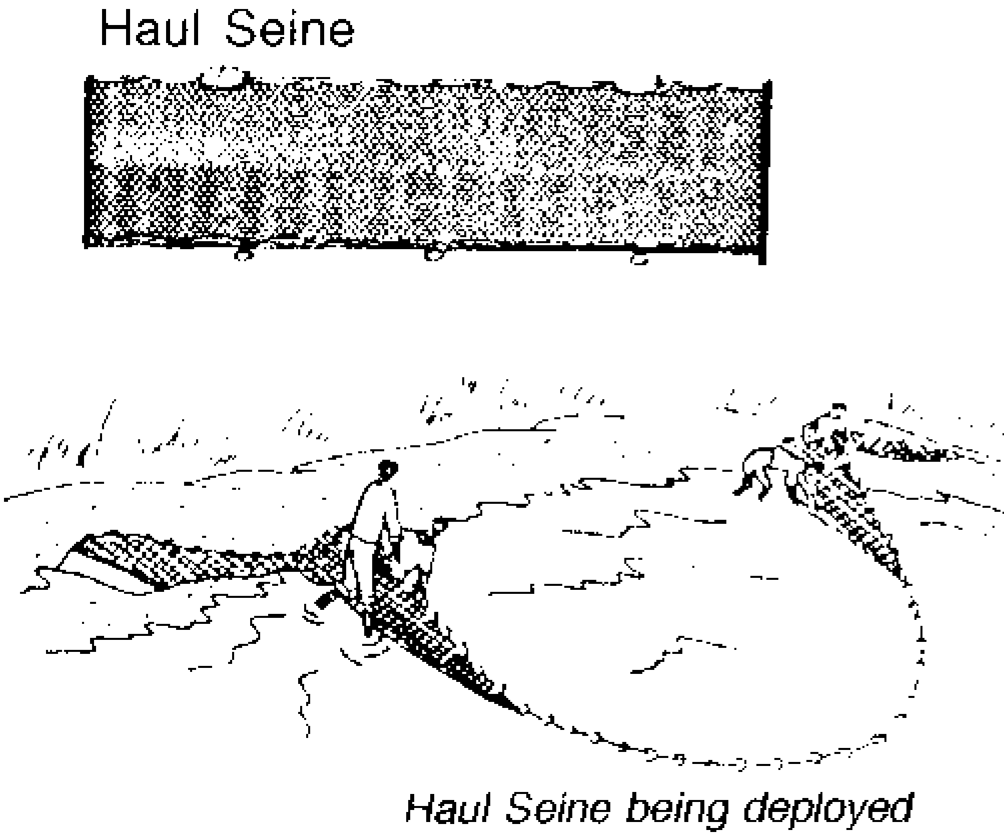
(Stolpe 1998)

Figure 15 - Schematic of a typical longline



(Humane Society 2004)

Figure 16 - Schematic of a typical haul seine



(Foltz 2003)

Figure 17 - Map of coastal North Carolina counties as designated by the Coastal Areas Managment Act

Coastal Counties Covered Under the Coastal Area Management Act (CAMA)

If a project is in one of the following 20 counties and is located along the state's rivers, sounds or the Atlantic Ocean, a permit may be required under CAMA:

Beaufort
Bertie
Brunswick
Camden
Carteret
Chowan
Craven
Currituck
Dare
Gates
Hertford
Hyde
New Hanover
Onslow
Pamlico
Pasquotank
Pender
Perquimans
Tyrrell
Washington

Source: CAMA Handbook for Development in Coastal North Carolina
http://dcm2.enr.state.nc.us/handbook/handbook.htm

Figure 18 - Percentage of total documents coded by each category for all articles and editorials

