Coastal defences versus coastal ecosystems: a regional appraisal

Abstract

Societal concern (both real and imagined) over coastal erosion and flooding, often results in construction of sea defences to protect property. Sea defences are, however, damaging to the natural ecosystems that provide quantifiable ecosystem services to the human population. Protection of property is, however, the most common driving force behind construction of sea defences and the basis of any associated economic appraisals. Protection of the coastal ecosystem (sedimentary, biological and chemical) while commonly implied in strategic documents (e.g. Habitats Directive 92/43/EEC, Water Framework Directive 2000/60/EC, OSPAR Convention), remain largely aspirational notions that currently have a much lower priority, or none at all, in sea defence decision-making. Under this anthropic view of coastal protection it is not surprising that defence structures proliferate. In many instances, shoreline armouring is considered on a case by case basis with little regard to the cumulative effects. This is true whether or not there is a strategic approach to coastal protection. In this paper the Northern Ireland coast is used as a case study to document the nature and extent of shoreline protection structures associated with sandy beaches. The nature and extent of sea defence structures were documented from a low-level oblique helicopter-based photographic survey and mapped in a GIS. The implications for the coastal ecosystem are considered. A sustainable approach to shoreline management demands a balance between protection of property and preservation of coastal ecosystem services.

1. Introduction

Coastal erosion and flooding is often cited as posing a risk to built infrastructure. This is a legitimate societal concern which does of course highlight that the infrastructure is located in a hazardous location. For many types of infrastructure (harbours, power plants, ports etc.) this is unavoidable and is either tacitly accepted as an operational risk, and/or minimised by construction of defences. Many other examples of infrastructure, however, do not need to be built in coastal locations and the root of their problems with coastal flooding and erosion lie in poor contemporary land-use planning or are inherited from periods when the risks were less understood. In some such cases where levels of risk are very low and only extreme events with low recurrence intervals pose a threat, communities have learned to accept the risk: the costs of preventing a low frequency risk are prohibitive and thus it is regarded as acceptable to live with it. In others, defences of various sorts are constructed to protect property.

The perceived or real threat to infrastructure is, however, often the dominant or only concern considered in the societal response to flooding or erosion (Penning-Rowsell et al., 2012). Typical of contemporary societal views is the statement by Marchand et al. (2011, p859) that "Coastal erosion in Europe causes significant economic loss, ecological damage and societal problems", without making either of the equally valid but opposing statements that (i) coastal erosion provides many societal benefits through its contribution

to coastal ecosystem services (in particular sustaining beaches) and (ii) efforts to combat coastal erosion are damaging to coastal ecosystems and the services they provide.

Constructing coastal defences (whether hard or soft) to protect human infrastructure has deleterious effects on the coastal ecosystem (including reducing or eliminating sediment supply, preventing energy attenuation, reflecting or redirecting excess energy, reducing or eliminating habitat (coastal squeeze), and altering habitat type (Greene, 2002; Jones et al., 2011). In a review of the losses of coastal and nearshore marine habitats in Europe, Airoldi and Beck (2007, p345) note that "coastal development and defence have the greatest impact on soft-sediment habitats…". These in turn negatively impact important coastal ecosystem services such as recreational area, landscape/seascape quality, storm attenuation, food production, assimilation of pollutants amongst other things (UK National Ecosystem Assessment, 2011). These effects are often ignored or overlooked in deference to the perceived social desirability of protecting infrastructure rather than ecosystems (Cooper and McKenna, 2008).

In large part, concern about coastal erosion and flooding is only loosely focussed and terms such as 'coastal protection' and 'working with natural processes' mean different things to different people (Cooper & McKenna, 2008). Protecting a beach is not the same as protecting a house behind the beach- to protect the house means damaging or destroying the beach, while protecting the beach may mean letting the house collapse when erosion reaches it, yet both meanings are encompassed in the term 'coastal protection'. Importantly, the different interpretations of these terms are diametrically

opposed- following one interpretation will compromise the other. The concept of 'building with nature" that is popular in the Netherlands at present (Van Koningsveld et al., 2008) is another example. In order to resist any movement of the shoreline from its 1991 position (whether by storms or sea level rise), beach nourishment is an essential part of the strategy. Concepts such as the 'sand engine', a massive beach nourishment scheme that is anticipated by its designers to spread sand along the coast over several years, are billed as examples of building with nature. Such efforts may rely on natural processes to redistribute sand, but the underlying cause for installation is to resist nature. Consequently the very term is disingenuous.

In practice, protection of property is the most widespread context within which the term 'coastal protection' is invoked. Protection of the coastal ecosystem (sedimentary, biological and chemical) while implied in policy documents (EU, OSPAR), has a much lower priority. This probably stems from the perceived immediacy of flooding or erosion risk versus the long-term benefits and cost associated with coastal ecosystem services. Under such an anthropic view of coastal protection it is not surprising that defences proliferate. Recent reviews of the state of Europe's coasts (EEA, 2006; 2011) show a progressive increase in the extent of coastal defences. While this is a response to ongoing development on the shoreline (Airoldi and Beck, 2007), it has implications for sustainability of the coast which have received little attention. In Europe the Water Framework Directive might in due course focus attention on the extent to which coastal and estuarine ecosystems have been compromised by sea defences, but in the meantime,

progressive shoreline armouring poses a major threat to the natural functioning of the coastal marine ecosystem.

