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How strategic ecosystem monitoring and assessments are relevant to the management of a marine industry: Offshore wind electricity generation

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ABSTRACT

In the northeast Atlantic region, the ecosystem approach to marine management has been partly implemented through the European Union Marine Strategy Framework Directive, which has been variously transposed into supporting national legislative frameworks. Within this implementation of the ecosystem approach, the health and status of the marine ecosystem is required to be regularly reviewed by Strategic Ecosystem Assessments (SEcAs). These are supported by strategic regional-scale ecosystem monitoring. SEcAs track progress towards Good Environmental Status (GES) and identify principal concerns related to specific ecosystem elements. At the same time, other regional and national legislative frameworks aimed at protecting the marine environment require three additional forms of ecosystem assessment. Public plans and policies that may result in human activities which impact the ecosystem are required to have Strategic Environmental Assessments (SEAs) in order to identify any potential impacts of such plans. These are often on a regional scale. At a smaller spatial scale, individual developments, such as offshore wind farms, need Environmental Impact Assessments (EIAs) and Cumulative Impact Assessments (CIAs) before they are granted a consent and/or licence to progress by the relevant competent authority. Licensing frameworks generally require related targeted monitoring at the scale of individual developments. Using the Scottish region of the North Sea as a case study, this paper considers how monitoring and assessment under these four processes (SEcAs, SEAs, EIAs and CIAs) interface. Better harmonisation between these legislative frameworks may be possible through coordination and data sharing to improve the protection of the marine environment.

1. Introduction

The protection of the marine environment is now a priority for regional and national governments, but this has not always been the case. In the North Sea, the commencement of industrial-scale fishing (1850s), powered commercial shipping (1900s) and the offshore oil and gas industry (1970s) all commenced before formal environmental impact assessment legislative frameworks had been established in this region [7,9,14]. However, the situation is very different for the offshore industry aiming to generate electricity using wind power [15,17].

In the UK, the first offshore wind farm (OWF) began operation in the year 2000 at the Blyth OWF. The first formal EIA system was developed in the United States in the 1970s, with EIA becoming a well-developed concept in national and international environmental legislation by the 1990s [17]. Thus, the offshore wind industry started at almost the same time as the implementation of the formal statutory framework requiring Strategic Environmental Assessments (SEAs), Environmental Impact Assessments (EIAs) or Cumulative Impact Assessments (CIAs) for any

new human activity that may impact the marine environment.

Now, in 2025, there has been 25 years of the growth of the offshore wind industry within the existing SEA / EIA / CIA framework within the case study area; the Scottish sector of the North Sea. In the UK, the industry is projected to continue to expand, utilising increasing amounts of maritime space with increasing potential to have both negative and positive ecosystem impacts (e.g., [10]), hence the need for environmental assessments will grow.

Alongside the SEA / EIA / CIA process and driven by the same overarching desire to protect the marine environment, a second statutory process has been developing in the case study area which has led to the requirement for Strategic Ecosystem Assessments (SEcAs). Since the 1960s there has been a desire to move towards an ecosystem approach to marine management, first incorporated into marine policy in the 1972 Stockholm Convention [13]. In the UK, the Government's vision of achieving *clean, safe, healthy, productive and biologically diverse oceans and seas* was first set out in the Marine Stewardship Report "Safeguarding our Seas", published in May 2002. This simple phrase was

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extremely powerful in organising the implementation of an ecosystem approach to marine management as it specified in clear terms what the aim of such a policy was. This phrase was subsequently adopted as the vision for the Marine Strategy Framework Directive (MSFD) when it was passed into EU law in 2008 and hence the MSFD implements the ecosystem approach within EU waters. When an area of the sea meets the overarching vision, it is said to be at Good Environmental Status (GES). EU member states under the MSFD, and the UK under national legislation, must regularly monitor and assess the status of their seas to demonstrate progress towards GES, and they must impose measures to achieve GES if certain elements of the ecosystem are failing to achieve this status. The assessment of the status of the ecosystem is performed by an SEcA.

The aim of this paper is not to review EIA, CIA, SEA and SEcA methodologies. There is a growing body of literature that presents such reviews (e.g., [1,5,8,15–17]). The aim rather is to explore how SEAs and SEcAs and their associated evidence generation including strategic in situ monitoring is currently being utilised in the EIA / CIA process for the offshore wind generation industry in a case study area, the Scottish sector of the North Sea.

The paper briefly describes the policy and legislative frameworks within the case study region that establish the need for EIAs, CIAs, SEAs and SEcAs with a particular focus on the stated ambitions to coordinate and harmonise these frameworks. It reviews what EIAs, CIAs, SEAs and SEcAs have been implemented in the study area over the last 25 years which are relevant to the offshore wind industry. It goes on to assess the interrelationship between these EIAs / CIAs, SEAs and SEcAs. A further section briefly discusses the supporting research that is needed to implement the assessment processes. A penultimate section discusses the environmental monitoring which offshore wind developers may be required to do once an OWF becomes operational by competent authorities, as this has relevance to the monitoring that is required to support the SEcA process. The paper concludes by framing areas of focus for the better harmonization of the relationships between the EIA/CIA, SEA and SEcA processes.

2. The legislative framework

This section is not meant to be a thorough description of the extremely complex legislative frameworks within which EIAs, CIAs, SEAs and SEcAs are implemented. Rather, it provides a brief overview which emphasises the aspects of the legislation related to the inter-relationship between these four types of environmental assessment. The [Supplementary Information](#) (SI) provides further details of the legislation, along with current (2025) web links for all referenced statutes, hence these are not provided here in the text.

2.1. Environmental impact assessments (EIAs)

The “parent” policy framework for EIAs in the case study region is provided by EU Directive 2011/92/EU. This has been amended by several later pieces of EU legislation and transposed into national legislation by a complex set of laws, summarised for Scotland in the SI (Section S1).

2.1.1. Scope of EIAs

The prologue to the parent Directive makes it clear that the objective of an EIA is to protect the health and status of the ocean following the imposition of a public or private development, which would include the construction and operation of an OWF in the sea. A development should not impact adversely “the diversity of species” or “the reproductive capacity of the ecosystem as a basic resource for life” (Prologue 14). This is emphasised by Prologue 4, which notes that EIAs are “necessary to achieve one of the objectives of the Union in the sphere of the protection of the environment and the quality of life”. Article 3 notes EIAs should address impacts on “flora, fauna”, “soil and water” and interactions

between these, which in the sea encompasses all marine life, the seabed and the water column.

Characteristics of a development that need to be considered include the production of waste, pollution and nuisances (Annex III) which brings in for OWFs the consideration of the release of litter, contaminants, invasive species and noise. These are also specifically listed in Annex IV. Each impact should be considered in terms of the geographical extent of the impact, any transfrontier nature of the impact, the magnitude and complexity of the impact, the probability of the impact, and the duration, frequency and reversibility of the impact.

National legislation relevant to the EIA process for OWF developments in the case study region (e.g., The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017) further clarify the scope of an EIA to include the impact on “biodiversity, and in particular species and habitats protected under any law”. Hence, while this introduces a focus on protected species and habitats, it does not remove the requirement to consider the health of the ecosystem and environment as a whole.

2.1.2. Integration of EIAs with other legislative processes

The parent EIA Directive also notes that the assessment of environmental impact of a development should be harmonised (Prologue 3) with other national and international statutory measures to protect the environment. The prologue makes it clear that the spirit of EIAs is that the assessment process should be coordinated with the other relevant legislative processes. This should include SEA and SEcA legislative processes which are also fundamental building blocks of the regional approach to a healthy marine environment, although these processes are not specifically listed.

The requirement for legislative harmonisation is repeated in national legislation in the case study region. For example, the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 states that the description of the likely impacts of a development should “take into account the environmental protection objectives established at Union level [...] or United Kingdom level which are relevant to the development including in particular those established under the [...]” Habitats Directive and the Birds Directive. While legislation related to SEAs and SEcAs (e.g., The Marine Strategy Regulations 2010, Marine Scotland Act 2010) are not specifically named, these should be included in the scope of an EIA. It should be noted that the title of the UK Marine Strategy Regulations 2010 highlights that the instrument is specifically for “environmental protection” within the body of all UK legislation. Under these regulations, the UK has set out a series of measures aimed to achieve GES (Defra, 2015). One of these measures is the desire that all marine developments comply with the relevant regulatory regime, and that associated EIA assessments take full consideration of any potential impacts that may compromise GES [3]. This once again emphasises the inter-relationship between the EIA and the SEcA processes.