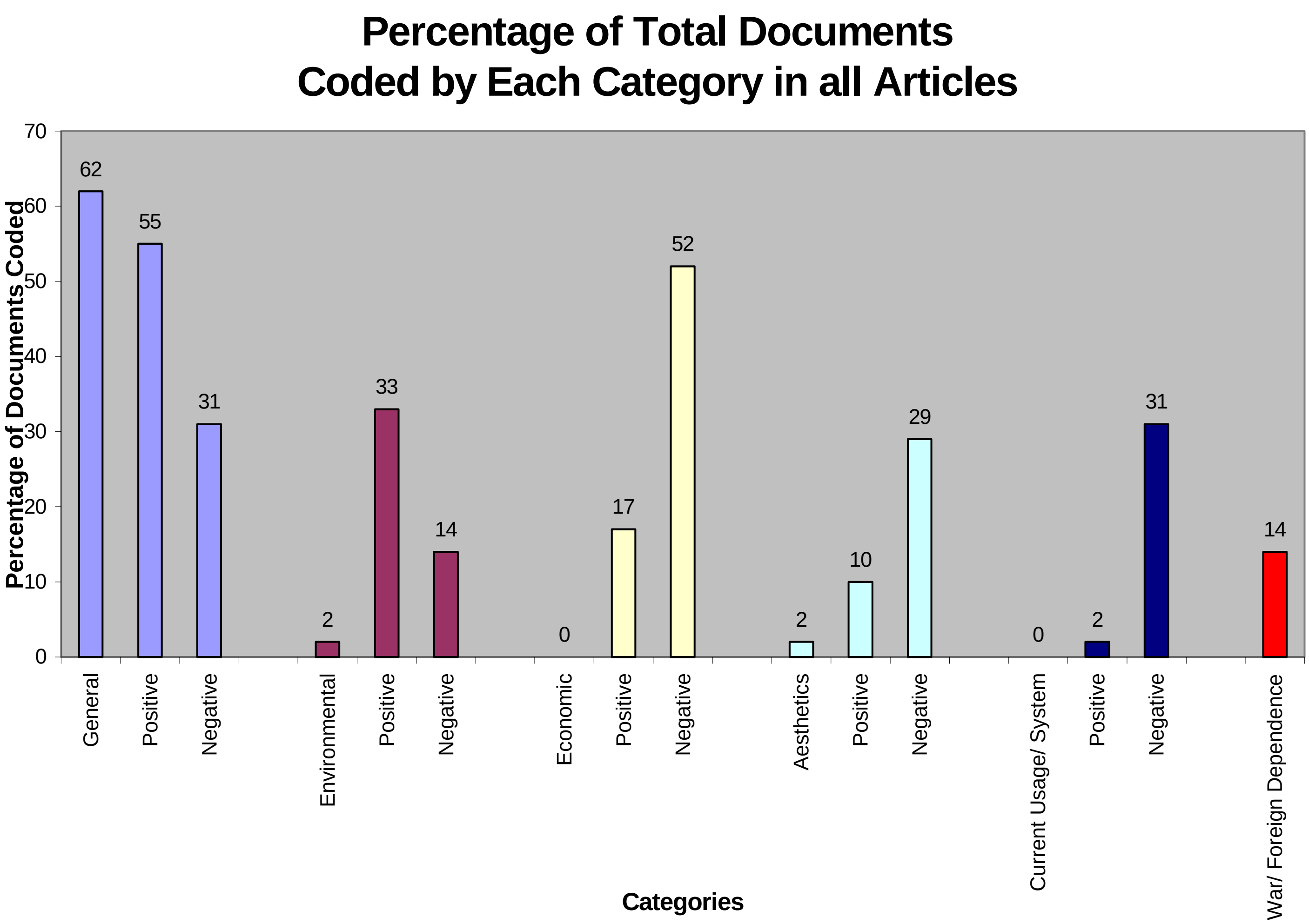


Figure 19 - Percentage of total characters coded by each category in all articles and editorials