In many (almost all) instances, shoreline armouring is considered on a case by case basis with little regard to the cumulative effects. This is true whether or not there is a strategic approach to coastal protection. In this paper we use the Northern Ireland coast as a case study to document the nature and extent of shoreline armouring in place, and consider the implications for the coastal ecosystem. We assess the need for an integrated approach to shoreline management that considers protection of the coastal ecosystem as well as protection of coastal property in order to derive a sustainable approach to coastal protection.

2. Study Area

The Northern Ireland coast (Figure 1) extends from Warrenpoint on Carlingford Lough, to Londonderry on Lough Foyle (Cooper, 2010). The open coastline is approximately 650 km in length of which more than 75% is under some form of statutory or non-statutory conservation designation. An additional 113 km of coast is contained within the sea loughs (semi-enclosed marine embayments) of Carlingford, Strangford, Larne and Foyle. Nature conservation designations applied to sections of the coast include the World Heritage Site of The Giants Causeway and Special Areas of Conservation such as Strangford Lough and the Bann Estuary (Department of Environment, 2010). Over 70% of the coastline is classified as an 'Area of Outstanding Natural Beauty (AONB)'

(McLaughlin & Bann, 2002). There is, however, no strategic approach to shoreline management in Northern Ireland (Dodds et al., 2010) and decision-making regarding coastal defences is conducted by a variety of past and present government bodies operating largely independently to fulfil their statutory obligations (Cooper, 2011). With no strategic approach to shoreline management, a wide variety of structures has been emplaced at various times.

(Figure 1.)

3. Methods

In 2009 a low-level helicopter aerial survey of the Northern Ireland coast was commissioned by the Maritime and Coastguard Agency (MCA) and Northern Ireland Environment Agency (NIEA) to identify access points for potential marine accidents. This resulted in a complete photographic coverage of the coast by low level (100ft) oblique aerial images whose origin was geo-referenced in a GIS. In this study these images were used to identify the nature and extent of sea defence structures, whose location was mapped in GIS using a 1:10,000-scale base map. In the GIS the location, nature and extent of sea defence structures associated with sandy beaches was mapped. The nature of what type of asset was protected was also assessed. Ground-truthing of selected sections of the coast was undertaken via field visits to confirm the type of defence structure identified from the aerial photography.

4. Shoreline armouring in Northern Ireland.

There is a long history of sea-defence structures in Northern Ireland, many of which were originally constructed to create safe harbours and facilitate navigation. In the 18th and particularly 19th century land claim in estuaries involved construction of sea defences that persist to the present time while in the 19th and 20th century construction and metaling of coastal roads was accompanied by construction of sea defences. Several arterial roads extend around the coast of Northern Ireland, including the Antrim Coast Road which was considered a major feat of engineering at the time of its construction between 1832 and 1842 (Orr, 2010). In the more recent past, a variety of embankments have been constructed in seaside resort towns to provide promenade access. In the past two decades in particular a variety of sea defences have been emplaced to protect individual seaside dwellings as well as caravan sites, agricultural fields, car parks and municipal facilities. Several seaside resorts (e.g. Portrush, Newcastle, Bangor, Millisle) have seen continuing construction and alteration of existing sea defences in efforts to improve civic amenity.

A variety of shoreline protection works are present in Northern Ireland**.** Formal rock armour involves large quarried stones placed along the shoreline in a systematic fashion. The rock is usually hard igneous rock (basalt or granite). The rocks are selected to withstand a specified wave impact and are emplaced to a particular design. They are not cemented in place. Vertical sea walls constructed of blocks of rock cemented together are also common. They tend to be historical features and many have recently been replaced by concrete sea walls.

Informal rubble is frequently used as an alternative to rock armour, whereby blocks of material, such as old concrete or bricks in various shapes and sizes are placed on the coast to dissipate some of the wave energy. This is usually done in an informal manner without design and often the material is simply dumped. It is most common on agricultural fields and private property (caravan parks and houses).

A variety of concrete seawalls have been constructed in Northern Ireland to protect the landward assets from erosion. They range from vertical walls that simply reflect wave energy to concave curved walls designed to re-direct incident wave energy. Several are topped by promenades or roads. Railway sleepers were used as a seawall at Cushendun.

Groynes, timber or concrete walls built perpendicular to the shoreline, designed to trap sand moving alongshore, have been constructed at a few locations in Northern Ireland. They are not common because most beaches are located in headland-bounded embayments in which longshore drift is subordinate to cross-shore transport (Cooper, 2013). Examples are present at Portballintrae (Jackson, 2012), Newcastle and Ballyholme

Flood embankments are designed primarily to prevent flooding of low-lying areas rather than prevent erosion. They are present in some of the sea loughs, particularly in front of reclaimed salt marsh and tidal flats in Strangford Lough and Lough Foyle.

5. Results

In total, 32% of the Northern Irish coast is fronted by man-made structures, with 68% natural. The extent of defended coastline compares to 44% in England and Wales, and 6% in Scotland (Defra, 2010).

5.1. North Coast

The sand beaches of the North Coast (Magilligan to Ballycastle) (Fig. 2) are among the least developed in Northern Ireland. The high cliffs and lack of coastal roads that directly impinge on beaches is the main reason. Nonetheless several do have sea defences landward of the beach. These are most prominent at Portrush, the region's main seaside resort. On the West Strand concave seawall and promenade are present along the rear of the beach which has lowered significantly since the wall was built. On the neighbouring East Strand, in contrast, a seawall and promenade suffers from regular inundation with wind-blown sand. Both walls seem to have been emplaced to facilitate pedestrian access on the associated promenade. Some rock armour and gabbions were emplaced at Whiterocks beach, Portrush at the toe of a high dune in order to protect part of a golf course (Fig. 3). The sea defence situation at Portballintrae was documented by Jackson (2013), who catalogued a series of interventions that led first to destruction of the beach and subsequently the need to armour the glacial bluffs.