2.1.3. Steps of an EIA

The parent EU EIA Directive also lays out the basic administrative steps of an EIA. These are complex, and are further described in the SI (Section S1), but the steps most relevant to this review are the Scoping Report and Opinion, and the EIA itself. In the Scoping Report, a developer contacts the competent authority to describe what aspects the subsequent EIA will include, and the licensing authority then confirms if this is sufficient or stipulates additional topics to be assessed. The developer then takes the opinion of the competent authority (the Scoping Opinion) provided to them based on the Scoping Report and produces an EIA in the form of an Environmental Statement (ES). This, along with statutory consultees comments, is then submitted to the competent authority in order to assess whether or not there will be an acceptable level of environmental impact from the development. It is on the basis of this assessment of the EIA that a competent authority would issue a consent to proceed with any associated mitigation and / or monitoring conditions.

2.2. Habitats regulations appraisals (HRAs)

As noted above, in the UK the EIA-related legislation has introduced a focus on protected habitats and species. In the consenting and licensing process, a Habitats Regulations Appraisal (HRA) is an essential step, and this determines if a development will have an adverse effect on the integrity of a protected area, habitat or species. As HRAs are focussed on specific impacts, and not on overarching impacts to the environment or ecosystem, it is considered that HRAs are outwith the scope of this paper and will not be further discussed in any detail.

2.3. Cumulative impact assessments (CIAs)

The requirement for CIAs comes from within the EIA legislative framework itself, and EIAs and CIAs are intrinsically linked. The parent EU EIA Directive notes that an EIA must particularly address effects that result from “cumulation with other projects” (Annex III). The description of any impact of a development should include “direct effects and any indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects” (Annex IV). These phrases are repeated in relevant national legislation. However, apart from the stipulation that cumulative impacts must be considered in the EIA process, no details are provided by the legislation itself as to how CIAs should be conducted. For example, in the legislation there is no guidance as to the geographical area over which a CIA for a development should be carried out (i.e., how far away from a development should other effects be included), nor the time frame for a CIA (i.e., how far in the past or future when other impacts occurred should be considered in the CIA). However, the Scoping Report and subsequent Scoping Opinion issued by the competent authority will usually include an assessment of what projects need to be considered by the CIA. Additionally, some competent authorities and their supporting agencies have developed such guidance themselves (e.g., [12]). Owing to the nature of CIAs, they often employ modelling techniques to integrate the impact of multiple activities in a region (e.g., [8,11]). See Willstead et al. [15,16] for extensive reviews of CIA methodologies, and Declerck et al. [2] for a discussion of CIA in relation to marine spatial planning.

2.4. Strategic environmental assessments (SEAs)

SEAs follow the same general principles in terms of scope and process as EIAs, but are applied to public plans, programmes or strategies which may ultimately result in activities that impact the ecosystem or environment. Hence, SEAs often consider environmental impacts on a regional (e.g., Greater North Sea) or sub-regional (e.g., Scottish sector of the North Sea) scale. As with EIAs, there is a parent regional EU Directive (Directive 2001/42/EC) which lays out the legislative framework, and this has been transposed into national (UK and Scottish) law (SI Section S4 for details). A SEA is meant to identify potentially significant environmental impacts early in the development of a national plan or policy. This permits policy formulation to include mitigation actions or policy changes that can minimise or eliminate negative impacts. In relation to a developing offshore wind industry in the case study region, SEAs have been required for overall offshore wind governmental strategies as well as for large scale leasing rounds. As SEAs are often applied at a regional scale rather than at the scale of an individual OWF site, they represent significant summaries of background context-setting environmental information and hence represent a significant resource for authors of EIAs.

2.5. Strategic ecosystem assessments (SEcAs)

In order to demonstrate progress towards the vision of clean, safe, healthy and biologically diverse seas, SEcAs are required by the MSFD (EU Directive 2008/56/EC) in order to assess the current status of the ecosystem in terms of its overall health and cleanliness with an aim to

reach or maintain GES. EU member States must define the characteristics of GES for key ecosystem elements (11 Descriptors, SI Section S6) within their marine regions and then develop indicators of progress towards GES for these elements. The status of the ecosystem is defined as the “overall state of the environment in marine waters, taking into account the structure, function and processes of the constituent marine ecosystems together with natural physiographic, geographic, biological, geological and climatic factors, as well as physical, acoustic and chemical conditions”. GES means that the sea is “clean, healthy and productive within their intrinsic conditions”. In the UK, the MSFD has been transposed into national legislation.

A second process within the case study area which requires SEcAs is under the Oslo Paris (OSPAR) Convention. The legislative framework for the OSPAR SEcA process is enshrined in the Convention for the Protection of the Marine Environment of the North-East Atlantic, otherwise known as the OSPAR Convention, of 1992. Thirteen states, including the UK, signed this convention, and for them this is legally binding. Article 6 of the Convention states that the contracting parties will “undertake and publish at regular intervals joint assessments of the quality status of the marine environment and of its development”. The more recent OSPAR North East Atlantic Environment Strategy (NEAES) 2030 provides further details of the required OSPAR SEcAs (www.ospar.org/convention/strategy).

A third requirement for SEcAs in the EU region comes from legislation associated with marine spatial planning. In the Scottish region of the North Sea, this has been implemented through the Marine (Scotland) Act 2010. This act requires Scottish Ministers to publish a national marine plan which describes the government’s policies to achieve a sustainable marine environment. When preparing a national marine plan, Scottish Ministers must “prepare an assessment of the condition of the Scottish marine area” as well as “a summary of significant pressures and the impact of human activity”, and this takes the form of an SEcA.

2.5.1. SEcA cycles

While the OSPAR Convention does not specify an interval for the repeat of OSPAR SEcAs by contracting parties, the OSPAR NEAES 2030 stipulates a 6-year cycle. Article 17 of the MSFD also specifies a 6-year cycle for SEcAs under this framework and this is repeated in national SEcA legislation. Scottish Ministers are required to review whether their national marine plan is achieving its environmental objectives every 5 years, and are required to renew the national marine plan “from time to time”.

2.6. Summary

The parent SEA EU Directive (Annex 1) and the associated national SEA legislation states that a SEA must describe “the relevant aspects of the current state of the environment and the likely evolution thereof without implementation of the plan or programme” as well as consider “any existing environmental problems which are relevant to the plan or programme”. In relation to the requirements of a CIA, the EIA Directive (Annex IV, Article 5e) repeats this phrase. It is one of the roles of SEcAs to identify the relevant environmental problems in a region as they identify how an ecosystem is not currently achieving GES. Hence there are clear links between the EIA / CIA, SEA and SEcA legislative frameworks and these processes should be cognisant of each other.

3. Implementation in the case study region

This section briefly describes the nature and content of the EIA/CIA, SEA and SEcA assessments that have been published for the case study region since the year 2000. The section also reviews the current (2025) accessibility of the SEcAs using a standard internet search engine as this is the method most researchers, developers and competent authorities would use when gathering evidence to support an EIA/CIA, or to investigate changes in relation to past baselines. Web links to all

assessments, as accessed in 2025, are presented in the SI and are not repeated here.

3.1. EIA/CIAs

There have been ten EIA/CIA processes for OWF developments in the case study region between the years 2000 and 2025 (Fig. 1), presented in published ESs, most of which were available on the Scottish Government licensing and consenting website in 2025 (SI Section S2 for all ES web links). All ten ESs follow the proscribed structure of EIAs, with CIAs as a separate section of each report. Most present a non-technical summary, the report itself and a set of technical annexes, all of which form substantial presentations of evidence supporting an application for a consent to construct and operate an OWF. Baseline information describing the local environment around the proposed OWF is normally provided using specifically commissioned in situ surveys as well as extensive literature searches. Thus, ESs present a source of new data in the case study region as well as collations of existing data.

Within an ES, the assessment of the local environment is set in the context of the status of the regional ecosystem. All potential environmental impacts of the proposed OWF are considered. Often, at the stage of writing an ES the full details of a proposed OWF are not known, and a design envelope (sometimes referred to as a ‘‘Rochdale Envelope’’) approach is taken whereby the maximum possible development is described along with any possible variations and their potential impacts, although the finally constructed OWF will be a sub-set within the design envelope proposal [12,17].

The CIA section of each ES considers all other relevant developments and activities within a certain spatial range and time of the proposed development, as defined during the scoping stage. Entire ESs, including all their technical annexes, can represent substantial bodies of work. For example, the ES for the Berwick Bank OWF runs to 4524 pages in total. All ten ESs were authored by commercial environmental consultancies on behalf of the company developing each OWF.

3.2. SEAs

Although the SEA legislation was not incorporated into UK law until 2004, since the year 2000 there have been fourteen SEAs which include the case study region, or parts thereof (Table 1).

Between 2000 and 2007 the UK Government published a series of seven SEAs, all related to rounds of leasing the seabed for oil and gas extraction and authored by a collection of governmental and academic scientists and consultants. Each SEA focussed on a sub-region of the UK continental shelf. SEA2 covered the offshore regions of the northern North Sea. It was a substantial assessment of all physical and biological aspects of the region, with the relevant chapters totalling 706 pages. SEA4 covered the waters to the north and west of the case study region and consisted of 801 pages of baseline ecological information in the relevant chapters. SEA5 was perhaps the most relevant, as it included the Moray Firth and Forth and Tay regions and provided 192 pages of information on the ecology of the region. Thus, although the assessment of environmental impact related to potential licensed offshore oil and gas activities, these SEAs provided a substantial review of baseline conditions relevant to the case study area.