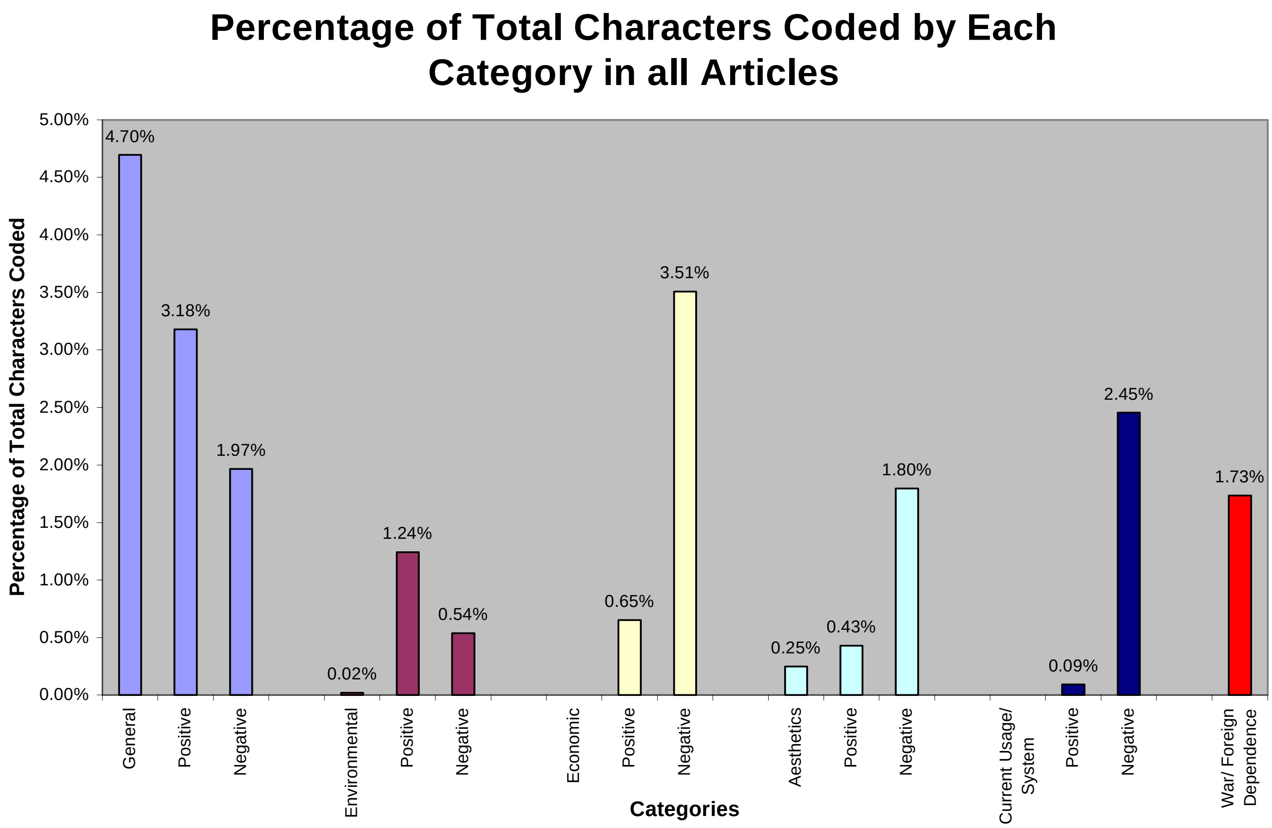


Figure 20 - Change in rank upon change in analysis method from percentage of documents to percentage of characters