(Fig.2 and Fig. 3)

5.2. North Antrim Coast

At Ballycastle the coastal orientation changes to run N-S (Fig. 4). Between Ballycastle and Larne is a series of glaciated valleys (the Antrim Glens) with headland-embayment beaches at the mouths of the valleys. The Antrim Coast Road runs semi-continuously along the shoreline and a number of small settlements are present. At Cushendun (Fig.5A,B), sand removal from the beach had caused beach erosion and shoreline retreat (Carter, 1991). Rock armour and railway sleeper defences were built to protect adjacent land. The practice of sand removal has now stopped and the walls are not being maintained. At neighbouring Cushendall, a seawall and promenade was built in front of a golf clubhouse. The wall collapsed during storms in 1996 and again in 2014. The Antrim coast Road runs adjacent to the shoreline and where it impinges on the shore, sea defences have been constructed at the rear of many beaches (Fig. 5E, F). In many cases such beaches are now entirely covered at high tide and the sea defences are subject to high wave energy.

(Fig.4 and Fig. 5)

5.3. Outer Ards Coast

A road runs semi-continuously along the outer coast of the Ards Peninsula connecting several small towns and villages (Fig. 6). Beaches are present in embayments on this low-lying rocky coast and where the road impinges on the beach, sea defences have been built (Fig.7). The beach margin of several caravan sites (mainly occupied by

holidaymakers in the summer season) are armoured with a variety of materials and most of the holiday and permanent homes built seaward of the road are defended by rock armour. The raised beach deposits along this stretch of coast were a source of sand during storms and a future sand reservoir that would be accessed as sea level rises. This has been rendered inaccessible to the beach by the sea defences. The popular seaside resorts of Bangor, and Donaghadee have promenades at the rear of beaches. For example, Ballyholme beach at Bangor is backed by a seawall topped by a promenade. This has cut off the supply of sand from a formerly eroding bluff to landward. Unsuccessful efforts to prevent the inevitable beach lowering involved construction of groynes which are now in a poor state of repair.

(Fig. 6, 7, 8.)

5.4. South Down Coast

South of the Ards peninsula, the County Down coast is a mix of hard rock and soft glacial deposits. The beaches are sustained by ongoing erosion of the soft glacial deposits immediately landward of them.

Roads are present at variable distances landward of the shoreline (Fig. 9). Where it impinges on the shoreline it has been defended. The largest single sea defences adjacent to beaches are at the resort of Newcastle and around caravan sites at Cranfield Point. The resort of Newcastle is fronted by a seawall (Fig. 10A) and a recreational centre was

252 constructed on top of part of the beach. Erosion of the shoreline has progressed
253 alongshore from the initial hard defences in front of the town and adjacent areas
254 (including a hotel and golf course) have been armoured in turn. The seawall in front of
255 the largest hotel (Fig 10B) has collapsed during storms in 2002 and was rebuilt.
256
257 Outside these resorts sea defences at the rear of the beach have been constructed to
258 protect individual houses, footpaths (Fig.10C) and agricultural land (Fig 10D).
259

260 **5.5. Sea Loughs**

261
262 Beaches and tidal flats are present within all of Northern Ireland's sea loughs. They are
263 large marine embayments in which wave energy is significantly lower than the open sea,
264 but within which periodic storms can cause significant morphological change. A variety
265 of sea defences are present at the rear of beaches in these sea Loughs (Fig.11). They
266 have been constructed for various reasons. In Strangford Lough the most common sea
267 defences are constructed to protect roads which run along the margins of the Lough.
268 (Fig11D). A single large structure at the landward limit of tidal flats in the north of the
269 lough was constructed originally as part of a saltmarsh reclamation project (McErlean et
270 al., 2002). It has subsequently been enhanced and strengthened several times to provide
271 flood and coastal defence for the low-lying parts of Newtownards. Other areas in
272 Strangford are defended to protect small patches of ground including picnic sites (Fig
273 11B). Approximately 25% of Strangford Lough's mainland shoreline (excluding its
274 islands) is armoured.

Over 40% of the Northern Ireland section of Carlingford Lough's coastline is defended by sea defence structures. Most of these consist of rock armour and seawalls to protect the A2 road. Several additional stretches of armouring have been emplaced to protect individual houses (Fig 11E) or new developments (Fig 11F).

Almost 50% of the shoreline of Belfast Lough has defensive structures. Much of this is protecting roads and other urban and port-related infrastructure. Some, however, is present at the rear of small pocket beaches such as those at Crawfordsburn (Fig. 11A). The purpose of these defences seems to be primarily to provide support for a footpath at the rear of the beach.

Just less than 30 % of Larne Lough's coastline comprises sea defences, constructed in association with port facilities and to protect roads.

About 40% of Northern Ireland's Lough Foyle coastline comprises sea defences with most of these constructed to protect reclaimed salt marshes.

6. Effects of coastal defences on the coastal ecosystem.

Erosion of shorelines and periodic flooding are entirely natural processes of coastal ecosystems. Shoreline erosion may be a response to a temporary increase in wave or tidal energy or a sediment imbalance that is either temporary or long-term. In the natural

world erosion is a mechanism by which the coastline adjusts to changing conditions. Erosion of land seaward of, or alongshore of beaches, provides a sediment source that sustains some beaches and yields sediment to the nearshore zone. Flooding too is a temporary condition during which excess water is accommodated within a system. During floods, wetlands (e.g. saltmarshes) are supplied with fresh inputs of sediment and nutrients.