In 2007, a UK governmental ‘‘white paper’’ entitled ‘‘Meeting the Energy Challenge’’ defined two key challenges for the country: the need to reduce greenhouse gas emissions, and the need for secure, clean and affordable energy independent from imports. To tackle these challenges, the government set itself the target of leasing areas of the continental shelf to offshore wind developers in order to generate 25 GW of electricity by 2020. This strategy of leasing rounds represented a plan which required a SEA under the 2004 regulations. Hence, after 2007, the UK SEA process changed from one focussed just on oil and gas extraction to one focussed on UK plans for offshore energy, including plans for offshore wind. Four such Offshore Energy SEAs (OESEA) have been published so far.

OESEA1 (2008) considered the UK continental shelf, divided into ‘‘Regional Seas’’. Regional Sea 1 included the case study region. The assessment of the impact of plans for developing offshore wind was restricted to water depths < 60 m, but in Scotland excluded the coast to

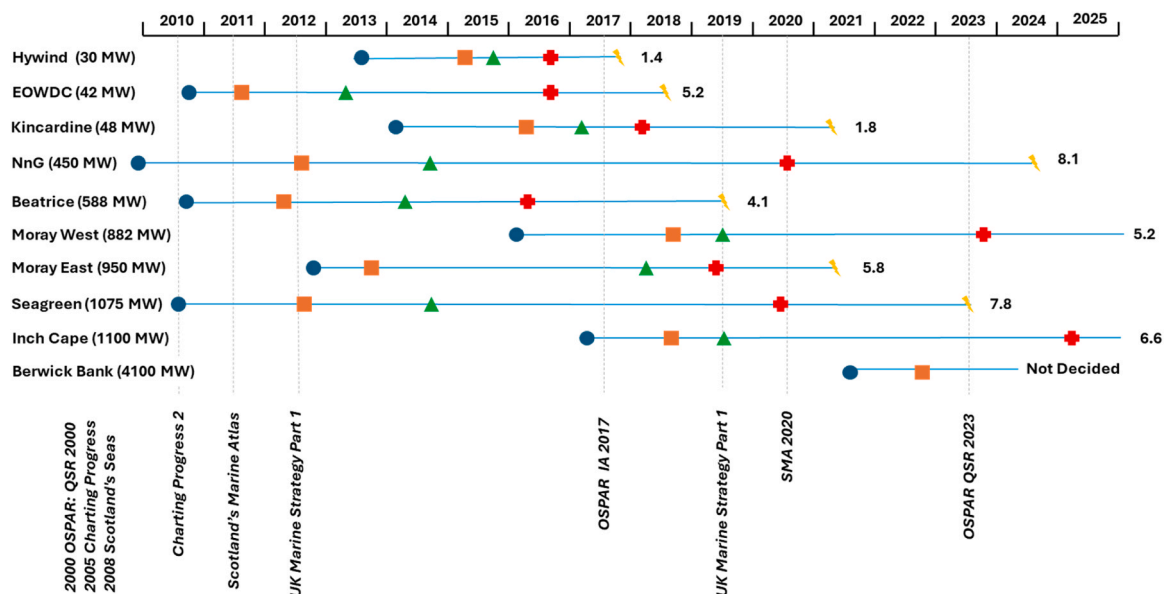


Fig. 1. The timeline from the start of the consenting process (submission of Scoping Report) to when an OWF becomes operational for ten Scottish North Sea OWFs. Milestones along each timeline are: Blue circle - Scoping Report submission; Orange square - Environmental Statement (ES) submission; Green triangle - Consent granted; Red cross - Construction starts; Yellow flash - OWF becomes operational. Vertical dashed lines indicate when SEAs were published for this region, with their names given below in italics. Numbers on the right of each timeline indicate the time in years between the Environmental Statement and when construction commences. EOWDC - European Offshore Wind Deployment Centre, Aberdeen Bay. NnG - Neart Na Gaoithe OWF. Note legal processes prolonged the period between consent and construction for the Seagreen and NnG OWFs. These also affected the timing of the Inch Cape EIA process. Detailed times presented in Supplementary Information Section S3.

Table 1

Summary of Strategic Environmental Assessments (SEAs) performed by the UK or Scotland (SCT) in the case study region since the year 2000. Relevant plans or projects which the SEAs were initiated by are also listed. OESEA – Offshore Energy SEA. OGR – Oil and gas licensing round. NNS – Northern North Sea. Web links to all SEAs and Scottish plans are given in the [Supplementary Information](#) (Section S5).

Year	Public Plan or Project	SEA
2000	UK: Offshore Wind Round 1 UK: Offshore OGR 19	UK: SEA 1 (Faroe/Shetland)
2001	UK: Offshore OGR 20	UK: SEA 2 (+Ext) (NNS)
2003	UK: Offshore Wind Round 2 UK: Offshore OGR 22	UK: SEA R2 (3 lease areas) UK: SEA 4 (Shetland / Orkney)
2004	UK: Offshore OGR 23	UK: SEA 5 (Central NS)
2005	UK: Offshore OGR 24	
2007	UK: Offshore OGR 25	SCT: Marine Renewables SEA UK: SEA 7 (W Scotland)
2008	UK: Offshore Wind Round 3 + OGR 26	UK: OESEA1
2010		SCT: SEA of Draft Plan Offshore Wind Energy in Scottish Territorial Waters
2011	UK: Offshore OGR 27/28 SCT: "Blue Seas, Green Energy": A Sectoral Marine Plan for Offshore Wind Energy in Scottish Territorial Waters	UK: OESEA2 SCT: SEA - Scoping study for Offshore Wind Development in Scottish Waters
2016	UK: Offshore OGR 29/32	UK: OESEA3
2017	Scottish Energy Strategy	
2019	Scottish Sectoral Plan for Offshore Wind	SCT: SEA - Sectoral Plan for Offshore Wind
2020	Scottish Offshore Wind Policy Statement Scottish Sectoral Marine Plan for Offshore Wind Energy (2020) Post Adoption Statement	
2021	Offshore Wind Round 4	
2022	ScotWind: 20 Seabed Option Agreements Scotland INTOG	UK: OESEA4

12 nm zone. OESEA1 with its technical annexes represented a further thorough review of baseline conditions in the case study region and its offshore boundaries along with an assessment of the potential impact from OWF developments related to impulsive noise from seismic survey and piling during installation, semi-continuous or continuous noise from turbines or vessels, acute and non-acute physical damage including smothering to seabed features and biota, colonisation of structures by organisms, avoidance of wind farm areas by birds, animal collisions with structures and turbine blades, chemical contamination from discharges and antifouling coatings, and the possible effects of electromagnetic fields associated with electricity transmission. OESEA2 (2011), OESEA3 (2016) and OESEA4 (2022) updated the information in OESEA1 and included offshore areas for OWF development.

For the coastal zone in Scotland, the Scottish Government implemented a series of SEAs to cover their own plans related to the development of offshore wind electricity generation. The first one was performed in 2007 to investigate the potential impacts of wave and tidal power in Scottish territorial waters (0–12 nm). The first SEA in Scotland directly addressing offshore wind developments was published in 2010 (Table 1). This SEA presented baseline information and an assessment of the potential impacts of OWFs within potential licensing areas, two of which were in the case study region. The Scottish SEA published in 2011 was not a formal SEA, but rather a scoping study of potential sites for OWF development. It did include, however, baseline information for the case study region. The SEA published in 2019 was a full SEA in relation to the Scottish Government’s “Scottish Sectoral Plan for Offshore Wind” and included ten new licensing areas in the case study region. As with previous offshore wind related SEAs, it examined the baseline conditions in these areas and assessed the potential impacts of OWF developments.

3.2.1. Accessibility in 2025

Currently all of the SEAs in the UK series of SEA 1–7, OESEA 1–4 are readily accessible on the UK Government’s information portal (see SI for all links). The first Scottish SEA published in 2007 is not readily available. The non-technical summary was found on the Tethys web archive (this archive hosts documents, information, and resources about the environmental effects of marine energy and wind energy and is sponsored by the US Department of Energy), but none of the technical annexes could be located. The Scottish 2010, 2011 and 2019 SEAs are readily accessible on the Scottish Government’s web site.

3.3. SEcAs

There have been eleven SEcAs completed that include the study region since the year 2000 (Fig. 2). These have been implemented under national (UK and Scottish) and regional (OSPAR) SEcA frameworks. While a 6-year SEcA cycle has not quite been achieved in the UK or Scotland, it has in a regional context with OSPAR SEcAs (Fig. 2).