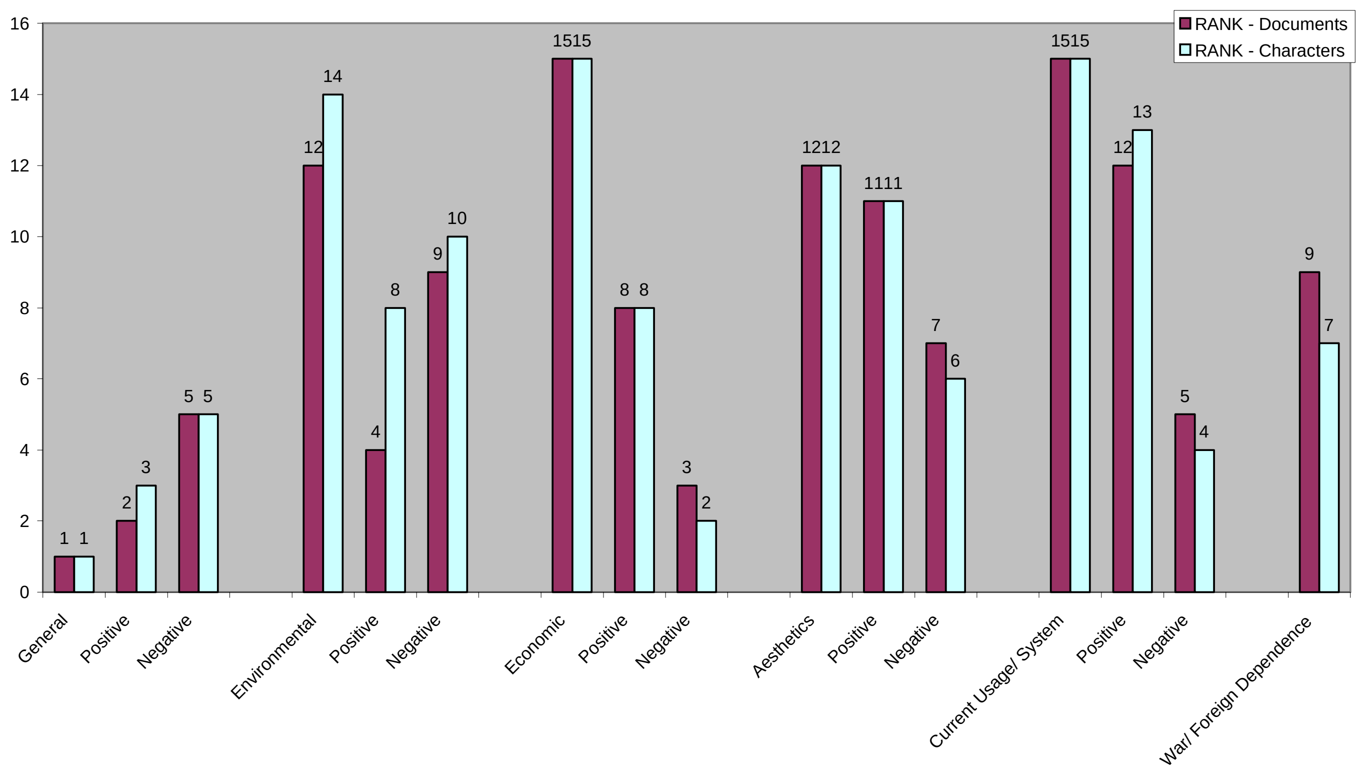


Table 1 - Sources of anthropogenic noise in the ocean: Frequency and source level

Anthropogenic noises	Frequency at highest level (Hz)	Source Level at Highest Level (dB)
vessels	10 Hz - 10 kHz	160-220
seismic surveying	10 - 120	>240
dredging		178-185
pile-driving	30 - 100 Hz	131-135
airborne noise	<100 Hz - 10 kHz	~150
sonar		~230
explosions	<20	>240
large tanker	125	177
5-m Zodiac inflatable boat	6300	152

Table 2 - Organisms of concern in North Carolina waters hearing and most sensitive ranges

Organisms of Concern	Hearing Frequency Range (Hz)	Most Sensitive Hearing Frequency (Hz)	Examples
Sea Turtles	200 - 700	400	Loggerhead, green, leatherback
Marine Mammals	10 - 200 kHz	variable	
Mysticetes	10 - 30,000 Hz*		Humpback whale, balaenid whales
Balaenids	15 Hz - 20 kHz	20 Hz - 2 kHz	Fin whale, Sei whale, Minke whale
Odontocetes	200 - 200,000	16 - 120 kHz	Dolphins, toothed whales, and porpoises

*Not directly tested - only a prediction

Table 3 - Percentage of state landings (2002) per gear type

Gear Type	% pounds	% pounds (excluding menhaden fishery)	Restricted by turbines?	How?
Purse seine	37.27%	-	No	Within 1 mile of shore
Pots	28.52%	45.46%	No	Located within sound
Gill nets	14.19%	22.63%	Yes	Navigation restricted
Trawls	11.91%	18.99%	Yes	Navigation restricted
Pound nets	1.74%	2.78%	No	Stationary
Haul seines	1.56%	2.49%	No	Used close to shore
Longlines	1.56%	2.48%	Yes	Navigation restricted
Rod and reel	1.24%	1.98%	Yes	Navigation restricted
Other nets	0.35%	0.56%		
Other gears	1.64%	2.62%		
Total	100.00%	100.00%		

Table 4 - Opinions of tourists and home owners on Cape Cod regarding wind turbines

	Percent of respondents	
The windmills…	Tourists	Home Owners
"improve the view a lot"	2.5	0.6
"improve the view slightly"	3.5	1.8
"neither improve or lessen the view"	32.3	27.5
"worsen the view slightly"	43	32.2
"worsen the view a lot"	18.7	37.7
Respondents	497	501

(Adapted from Haughton et al 2003)

Table 5- Search terms and coastal newspapers used for content analysis

Search terms
offshore wind energy
wind energy
wind turbine
wind
-hurricane
renewable energy
energy
wind farm

Sources
Associated Press State and Local Wire (lexisnexis.com)
Washington Daily News, Washington
Wilmington Morning Star, Wilmington
The Seahawk, UNC Wilmington
The Daily Advance, Elizabeth City
The Daily News, Jacksonville
Outer Banks Sentinel, Nags Head
Sun Journal, New Bern
Roanoke-Chowan Herald, Ahoskie

Table 6 - Coding variables used in content analysis

Variables	
General	
	Positive
	Negative
Environmental	
	Positive
	Negative
Economic	
	Positive
	Negative
Aesthetics	
	Positive
	Negative
Current Usage/ System	
	Positive
	Negative
War/ Foreign Dependence	