Faculty of Science and Technology

A critical evaluation of the effectiveness of policy and law protecting UK seahorse populations.

A dissertation submitted as part of the requirement for the BSc Ecology and Wildlife Conservation.

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Abstract

Marine biodiversity experiences pressure from multiple anthropogenic sources, which is leading to accelerating extinction rates. Loss of marine biodiversity will impact ecosystem services, stability and function, having negative impacts for humanity. In response to concerns over anthropogenic impacts on the marine environment, environmental laws have been enacted. There are, however, concerns over the effectiveness of environmental law at alleviating pressures and efficiency of protection legislation provides as marine biodiversity loss is continuing. Native seahorse populations are threatened by these anthropogenic pressures. This study, therefore uses seahorse populations at three UK reference sites with varying levels of pressures and different applicable legislation to evaluate the effectiveness of legal protection. The results, obtained through the use of a Bayesian Belief Network suggest that the current implementation of international, European and national laws will not provide strong protection to seahorses. Furthermore, even a stronger implementation of the laws, will not guarantee strong protection to ensure their survival. The results validate the concerns of non-governmental organisations who suggest the law is not robust enough to protect marine biodiversity. Evaluation of these legal frameworks allows policy makers to make prioritised amendments to strengthen protection, of which recommendations are provided in this study and will aid in ultimately ensuring laws are fulfilling their purpose. This is particularly pertinent as national legislation is transitioning through a fundamental review following departure from the European Union.

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I would like to thank my supervisor Tilak Ginige, for his guidance and support throughout. I am extremely grateful for your time, knowledge and enthusiasm. I also wish to thank Professor Rick Stafford and Molly Bridger for their patience and help with the Bayesian Belief Network. I am most grateful.

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Glossary

BBN- Bayesian Belief Network

CITES- Convention on International Trade in Endangered Species

COTES- Control of Trade in Endangered Species regulations 2018

EIP- Environment Improvement Plan

Fry- young seahorse

GES- Good Environmental Status

IFCA- Inshore Fisheries and Conservation Authorities

IWT- Illegal wildlife trade

MCAA- Marine and Coastal Access Act 2009

MCZ- Marine Conservation Zone

MS- Marine Strategy

MSFD- Marine Strategy Framework Directive (2008/56/EC)

MPA- Marine Protected Area

NERC- Natural Environment and Rural Communities Act 2006

NGOs- Non-governmental organisations

OSPAR- Convention for the Protection of the Marine Environment of the North-East Atlantic

PoM- Programme of Measures

RAMSAR- Ramsar Wetlands Convention

RBD- River Basin District

SAC- Special Area of Conservation

SPA- Special Protection Areas

UKBAP- UK Biodiversity Action Plan

UKBF- UK Border Force

uPBTs- ubiquitous (present, appearing or found everywhere)

WFD- Water Framework Directive 2000/60/EC

WCA- The Wildlife and Countryside Act (1981)

BBN descriptive language modified from Landscape Logic 2010:

1- 0.81 = major probability of increasing

0.80- 0.51 = moderate probability of increasing

0.49- 0.2 = moderate probability of decreasing

0.19 - 0 = major probability of decreasing

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1.0 Introduction

1.1 Identification of marine conservation issues

Marine ecosystems are threatened by anthropogenic pressures including climate change, overexploitation, habitat destruction, invasive species and pollution (Young et al. 2016; Luypaert et al. 2020; WISE Marine 2022). The cumulative effect of these pressures and the rate of ecosystem change means species extinction is occurring at faster rates (WISE Marine 2022). This puts the core planetary boundary of 'biosphere integrity' within the high risk zone (Steffen et al. 2015). Of the IUCN Red List assessed species, 1,550 marine species are at risk of extinction (IUCN 2022); however, the actual status of marine species is still poorly understood and underassessed (IUCN 2023). Marine extinction rate, therefore, is likely to be underestimated. Continued loss of marine species will have a direct impact on ecosystem function, ecosystem services and will jeopardise the stability and resilience of ecosystems (Luypaert et al. 2020). Exceeding the planetary tipping point could result in irreversible system change (Lenton et al. 2019). The UK marine environment is being highly impacted by these anthropogenic pressures (Halpern et al. 2008), such as 86% of habitats within the North Sea being highly disturbed (Vaughan et al. 2020). The status of biodiversity around the British coast is therefore poor (EEA 2021) and further loss of UK marine species will contribute to the negative impacts of biodiversity loss.