3.3.1. National (UK)

The first UK SEcA was performed in 2005 as Charting Progress, which was updated in 2010 by Charting Progress 2. The EU MSFD came into regional legislation in 2008 and this was transposed into UK legislation in 2010 by the UK Marine Strategy Regulations. Hence subsequent SEcAs were performed under these regulations in 2012 and 2019 (UK Marine Strategy Part 1, 2012 and 2019).

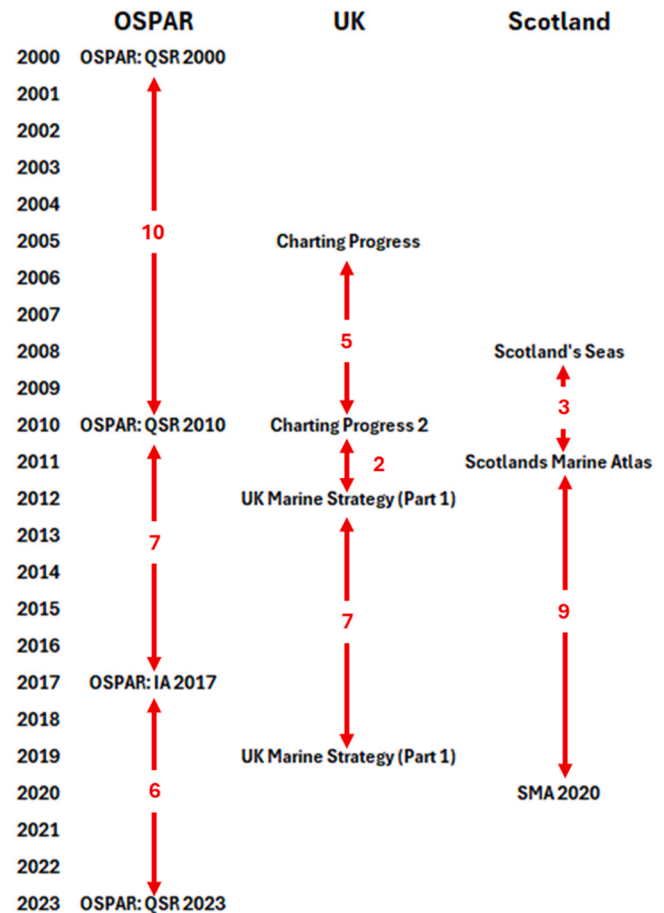


Fig. 2. The timing of SEcAs by year of publication in the case study region as performed regionally by OSPAR, and nationally by the UK and by Scotland. Red numerals indicate the spacing in years between assessments. The EU MSFD stipulates a 6-year repeat cycle for SEcAs. Links to all named assessments given in [Supplementary Information](#) Sections S5 and S7.

Charting Progress (2005) was heavily text based, built around case studies and examples of ecosystem component health. There were detailed supporting evidence reports based on impact sectors (fish and fishing, environmental quality, habitat and species, processes and climate). One table provided a Red-Amber-Green (RAG) “traffic light” type summary of the overall status of some ecosystem components of UK waters, with brief summaries for sub-regions including the northern North Sea.

In contrast to Charting Progress (2005), Charting Progress 2 (2010) had assessments of status presented regionally in maps for many ecosystem components, allowing easy interpretation of the assessment results. This was aided by a consistent approach to summarising the status using RAG coloured symbols and trends using arrows within the RAG symbols between all ecosystem components and all regions.

The UK Marine Strategy Part 1 (2012) was the first time a SEcA in the UK was implemented using MSFD descriptors, indicators and criteria, providing a more formal assessment process. This document explains that Good Environmental Status (GES), and associated targets and descriptors, would be defined in 2012, monitoring programmes would be established in 2014, a programme of measures would be established in 2015. However, as a SEcA, the UK Marine Strategy Part 1 (2012) was rather sparse. Its principal aim was to define the future process for MSFD-related assessments and it only presented a brief summary assessment, in text form, for individual MSFD ecosystem descriptors and for all UK waters. To do this, it drew heavily as evidence on Charting Progress 2 (2010), augmented with Scotland’s Marine Atlas (2011), as its evidence base.

The UK Marine Strategy Part 1 (2019) presented for the first time for UK waters the result of a systematic SEcA using the full set of MSFD Descriptors. A useful overall summary was included with RAG coloured symbols for status, and arrows for trends, in a similar manner to Charting Progress (2005) and Charting Progress 2 (2010).

3.3.2. Accessibility in 2025

At the time of writing (2025), this author could not locate full copies of Charting Progress or Charting Progress 2 using a standard internet search engine, except on the Tethys web archive (tethys.pnnl.gov). In 2025, individual Charting Progress and Charting Progress 2 pages and sub-reports were available at various UK government-related archives, but these were all incomplete and reside in obscure locations. The UK Marine Strategy Part 1 (2012 and 2019) were both available as single downloadable PDF files on the UK Government’s web site. These assessments were supported by an interactive web site named the Marine Online Assessment Tool (MOAT), which presented the supporting evidence for the more complete 2019 SEcA.

3.3.3. Scotland

As part of the MSFD and related marine spatial planning EU legislation, devolved nations in the UK began to formulate their own marine plans. As supporting evidence for these plans in Scotland, SEcAs were performed in 2008 (Scotland’s Seas), 2011 (Scotland’s Marine Atlas), and 2020 (Scotland’s Marine Assessment 2020).

Scotland’s Seas (2008) was a preliminary report leading to the more comprehensive assessment in 2011. While it provided more details related to methodology than status assessments themselves, some MSFD status indicators were discussed, as well as Scottish Biodiversity Indicators (e.g., their Table 4.2). However, there was a mix of ways of expressing status between ecosystem components, and clear messages were difficult to extract.

Scotland’s Marine Atlas (2011) used a similar method to display the results of its assessment as the UK’s Charting Progress 2 (2010) and the OSPAR QSR (2010), i.e. using RAG-coloured symbols to indicate status and associated arrows to indicate trend. This assessment split the Scottish North Sea region into 6 sub-regions (Forth, East Scotland Coast, Moray Firth, Forties, Fladen, East Shetland) and reported assessments for all six.

Scotland’s Marine Assessment 2020 presented an overall assessment summary in a downloadable document using RAG coloured symbols and arrows for trends, for key biodiversity-related ecosystem elements in a similar way to that used in the 2011 SEcA. While the overall summary pulled together results for all Scottish sea regions, an interactive web-site presented more detailed assessments using the same sub-regions as in 2011.

3.3.4. Accessibility in 2025

For Scotland, Scotland’s Seas (2008) was still available in 2025 as a single PDF file on a Scottish Government website. Scotland’s Marine Atlas (2011) was available as separate chapters as HTML pages on a SG web site, although no downloadable PDF was available. A single downloadable version was available for purchase on Amazon for the Kindle digital book reader. Scotland’s Marine Assessment 2020 was primarily an interactive web-based product, although a downloadable PDF is available for the overall summary.

3.3.5. Northeast Atlantic (OSPAR)

Under the OSPAR process, the first SEcAs for all sub-regions within the OSPAR region (essentially the northeast Atlantic) were published in 2000 (OSPAR QSR 2000). In essence, this was a fundamental review of all available scientific evidence regarding pressures and ecosystem state in the region. Each sector and theme was presented in different ways, depending on the available sources of information, and there were no systematic and consistent use of indicators. The overall assessment (Chapter 6) lists human pressures in five priority classes but provides little in the form of ecosystem element status assessment.

The OSPAR QSR 2010 followed a very similar systematic approach as followed by Charting Progress 2 in the UK, presenting very easily digestible maps with ecosystem element status (RAG symbols) and trends (arrows) for all ecosystem components used, although fewer were included.

The OSPAR Intermediate Assessment 2017 utilised the MSFD Descriptors in its assessment. As this was an intermediate assessment rather than a full assessment, a variety of summary graphics were used, with no overall RAG-type symbols presented. Presentation methods varied between Descriptors. There was an overall summary of highlight concerns for the entire OSPAR region, presented in text form.

The OSPAR QSR 2023 presented detailed maps summarising ecosystem element status within each of the OSPAR sub-regions, including the Greater North Sea. The methodologies employed mirrored those of the EU MSFD. RAG-type symbols were used to indicate status related to relevant definitions of GES for mammals, seabirds and fish. No overall assessment was provided for the status of the seabed, or the presence of contaminants. The assessment of invasive non-native species (INNS) focussed on the trend in introductions and not status.

3.3.6. Accessibility in 2025

The OSPAR QSR 2000 and QSR 2010 were accessible in downloadable and citable PDF format in 2025. The OSPAR Intermediate Assessment 2017 and the OSPAR QSR 2023 were only available as interactive web-sites at the time of writing this paper. No downloadable, or citable documents were available for these later assessments.