Coastal defences compromise the natural sedimentary system and the associated coastal ecosystem (McKenna et al., 2000). They do so in a number of ways and at different timescales. In areas where the supply of sand or gravel to beaches is dependent on periodic bluff erosion, sea defences eliminate or reduce the sediment supply. This effect was noted by Carter (1984) in the case of the Antrim Coast Road where the road had severed the supply of cliff-derived debris from the adjacent cobble beaches. Active cliff recession also sustains beaches on the coast south of Newcastle and around Strangford Lough. Ultimately any reduction in sediment supply causes such beaches to narrow and ultimately disappear as the existing sediment is reworked by waves. On long stretches of the Northern Ireland coast, a 'raised beach' deposited during a previous high sea level is present behind the modern beach. It contains a large supply of sediment but much of it has been rendered inaccessible to the modern sedimentary system by seawall construction. This effect is particularly noticeable on the outer Ards Peninsula where the coast road and small settlements have been built on the raised beach. In other areas, erosion of glacial sediments is the only contemporary source of sediment to beaches and tidal flats (Greenwood and Orford, 2007).

Armouring at the rear of many sand beaches cuts the link between beach and dune, thus preventing the additional dissipation of storm energy that occurs by dune erosion during storms (McKenna et al., 2000). It also creates 'edge effects' where erosion is focussed as the margins of the defences causing them to be gradually extended- the beach at Newcastle County Down is a good example where Navas and Cooper (1998) showed the progressive extension of sea defences. Separation of beach and dune by seawalls cuts the sediment supply from dunes that is often part of the natural post-storm recovery mechanism (Lynch et al., 2009). This means that excess energy remains within the system and is used to export sediment seawards.

The direct effects of shoreline armouring include reflection of waves during storms. This leads to enhanced offshore transport of sediment. Carter (1991) reported a 2m drop in beach level at Portrush since construction of a sea wall. In other instances armouring has caused loss of beach habitat by being constructed on top of the beach. A recreational facility at Newcastle is a prime example that is extended onto the former beach and now overlies it.

In the medium term anticipated changes in global sea level and its outworking at local level as relative sea level rise have serious implications for coastal sedimentary systems and ecosystems. Although Northern Ireland has historically seen little sea level rise (due to post-glacial land uplift) recent studies point to a rising sea level trend (Orford et al., 2006) Rising sea level typically causes a landward migration of shorelines as dynamic

zones shift landwards and upwards. A migrating shoreline rising across the coastal hinterland results in erosion of adjacent materials liberating sediment that, in turn, sustains the migrating landforms. The glacial sediments and raised beaches of the Northern Ireland coast contain a ready source of beach-building material that will be accessed by the rising sea. In cases where this has been armoured the future sediment supply has been cut off and beaches will be lost.

The same is true for tidal flats. In all the sea loughs, armouring at the landward margin of the tidal flats inhibits the ability of the tidal flats to migrate and they will thus narrow and become more energetic as wave energy is dissipated across a narrower zone. The implications for resident and migratory creatures are potentially serious. In a study for the National Trust Orford et al. (2006) contended that about 50% of the intertidal habitat at the northern end of Strangford Lough (backed by a sea defence) would be lost if sea level were to rise by 1m in the next century. Tidal flats not backed by seawalls could instead migrate landwards.

Decreased width reduces the natural coastal defence capacity of beaches, tidal flats and salt marshes. An inability to access sand dunes during storms has the same effect since excess energy is then reflected seawards, causing enhanced erosion, rather than being dissipated in the dunes.

There are many ecological implications of coastal armouring on sandy beaches and tidal flats (Dugan et al., 2008; Defeo et al., 2009). Perhaps most fundamentally, a reduced

area for beach debris (e.g. seaweed) to accumulate causes a marked reduction in beach productivity. The reduced areas of beaches and tidal flats also provide less habitat area for foraging and nesting birds and other beach-dependent organisms (Dugan and Hubbard, 2006). The coastal defence structures themselves become habitats that impact on native biological communities and can promote colonisation by invasive creatures (Defeo et al., 2009). The loss in area of beaches, caused by sea defence structures ultimately impacts on the entire nearshore ecosystem via a complex set of interacting nutrient and material flows.

7. Discussion

Over a quarter of all Northern Ireland's sandy beaches are backed by sea defences. The reasons for emplacement of coastal defences are varied, but the most common (defence of roads and defence of homes) relate to structures that do not necessarily have to be built on the coast. In many instances, even low value and undeveloped land is defended at great expense. In a number of instances armouring of sand beaches appears to have been an unnecessary 'knee-jerk' reaction to winter storms – several seawalls between the beach and dune appear to serve no practical purpose. In the case of seaside resorts, defences at the rear of beaches serve mainly as the basis of a promenade.

With few exceptions (one of which was the upgrade of Newtownards sea defences (Navas et al., 2002)), construction of sea defences takes little account of the environmental or ecological implications either individually or cumulatively for the

Northern Ireland coast. Applying Kahn's (1966) premise regarding the "the tyranny of small decisions" to environmental impacts Odum (1982) noted that the effects of small, independent decisions are often experienced *post hoc* and they often result in detrimental outcomes in which the larger issue is never directly addressed. This appears to be the case regarding sea defences behind beaches in Northern Ireland and elsewhere. One project might be administratively acceptable and have subtle effects on habitats and organisms, but numerous projects over time may exert multiple assaults that result in "death by a thousand cuts (Lindeman, 1997b)." With rising sea level and increasing development, the demand for protection of built infrastructure and property will undoubtedly increase. The impacts on the coastal ecosystem are likely to continue to be ignored (Greene, 2002).