3.4. Summary of the SEcAs in the case study region

Fig. 3 summarises the highlight messages from each of the eleven SEcAs performed for the case study region. These are assumed to encapsulate the main concerns the authors of each assessment wished to convey to users of the assessments. Each assessment has more detailed sub-reports and evidence associated with them, with varying degrees of accessibility at the current time (2025). Many of the eleven assessments include assessments of pressures along with assessments of status. However, here, the assessments of status of ecological elements are focussed on, rather than pressures.

Year	Evidence Generation	Region	Mammals	Birds	Fish	Seabed	Contaminants	INNS	Litter	Noise	
2000	OSPAR: QSR 2000	GNS	Status not assessed	Status not assessed	A primary concern	State of seabed not assessed	A primary concern	Status not assessed	Still a problem	Status not assessed	PDF
2005	Charting Progress	UK-NS	Poor data highlighted	Status briefly discussed	Outside safe limits	Localised state details unknown	Legacy issues in hotspots	Introduction from shipping	Beach litter highlighted	Status not assessed	PDF
2008	Scotland's Seas	SC-NS	Harbour seals	Breeding seabirds	Stocks status fluctuating	97% of SACs good	Legacy issues in hotspots	INNS deteriorating	Beach litter continues	Status not assessed	WEB
2010	Charting Progress 2	SCW	Harbour seals	Some problems	Some problems	Many problems	Some Problems	Absence of data	Some Problems	No data	PDF
2010	OSPAR: QSR 2010	GNS	Not enough data	No RAG assessment	Many Problems	No RAG assessment	Many Problems	Not assessed	Many Problems	Not enough data noted	PDF
2011	Scotland's Marine Atlas	East Shetland	Harbour seals	Many Concerns	Some Concerns	Some Concerns	No Concerns	Not assessed	No Concerns	Status not assessed	WEB
		Fladen	No Concerns	Some Concerns	Some Concerns	Some Concerns: Shelf sediments	No Concerns	Not assessed	Not assessed	Status not assessed	WEB
		Moray Firth	Harbour seals	Some Concerns	Some Concerns	Many Concerns	No Concerns	Not assessed	Some Concerns	Status not assessed	WEB
		Forties	No Concerns	Some Concerns	Some Concerns	Many Concerns	No data	Not assessed	Not assessed	Status not assessed	WEB
		E Coast	Harbour seals	Some Concerns	Some Concerns	Many Concerns	No Concerns	Not assessed	Some Concerns	Status not assessed	WEB
2011		Forth	Harbour seals	Some Concerns	Some Concerns	Many Concerns	Some Concerns	Not assessed	Some Concerns	Status not assessed	WEB
2012	UK Marine Strategy (Part 1)	UKW	Harbour seals	Substantial declines	Fish community impacted	Widespread impacts	Coastal areas	60 INNS species	Concern in all areas	Status not assessed	PDF
2017	OSPAR: Intermediate Assm.	NE Atl.	Mixed signals	In Trouble	Affected by fisheries	Concerns remain	Not a Highlight	signs of recovery	A Problem	Not a Highlight	WEB
2019	UK Marine Strategy (Part 1)	UKW-NS	GES uncertain	Not achieved GES	Not achieved GES	Not achieved GES	Largely achieved GES	Not achieved GES	Not achieved GES	Uncertain	PDF
2020	SMA 2020	SCW	Harbour seals	Some concerns	No concern	Many concerns	No RAG assessment	Lack of Data	No RAG assessment	No RAG assessment	PDF
2023	OSPAR: QSR 2023	GNS	Not at GES	Not at GES	Not at GES	No assessment possible	No RAG assessment	No RAG assessment	No RAG assessment	No RAG assessment	WEB

Fig. 3. Summary of the assessment of status of key marine ecosystem elements relevant to the consenting and licencing of offshore wind developments in published Strategic Ecosystem Assessments (SEcAs) which include the North Sea region of Scottish waters. Region codes: GNS – Greater North Sea; UK-NS – UK sector of North Sea; SC-NS – Scottish sector of North Sea; SCW – Scottish waters. NE Atl. – Northeast Atlantic. PDF – available (2025) as a downloadable PDF file. WEB – only available (2025) as a web-based interactive page. Current (2025) links to sources are given in the Supplementary Information Section S7.

It can be seen from Fig. 3 that the principal messages conveyed by the SEcAs regarding ecosystem elements of concern in the case study region have been variable over the last two decades. There is no ecosystem element with a consistent message, or consistent trend, between assessments. The status of mammals, seabirds, fish and the seabed do raise either amber or red warnings of status most often. The status of an ecosystem element may truly vary between assessments, or the criteria used by authors of each assessment may vary. It is to be hoped that the MSFD-based process may introduce a more rigorous approach to ecosystem health assessment, with quantifiable indicators and criteria.

Noise, invasive species and litter can all be viewed as both pressures and ecosystem elements. As ecosystem elements, the status of ambient noise levels has never been assessed but was commented on by the 2019 UK Marine Strategy Part1. The status of invasive species and litter has been assessed more often by published SEcAs.

Foden et al. [5] reviewed the methodologies utilised globally in SEcAs. They noted that one advantage of using a RAG-type traffic light

system is that it makes it easier to track changes between time periods in different assessments. Fig. 3 suggests that authors of the current set of SEcAs in the case study region have not yet achieved a coordinated approach and one which can track changes in the status of ecosystem elements through time.

Despite the limitations described above, the eleven SEcAs in the case study region do provide evidence which EIA / CIAs could utilise. The highlighted concerns could be used by competent authorities to ensure all relevant topics have been included at the scoping stage of a development application. The detailed sub-reports and sub-chapters that support the highlights of an SEcA could be used by authors of EIAs / CIAs to relate potential impacts of a development to existing ecosystem health status in the area under assessment.

4. Interrelationship between EIAs/CIAs, SEAs and SEcAs

This section briefly examines whether in practice the ten EIAs / CIAs

Year	Type	Assessment	N Uses	2011 Aberdeen	2012 Beatrice	2012 NnG	2012 Seagreen	2013 Moray East*	2015 Hywind	2016 Kincardine	2018 Moray West	2018 Inch Cape	2022 Berwick Bank
2000	SEcA	QSR 2000	1	SOI	X	X	X	X	X	X	X	X	X
2005	SEcA	Charting Progress	0	X	X	X	X	X	X	X	X	X	X
2007	SEA	SEAS 1 TO 7	6	SOI	SOI	SOI	SOI	X	X	X	X	X	X
2007	SEA	Marine Renewables SEA	4	X	X	SOI	SOI	X	SOI	SOI	X	X	X
2008	SEcA	Scotland's Seas	0	X	X	X	X	X	X	X	X	X	X
2009	SEA	OESE1	3	X	SOI	SOI	SOI	X	X	X	X	X	X
2010	SEcA	Charting Progress 2	0	X	X	X	X	X	X	X	X	X	X
2010	SEcA	OSPAR QSR 2010	2	X	X	X	SOI	ASM	X	X	X	X	X
2010	SEA	SEA of Draft Plan	6	X	SOI	SOI	SOI	X	X	SOI	SOI	SOI	X
2011	SEA	OESE2	2	X	X	X	SOI	X	X	X	SOI	X	X
2011	SEA	Scoping Study	0	X	X	X	X	X	X	X	X	X	X
2011	SEcA	Scotland's Marine Atlas	4	SOI	SOI	SOI	X	X	X	X	X	X	SOI
2012	SEcA	UK Marine Strategy (Part 1)	0					X	X	X	X	X	X
2016	SEA	OESE3	1						X	X	SOI	X	X
2017	SEcA	OSPAR IA 2017	1								X	X	ASM
2019	SEA	SEA SC - Sectoral Plan	0									X	X
2019	SEcA	UK Marine Strategy (Part 1)	0									X	X
2020	SEcA	SMA 2020	1									X	SOI
2022	SEA	OESE4	na										
2023	SEcA	OSPAR QSR 2023	na										

Fig. 4. The use of SEcAs and SEAs as evidence presented to the competent authority the case study region by ten individual OWF developments in Environmental Statements (i.e. their EIA and CIA). IOS (green shade): The indicated SEA/SEcA was used as a source of information only. ASM (red shade): The ES cited an assessment in a SEcA and used this to place at least one EIA/CIA topic into context. Red cross – no reference to SEA/SEcA in the ES. Grey shading – indicates SEA/SEcAs published after the respective ES, hence not relevant. N Uses – the number of times the SEA or SEcA has been cited by ESs. Dates refer to the year of publication of an ES / SEA / SEcA. NnG - Neart Na Gaoithe OWF.

published in ESs in the case study region have utilised the available SEAs and SEcAs. Each of the ten ESs was reviewed in order to identify the use of SEAs and SEcAs. The results are summarised in Fig. 4. Full details of cross-referencing are given in SI Section S12.

All EIAs/CIAs refer to at least one SEA or SEcA, and most refer to multiple assessments. However, the majority of these references are used as sources of information only. Only two EIAs used the status assessment presented in a SEcA, and then only in a very marginal way. The Moray East EIA used the OSPAR 2010 QSR to discuss the status of invasive non-native species in the region of the proposed OWF. The 2019 Berwick Bank EIA discusses the assessed status of breeding seabirds from the OSPAR Intermediate Assessment 2017. It can be noted that Willstead et al. [16] also found variability in how evidence was utilised by UK OWF EIAs in their study of nine ESs.

From the perspective of SEAs and SEcAs, Charting Progress (2005), Scotland's Seas (2008), Charting Progress 2 (2010), the 2011 Scottish Scoping Study, the 2012 and 2019 UK Marine Strategy (Part 1) assessments and the 2019 SEA for the Scottish OWF sectoral plan have never been cited by any EIA/CIA. It should also be noted, however, that several ESs utilise the data layers presented in the Scottish Government's National Marine Plan Interactive (NMPi) data portal. This portal presents information from Scottish SEcAs, but also a large range of additional information from external sources. It is impossible from the ESs to determine which data layers were actually used.

In summary, the inter-relationship between SEAs, SEcAs and EIAs/CIAs in the case study region has not been extensive. The strategic assessments have been variously used as sources of information rather than their assessments of status being used to set the regional context for local assessments. It is obvious that as time progresses, the older strategic assessments will become less relevant, but this factor does not explain the lack of links between EIAs/CIAs, SEAs and SEcAs published since 2000.

From Fig. 1 it can be seen that several of the ten EIA processes performed in the case study region since the year 2000 have exceeded the target 6-year cycle of SEcAs in the area. Table 2 presents the total time in years for individual steps in the EIA process for the ten EIAs. The average time between the submission of a Scoping Report and the

commencement of the operation of an OWF in the case study region is 9.3 years, which is longer than the interval between SEcAs for the area. Fig. 5 suggests that as OWFs become larger and more complex, the time taken by the whole development process becomes longer. If the status of key ecosystem elements changes between SEcAs, it might be questioned whether updates of the consenting processes may be needed if the start of construction is delayed beyond a relevant time period.

5. Supporting research

In the case study region, authors of EIAs and CIAs clearly do not currently utilise SEAs and SEcAs to their full extent. The principal source of evidence cited in the ten ESs were peer-reviewed published scientific studies. For example, the Moray East ES used a total of 439 citations, 217 of which were peer-reviewed science papers. A brief search of the peer-reviewed literature (Fig. 6) reveals two things. Firstly, the number of papers being published each year on the topic of the potential impacts of offshore wind developments on the ecosystem is growing exponentially. Secondly, the number of potentially impacted ecosystem elements being studied is also growing. At the turn of the 21st century, the principal impacts being studied were impacts on birds through collision and displacement, and the impact on marine mammals from impulsive noise. Currently (2025) a much greater range of impacts are being studied, including physical effects such as changes in ocean circulation and turbulence, changes in primary and secondary production, changes in fish reproduction, abundance and distribution, impacts on the seabed and benthos, the effects of electromagnetic fields and the release of litter, contaminants and invasive species. It may be expected that the increase in the number and diversity of studies will continue, and hence the task of authors of EIAs and CIAs and those that assess them will grow in complexity. While substantial literature reviews are becoming available (e.g., [4,6,10]), regional SEcAs and more particularly regional SEAs could be used to provide periodic strategic reviews of the current peer-reviewed science in order to identify the principal issues and key science for any particular region or development area, tailored towards the OWF technology (e.g., construction method, foundation type, turbine size, etc.) being proposed for that region.

Table 2

Times in years between key events in the development of ten offshore wind farms (OWF) in the case study region. ES: Date of submission of Environmental Statement. CON: Date of issuing of Section 36 consent. CST: Date of start of construction. SCR: Date of submission of Scoping Report (i.e., start of process). OPN: Date of start of operation (i.e., end of process). na: OWF not yet operational (2025). Dates can be seen in Fig. 1. Shaded cells indicate steps in the process which took longer than the 6-year cycle of SEcAs. Generating power and number of turbines are as constructed. NnG - Neart Na Gaoithe OWF. Note that a number of factors are involved in determining the time, from submission of a Scoping Report to start of operation, that are outwith the EIA / consenting process, including contractual, legal, financial and engineering constraints and challenges.

OWF	Date of ES Report	Generating Power (MW)	N Turbines	ES to CON	ES to CST	ES to OPN	SCR to CON	CON to CST	SCR to OPN
Hywind	01/04/2015	30	5	0.6	1.4	2.5	2.1	0.8	4.0
Aberdeen Bay	01/08/2011	42	11	1.7	5.2	6.9	2.7	3.5	7.9
Kincardine	01/03/2016	48	5	1.0	1.8	5.0	3.2	0.8	7.2
NnG	09/07/2012	450	54	2.3	8.1	12.2	4.9	5.8	14.9
Beatrice	01/04/2012	588	84	2.0	4.1	7.3	3.4	2.1	8.8
Moray West	01/08/2018	882	60	0.9	5.2	na	3.5	4.3	na
Moray East	02/08/2013	950	100	4.6	5.7	7.8	5.6	1.1	8.8
Seagreen	01/09/2012	1075	114	2.1	7.8	11.1	4.3	5.6	13.3
Inch Cape	15/08/2018	1100	72	0.8	6.6	na	2.1	5.8	na
Berwick Bank	07/08/2021	4100	307	Not Yet Decided					
<i>Averages</i>				1.8	5.1	7.6	3.5	3.3	9.3

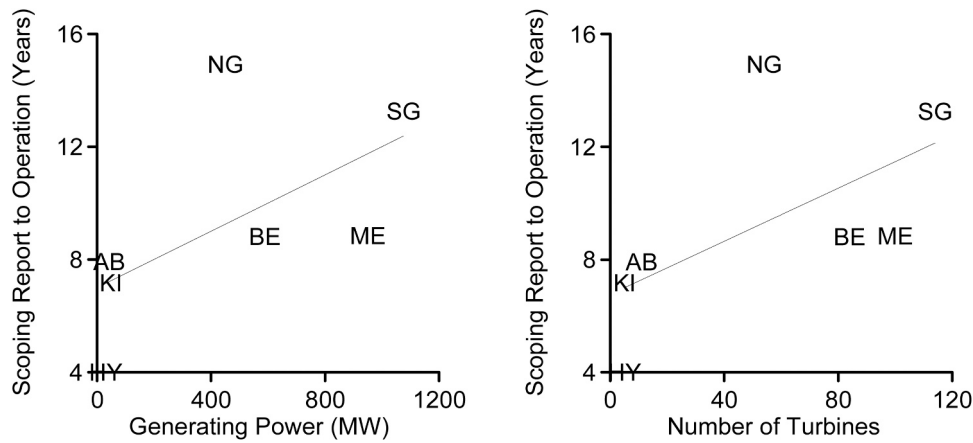


Fig. 5. Time in years between the submission of a Scoping Report to the competent authority and the date a OWF development becomes operational. This represents the duration of the entire EIA / consenting process for nine OWFs in the case study region. Note the tenth OWF (Berwick Bank) has not completed the entire process at the time of writing (2025). Wind farm codes: HY - Hywind. AB - Aberdeen Bay. MW - Moray West. BE – Beatrice. KI – Kincardine. IC - Inch Cape. ME - Moray East. NG – Neart Na Gaoithe. SG – Seagreen. BB - Berwick Bank. Durations of sub-parts of the process are given in Table 2. All date details are presented in SI Section S2. Thin lines represent least-squares fits to the data.