In addition, despite a brief phase of government engagement with ICZM (Cooper, 2011), Boyer-Villemaire et al. (2014a,b) have drawn attention to the shortcomings in the administration of coastal management and the lack of participation by citizens in decision-making in coastal defence specifically in Northern Ireland. This, coupled with a general lack of awareness of the impacts of coastal defences, is a major challenge to changing the *status quo*.

8. Conclusions

The prevailing one-dimensional view of coastal protection in Northern Ireland, and indeed globally, is causing severe impacts on natural coastal ecosystems and compromising their ability to adapt and survive during rising global sea level. This situation is the result of several combined factors. These are:

1. Ignorance on the part of the public and managers of the implications of sea defences for coastal ecosystems;
2. Structuring of decision-making processes such that some form of defence is the only plausible outcome;
3. Active lobbying for engineered interventions by the engineering profession;
4. Poor planning decisions that permit construction in high risk zones;
5. A higher priority being afforded to private property than maintenance of the communal coastal resource; and
6. An inability to contemplate large scale removal of infrastructure to less vulnerable locations.

The inevitable outcome is an ever-increasing maintenance bill for sea defences and an ever more degraded environment with implications for the quality of life of residents, impacts on tourism and recreation (that rely to a large extent on a high quality scenic environment) and deleterious impacts on the natural coastal ecosystem. Protection of some types of infrastructure at the coast is of course needed, but in many cases more sustainable alternatives to defence can be found. In many instances defence measures were unnecessary and can safely be removed. Amenity can be provided by less intrusive

and even demountable structures such as being implemented by the National Trust at Portstewart beach. From a planning perspective, a strategic approach to the shoreline is needed that makes it clear that ill-placed development will not be permitted to be defended. This would have the immediate effect of still enabling development at the owners risk but would halt the ongoing pattern of development in erosion-prone locations with inevitable subsequent calls for armouring (even at public expense).

Acknowledgements

This work was undertaken in the context of the IMCORE (Innovative Management for Europe's Changing Coastal Resource) Project funded under the Interreg IVB programme. We are grateful to NIEA for access to its oblique aerial photography set from which information on sea defences was mapped.

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Figure Captions

Figure 1. Map of Northern Ireland showing main roads, coastal towns Areas of Outstanding Natural Beauty (AONB's)

Figure 2. Map of North coast from Magilligan to Ballycastle illustrating the location of Lough Foyle and including major towns, roads and AONB.

Figure 3. Sea defences on the north coast. A. Curved seawall and promenade, West Strand, Portrush. B. Seawall and promenade at East Strand, Portrush. This suffers regular inundation with wind-blown sand and requires regular mechanical clearing. C. Rock armour to protect part of gold course. D. Portballintrae groynes ,seawall and stabilized back-beach slope.

Figure 4. Map of the North Antrim coast from Ballycastle to Larne illustrating Larne Lough.

Figure 5. A. Cushendun rock armouring at a car park. B. Railway sleepers used as sea defence, Cushendun. C. Sloping stone wall, Cushendall. Gabbion baskets, Red Bay. E. and F. Near vertical, stepped seawall at Carnlough at low and high tide.

Figure 6. Map of the Outer Ards coast from Larne Lough to Dundrum Bay.

Figure 7. Sea defences on the outer Ards Peninsula. A. wall and rock armour defending house. B. concrete wall defending car park. C. Concrete wall defending road. D. Rubble dumped as sea defence. E. Vertical wall defending road. F. Massive rock armour defending road.

Figure 8. Ballyholme, Bangor. A. Sea wall and subsequent toe defence. B. Low promenade and seawall. C/ Groynefield/ D. Collapsing concrete groynes

Figure 9 Map of the South Down coast from Newtownards to Warrenpoint including Strangford Lough, Dundrum Bay and Carlingford Lough.

Figure 10. A. Rock armour fronting Newcastle promenade. B. Failed sea defence, Slieve Donard Hotel, 2002. C. Gabbion armouring of coastal footpath, Annalong. D. Rock armour of agricultural land.

Figure 11. Sea defences on estuarine beaches. A. Crawfordsburn, Belfast Lough. Seawall and promenade. B. Rock armour protecting picnic site, Strangford Lough, Sea Defences protecting Newtownards from flooding,. D. Vertical wall with several generations of repairs, protecting road,