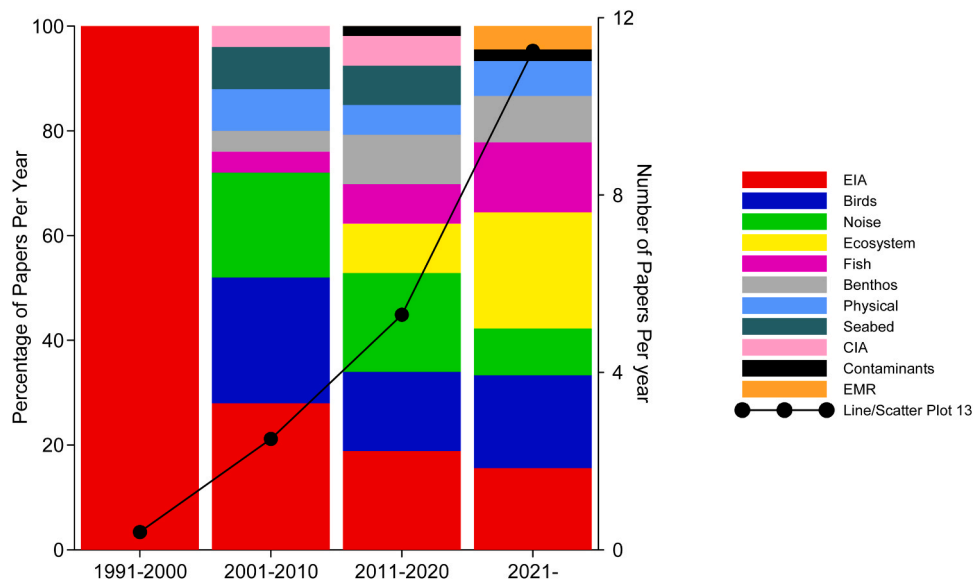


Fig. 6. Summary of the numbers of papers per year (black line) published in three decadal periods (1991–2000, 2001–2010, 2011–2020), and a more recent four year period (2021–2024) which address the impact of offshore wind developments. A Google Scholar search was used on the terms “offshore wind” and “impact” in the title of English language scientific papers, noting only those relevant to environmental impacts (i.e., excluding impacts on grid power, meteorology, visual impacts, etc.) and with duplicates and citations removed. All papers were assessed for the ecosystem element (i.e., seabirds, marine mammals, marine fish, benthos, seabed physical state, water column physical state, contaminant concentrations, noise levels, EMR levels) they primarily addressed. Papers identified by the search also discussed EIA and CIA methodologies. Analysis details given in Supplementary Information.

A second source of evidence used by authors of ESs is that of industry sponsored scientific reports or reports arising from other EIA/CIA processes. Often these are not published in publicly accessible journals but are published on web sites related to the industry. As an example, the Moray East Scoping Report published in 2010 was analysed for such citations. In total, the report used 118 citations in its bibliography, of which 37 relied on web addresses as the reference. A total of 33 of these web addresses were invalid in 2025 (89 %).

6. Monitoring

No assessment, whether EIA, CIA, SEA or SecA, can be performed without current data describing all relevant aspects of the ecosystem. This is provided by in situ monitoring. All of the frameworks described above require in one way or another in situ monitoring.

6.1. EIA/CIA monitoring

The EIA legislation does not directly include provisions for monitoring. However, monitoring to support the EIA / CIA process is required by the consenting legislation in the case study area as post-consent monitoring requirements are incorporated into licence conditions [12]. This monitoring aims to “validate, or reduce uncertainty in, predictions of environmental impacts recorded in supporting EIAs” and to “provide evidence on the effectiveness of mitigation measures to inform future decisions through adaptive management processes”. Post-consent monitoring is often targeted on specific habitats or species. CIAs often require complex modelling to assess the cumulative effects of human activities on a regional scale around a proposed OWF. This modelling itself generates extremely useful data which can be used to inform an SecA. More details on the consenting legislation in the case study region

is given in SI Section S8.

6.2. SEA monitoring

Article 10 of the EU SEA Directive states that “Member States shall monitor the significant environmental effects of the implementation of plans and programmes”, and that “existing monitoring arrangements may be used if appropriate, with a view to avoiding duplication of monitoring”.

6.3. SEcA monitoring

Article 11 of the MSFD states that “member states shall establish and implement coordinated

monitoring programmes for the ongoing assessment of the environmental status of their marine waters” and goes on to list the elements that should be monitored. The Directive also states that monitoring programmes need to be compatible within subregions and should “build upon” other monitoring stipulated by other legislation and “international agreements”. Member states are required to describe their monitoring in Part 2 of their marine strategies, published every 6 years.

Annex IV of the 1992 OSPAR Convention specifies that contracting parties will undertake monitoring within the OSPAR region of “the quality of the marine environment and each of its compartments, that is, water, sediments and biota”. OSPAR’s Coordinated Environmental Monitoring Programme (CEMP) aims to deliver comparable data from across the OSPAR region to support the set of OSPAR SEcAs.

6.4. Summary

All of the legislative frameworks requiring EIAs, CIAs, SEAs and SEcAs also require supporting in situ monitoring, although the details of this monitoring can vary. The monitoring that is required aims to document the same key ecosystem elements, but on varying spatial scales associated with individual OWFs, OWF development areas, subregions (e.g., the Scottish sector of the North Sea) and regions (e.g. the Greater North Sea). Using the principle of “collect once, use many times”, there is a clear benefit of coordination between these scales and between the different statutory frameworks that are driving in situ monitoring in the case study region, as well as regional-scale modelling performed for CIAs. Currently, data ownership issues and different data management structures that exist in the commercial, academic and governmental monitoring communities can hinder data sharing. Licensing authorities, competent authorities and national governments have the ability to overcome these issues given the desire and resources to do so.

7. Discussion

From the evidence presented here, it is clear that links between the EIA/CIA process and the SEA and SEcA processes have not been fully established for the ten case-study OWF developments. It is important to note that a closer coordination between the EIA/CIA and SEA and SEcA processes would not in any way change the outcome of the associated ten Electricity Act consent applications. The concerns SEcAs highlight in their assessments in the case study region have all been addressed by all ten EIAs, and by their assessment by the competent authority. This is because, in the case study region during the period 2000–2025, the principal authors of all SEAs and SEcAs were also statutory consultees in the consenting process owing to their professional posts within consultee agencies, hence were fully aware of the major ecological concerns in the region. However, this circumstance may not always be the case in the future, or in other regions. If EIAs and SEAs explicitly address the “red flags” of the most recent regional SEcA, this can set an EIA into a formal framework of addressing the current ecological concerns in a region of a proposed OWF rather than relying on these to be raised by

individual consultees in the scoping process.

Fig. 7 demonstrates how the EIA, CIA, SEA and SEcA processes could sit within a coordinated and harmonised system aimed at protecting the marine environment. Evidence in the form of coordinated in situ monitoring, impact modelling and scientific interpretation and assessment should flow between all elements of such a system [2,15]. This will require improved coordination mechanisms, data sharing agreements, and evidence and information sharing web-based portals with robust permanent digital object labelling. All evidence used to support a publicly accessible EIA or CIA should also be published and not withheld owing to commercial confidentiality.

Coordination between the different components of a streamlined EIA / CIA / SEA / SEcA legislative and consenting framework (Fig. 7) could have many benefits. The removal of duplication of effort, in terms of evidence collection, interpretation, modelling and assessment, would aid both the industry and competent authorities. Streamlining the processes may also result in faster consenting times and a reduced risk of legal challenges to consenting decisions, as it will be easier to demonstrate that all principal ecological concerns have been addressed. Currently in Scotland, although the same overarching organisations are involved in EIA / CIA scoping and assessments, and SEA / SEcA evidence collection and assessments, they are often delivered by separate departments with little communication between them. Such internal barriers to improved coordination can be readily removed given the desire to do so, and the necessary governance arrangements.

Wright [17] came to similar conclusions when considering EIAs and SEAs in several case studies globally, including in the case study region. Specifically, he suggested that the EIA process should do more to utilise all available scientific evidence, and that all of the environmental assessment processes (in his case EIA and SEA) require better governance arrangements to ensure the flow of knowledge between them. He also identified the role of SEA in identifying knowledge gaps.

It is clear from Fig. 7 that data sharing and information management is a key function to allow a coordinated, harmonised system to function. This not only requires data sharing agreements, and the removal of commercial confidentiality clauses, but also efficient, searchable, discoverable and durable data and information repositories. Examples presented here demonstrate the ephemeral and inaccessible nature of some web-based information publication mechanisms. The importance of permanent well-managed repositories such as the US Tethys web site (tethys.pnnl.gov) cannot be over emphasised. In the UK, similar repositories such as the Marine Data Exchange (marinedataexchange.co.uk) are beginning to provide a similar function. In the context of data sharing, the FAIR (Findable, Accessible, Interoperable, and Reusable) principles for scientific data management and stewardship should be applied (go-fair.org/fair-principles).

In the UK, the current particular emphasis on protected habitats and species, which is specified in the national legislation and implemented through HRAs, may inadvertently remove focus on impacts to the wider ecosystem and biodiversity by an OWF development, which is also specified in the legislation but in more general wording. By forming a clear link between an EIA and the relevant SEcAs that includes the region of a development, it would make it clear that wider ecosystem concerns have also been addressed. SEcAs could also be used to include or exclude specific receptors during the EIA scoping stage.

A clear link between EIAs / CIAs and SEcAs would also be of benefit to the SEcA process itself. The extensive science that goes into CIAs in particular would benefit the next subsequent SEcA. The extensive monitoring, data collection, modelling and assessment that is carried out in a CIA that by necessity includes a large spatial area, often as large as SEcA assessment regions or sub-regions, has not effectively fed into the past SEcA assessment processes owing to the gap that exists between industry science and public body science. Licensing bodies and competent authorities may be able to help close this gap in the future.

Willstead et al. [16] identified methodological weaknesses in regional SEAs and SEcAs especially when evaluating cumulative effects

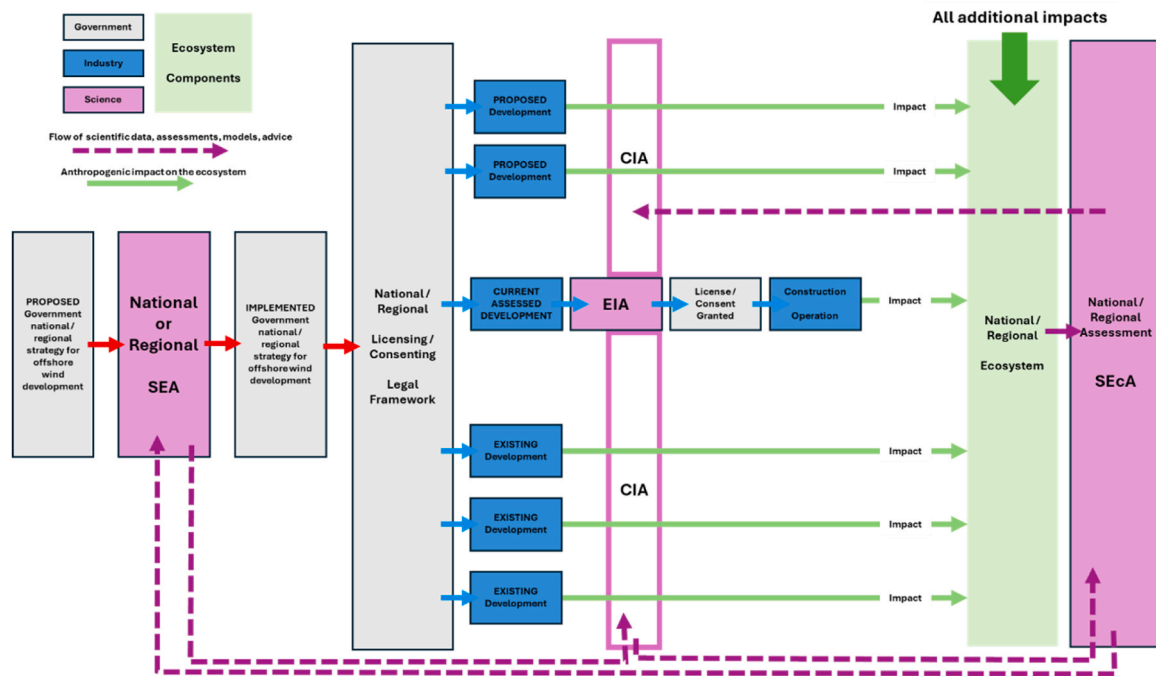


Fig. 7. Relationships between Environmental Impact Assessments (EIAs), Cumulative Impact Assessments (CIAs), Strategic Environmental Assessments (SEAs) and Strategic Ecosystem Assessments (SEcAs) in the process of planning, developing, consenting and implementing offshore wind farms. Purple dashed arrows show the flow of evidence between processes in a harmonised system. The EIA/CIA is implemented as a linked process.

within a region. They propose changes that could improve both CIAs and SEAs and they note the weak relationship currently between project-level EIAs and regional-level SEAs. They also note that individual CIAs conducted for OWF developments represent a vital source of information for regulators, marine managers and their statutory advisers. Declerck et al. [2] proposed the need for improved coordination between the MSFD process and the CIA process in relation to offshore wind developments, focussing on marine spatial planning frameworks, and CIA in relation to bottom-up ecosystem controls influenced by offshore wind developments. They also identified the need for greater coordination of legislative processes, as well as evidence collection, assessment and modelling.

The lack of reference to SEAs by many of the ten case-study EIAs is puzzling, as the SEAs offer an excellent source of collated evidence which would have benefited the authors of these assessments. However, the accessibility of this evidence can be problematic, especially as a SEA ages. Public authorities that are obliged to run SEAs for their plans should ensure that the supporting evidence is well archived and made readily accessible for the long term. SEAs can also guide developers to consider specific mitigation or monitoring actions that have been identified at the strategic level, and which need to be implemented at the individual project level.

Many of the SEcAs reviewed here primarily aim to demonstrate a region's progress towards GES. This is not essential for consenting or planning purposes. What is needed is a clear highlighting of the primary ecosystem elements for specific geographic areas which an assessment finds are of current and potentially future concern, and why they are of concern. It is the potential impacts on these elements and areas which should be examined in detail by a licensing authority during the scoping stage when a development is being planned. However, there will most likely always be a tension when authoring an SEcA between a national or regional government's wish to demonstrate their plans and policies are leading to environmental improvement, and the need to highlight explicitly the components of an ecosystem which have been most damaged, and which hence require greatest consideration.

As the complexity and size of OWF applications increases, so does the

time which elapses between the start of the EIA process and either the start of construction or the start of operation. In the case of seven existing OWFs in the Scottish sector of the North Sea, for two (construction) and six (operation) of these OWFs these times exceeded the 6-year cycle of SEcAs in the region (Table 2). While it may be expected that the status of relevant ecosystem elements may not change significantly between SEcA cycles, this is not necessarily true, especially as pressures mount within the ecosystem. Hence an update process may need to be considered for protracted periods between EIA statements and OWF construction / operation.

8. Conclusions

8.1. Relevance to member states and competent authorities

Focus may need to be applied to the integration and coordination of the EIA/CIA, SEA and SEcA processes. This would have the benefits of:

- Improved harmonisation of legislation aimed at protecting the marine environment.
- Assurance that the EIA/CIA process is properly addressing impacts on the ecosystem and biodiversity.
- Assurance that regional SEAs and SEcAs utilise the best available evidence.
- Assurance that best value for money is being achieved from investments in marine environmental monitoring and assessment.

8.2. Relevance to EIA authors

Authors of EIAs would benefit from better access to SEA and SEcA assessments and their related evidence bases. These offer a huge, ready-assembled resource for the authors of EIAs.

Greater effort should be applied to ensure industry-sourced evidence in the forms of reports published on web sites, and their supporting data, are permanently available. This may need coordinated evidence archives which use robust archiving techniques such as digital object

identifiers.

8.3. Relevance to SEcA authors

While web-based interactive products are excellent to allow the general public access to the results of SEAs, they are not ideal as evidence for planners, licensing authorities or industrial developers. If assessments are released through web-based interactive portals, a single supporting document should be considered for planners, licensing authorities and developers which is dated, citable and properly archived, preferably in a universal format such as the PDF format.

Web-based products are vulnerable to being lost, despite all best intentions to maintain them. Using web-based assessments is not always a secure method of documenting ecosystem status at a point in time for future reference and better archiving systems, probably employing tools such as doi labelling, could be used.

A disadvantage of web-based only assessments is that they can be, and often are, updated with no way of tracking previous versions. It is important when considering baselines and assessing impacts compared to baselines that the evidence is secured for individual moments in time, and that such evidence is citable and easily accessed at any time in the future. This can be provided by single, published documents preferably in PDF format and available on the internet.

The year which an assessment relates to should be clearly stated. This is not necessarily, and is generally not, the year of publication of an SEcA as a whole. The year which the assessment of each ecosystem element in a single SEcA may be different. Generally physical elements (e.g., temperature, litter) have data that are almost real-time, whereas biological elements (e.g., mammal population size) may have data which is several years “old” when an SEcA is published. Hence each individual SEcA element should have the year it relates to explicitly stated. SEcAs should also attempt to detect trends in ecosystem elements, and provide the explicit time-period over which these trends may likely persist for each element.

To maintain the credibility of SEcAs, and to facilitate their use in formal statutory processes such as EIAs, SEcAs should explicitly refer back to the most recent prior SEcA in a region and explanations given as to why the status or concern level associated with an individual ecosystem element has changed between assessments, if they have changed.

A single, identified “owner” of an SEcA may need to be nominated after it has been published, who can represent the results of the SEcA in any formal consultation process associated with an EIA. This could be a post within the publishing body, agency or government department, and the contact details of the SEcA representative post should be published along with the SEcA itself. These contact details should be valid until at least the subsequent SEcA is published for that region.

8.4. Relevance to marine monitoring

Greater focus could be applied to coordinate in situ monitoring and modelling data sharing between the industry, academic and governmental actors involved in EIA pre- and post-consent monitoring, CIA modelling and SEcA strategic monitoring. Programmes such as the Offshore Wind Evidence and Change (OWEC) programme and the Scottish Marine Energy Research (ScotMER) programme are already promoting joint work between these sectors. Industry on occasions use academic institutions to perform marine monitoring and evidence generation on their behalf, but there still seems to be barriers in data sharing between industry-funded monitoring, whether performed by academia or consultancies, and governmental bodies, and this gap needs to be addressed.

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W.R. Turrell: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of Competing Interest

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.marpol.2025.106890](https://doi.org/10.1016/j.marpol.2025.106890).

Data availability

No data was used for the research described in the article.

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