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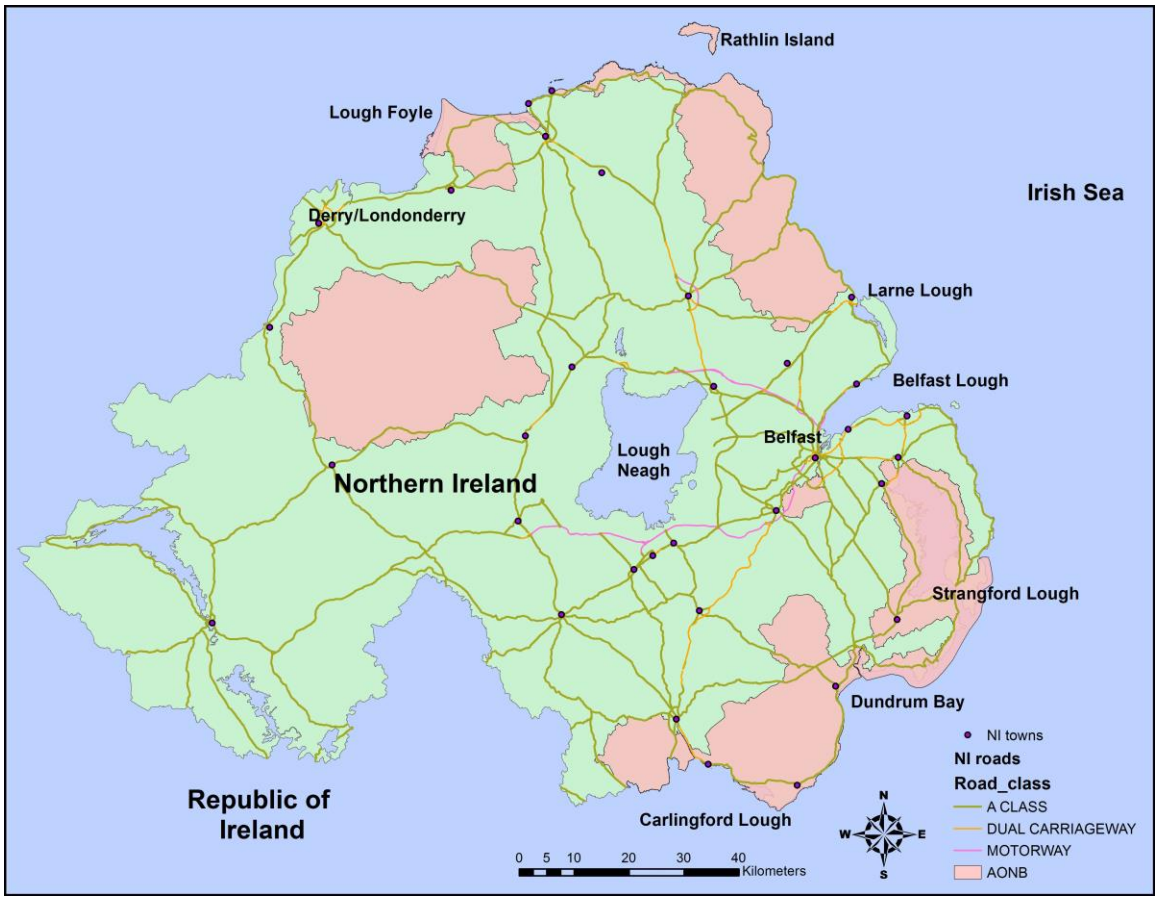

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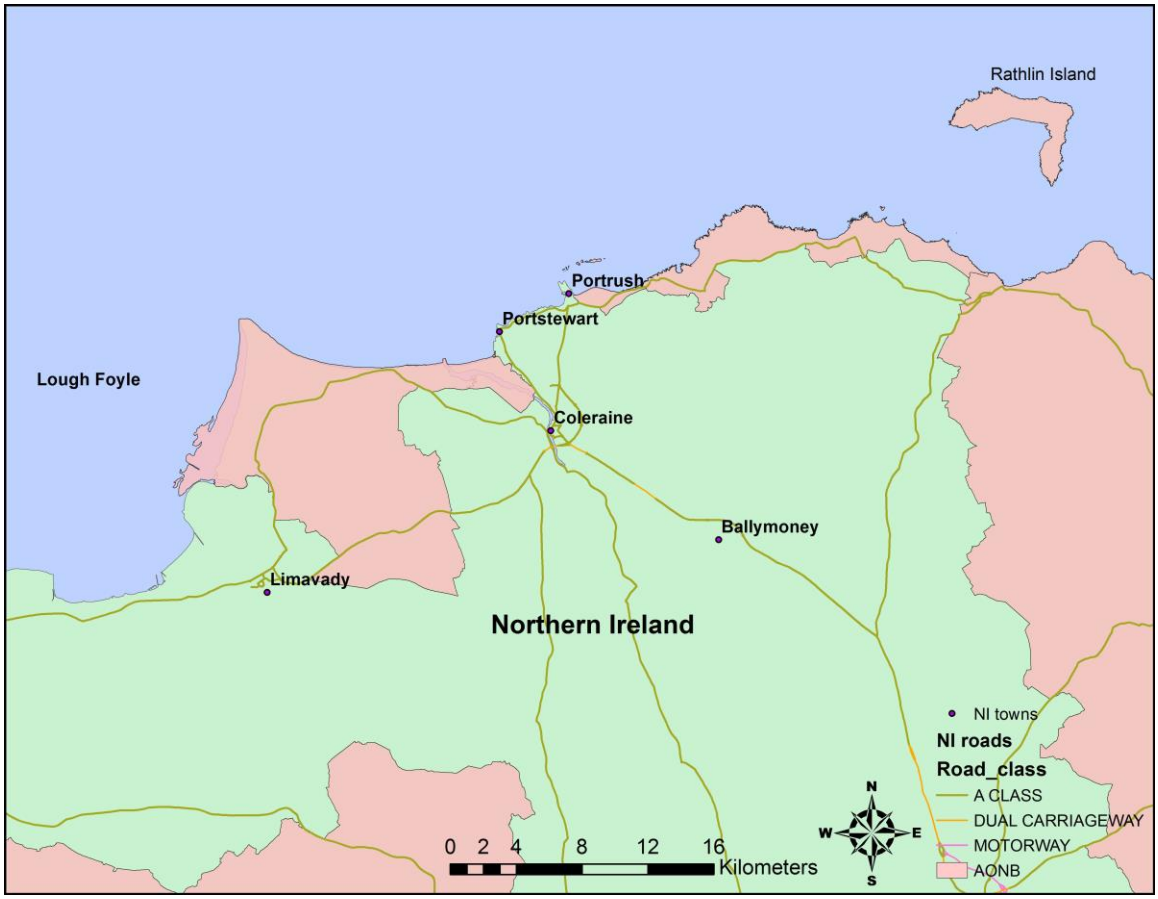

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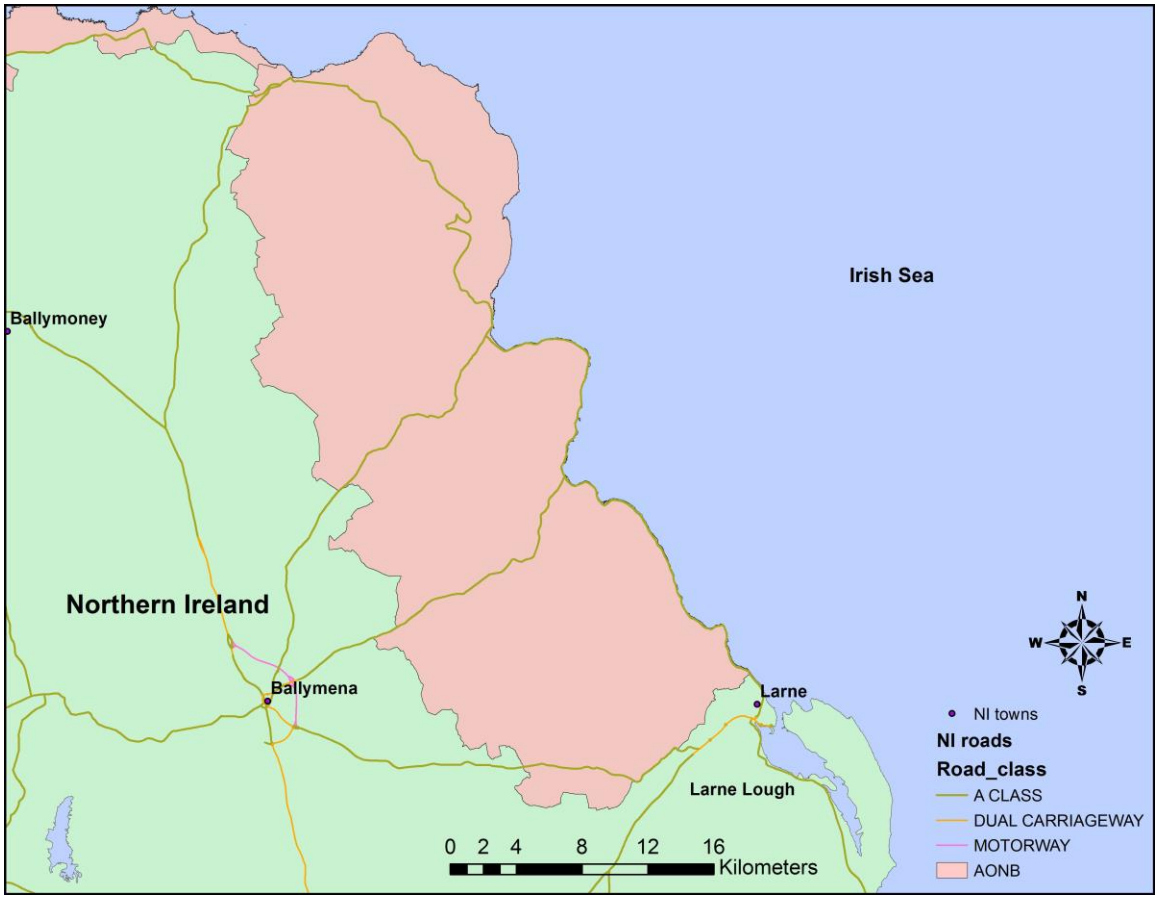

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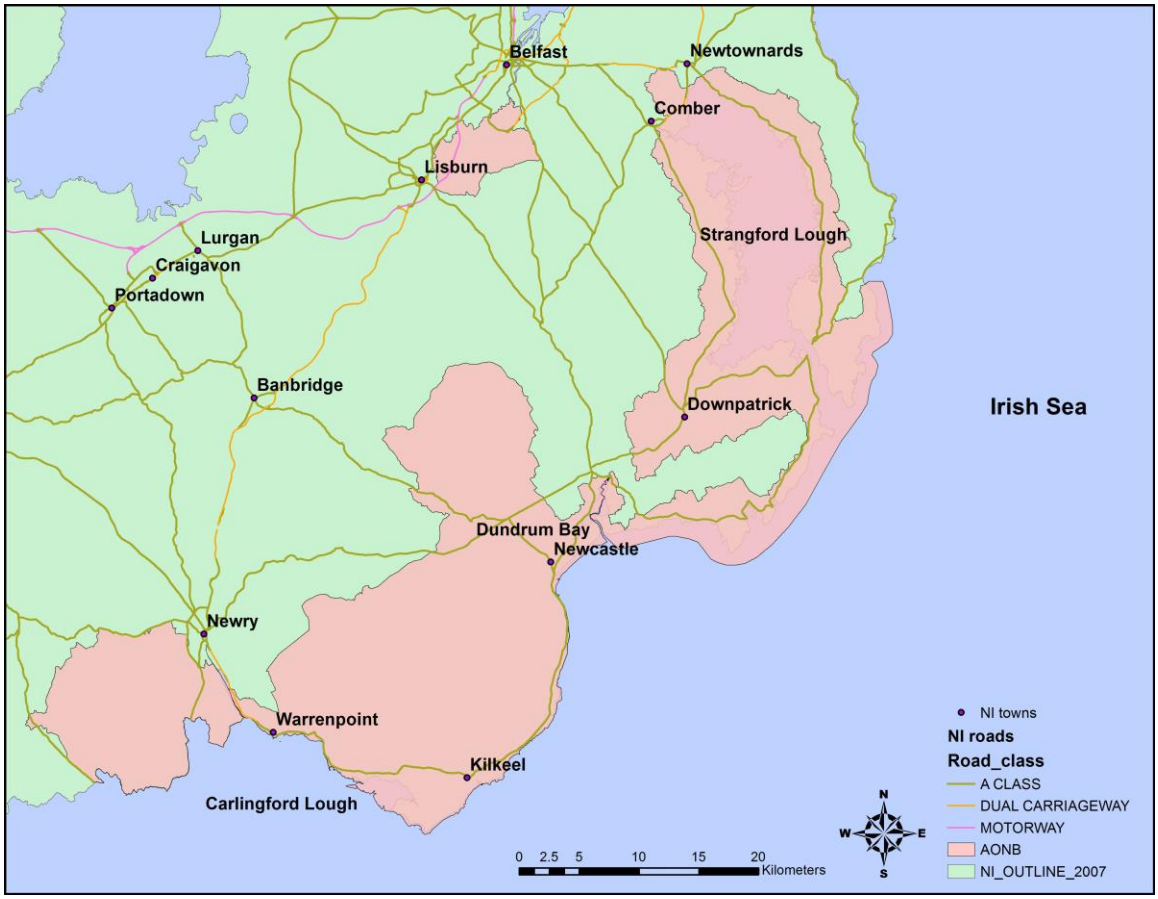

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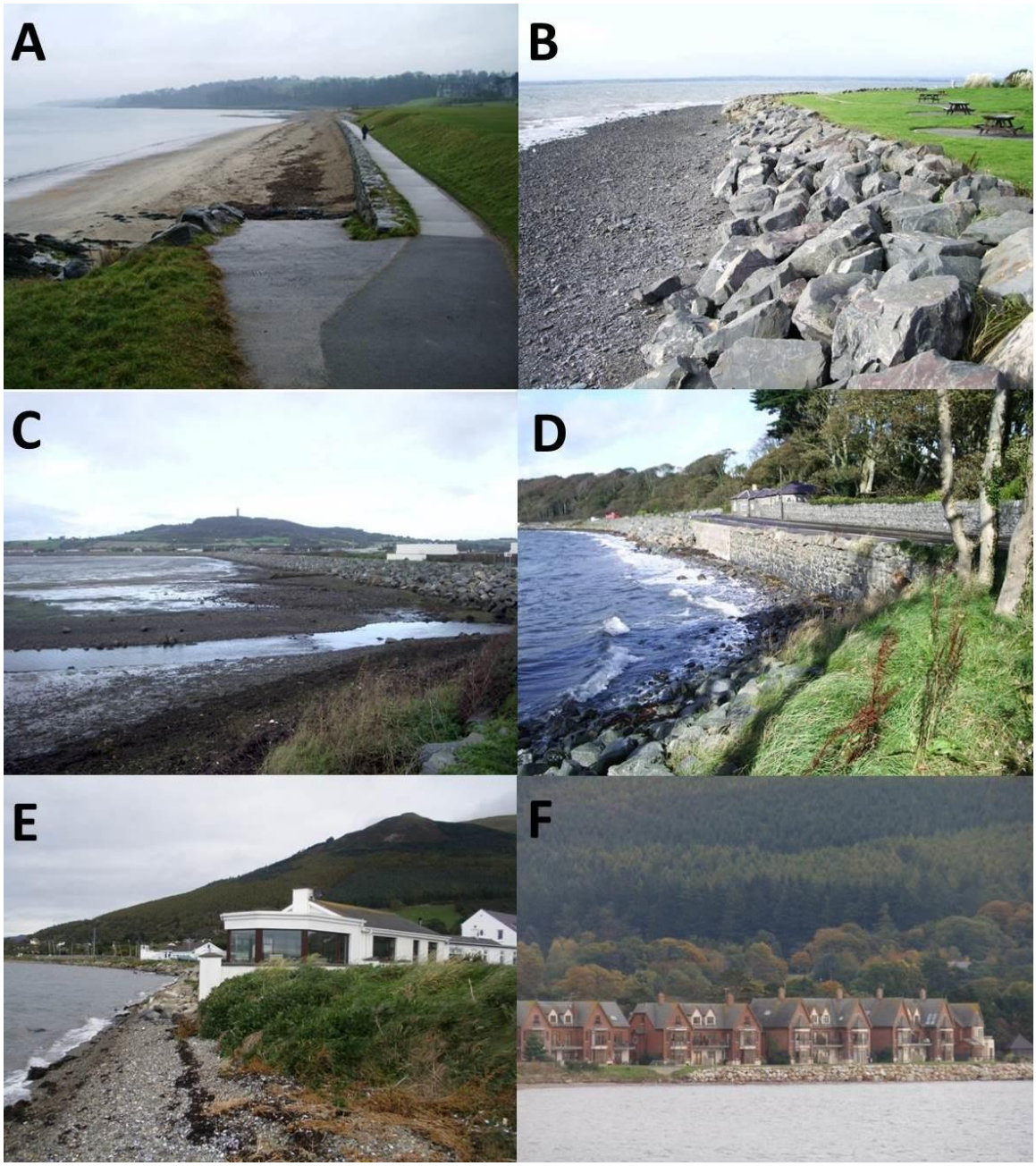

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