Scientific concern over biodiversity loss has led to the push for legal protection for marine species in an effort to alleviate the effect of anthropogenic pressures. Whilst the improved status of some European marine species such as seals has been attributed to better protection policies (Vaughan et al. 2020), concerns remain over how effective law and policy really are, when scientific literature and NGOs demonstrate that destructive anthropogenic activities are allowed to continue under alleged protection (Mazaris et al. 2019; Grorud-Colvert et al. 2021). Furthermore, reports that drivers of biodiversity loss will continue to increase into 2030 (EEA 2019a) highlight the importance of effective legal protection.

Whilst anthropogenic pressures are impacting a wide range of marine species (IUCN 2022), this work uses seahorses, a marine fish, as a case study to demonstrate the impact of pressures and shortcomings of current protection and suggests mitigation strategies. Whilst governments suggest international, European and national regulations protect the marine environment and promote marine ecosystem integrity, this work suggests these laws need to be revised and better enforced.

Seahorses which live in transitional waters are exposed to many anthropogenic pressures putting them at risk of extinction. Loss of seahorses will have direct consequences on the surrounding environment, as they are efficient predators (Sabatini et al. 2021) declines in their abundance could disrupt ecological webs. Their decline would add to the negative impacts of biodiversity loss mentioned above. As an easily recognisable, charismatic species (Jefferson et al. 2014), seahorses could be also used as flagship species in the UK, harnessing funding for their seagrass habitats. Seagrass has the potential for carbon sequestration (Oreska et al. 2020) and is an ecosystem engineer (Smith et al. 2014). Protecting seagrass beds, therefore, will have substantial benefits, making seahorse conservation a priority. Whilst seahorses have not been declared as an indicator species, sensitivities to changes in water temperature (Aurélio et al. 2013), habitat degradation (Project Seahorse 2022a) and chemical pollution (D'Alvise et al. 2020) means they should be perceived as indicator species, alerting us to changes in water and marine habitat quality. Yet, despite being an important, native species, seahorses still face an array of anthropogenic threats including habitat loss (Gubbay et al. 2016).

This work uses a Bayesian Belief Network (BBN) diagram to identify the scale and range of pressures impacting seahorses and then critically evaluates the effectiveness of marine policy and law at protecting three reference seahorse populations (Studland Bay, The Essex Estuaries and The Thames Estuary) in the UK. This approach has the potential to be applied to other species worldwide, to help us understand threats to all marine species. Combining ecological knowledge with reviews of legal protection using BBN allows scientists and conservationists to prioritise conservation efforts and

increase efficiency of policy and law. To date limited studies have used BBN to discuss probabilistic effects of regulations on specific species. Therefore this paper contributes new ways of thinking about assessing and enhancing conservation of marine life.

1.2 Aim

To critically evaluate the effectiveness of policy and law protecting UK seahorse populations.

1.3 The objectives of this research are to;

1. Assess the scientific importance of UK seahorses populations and assess current population status.
2. Critically analyse the scientific literature related to the anthropogenic pressures on UK seahorses.
3. Evaluate current international, European and national laws and enforcement measures protecting seahorses, using Studland Bay, The Essex Estuaries and The Thames Estuary as reference sites.
4. Critically discuss the BBN data obtained with reference to science, policy and law to understand and determine effectiveness of legal protection for seahorse populations within the reference sites.

1.4 How this work will be presented

This dissertation will address whether the law is effectively protecting UK seahorse populations by considering seahorse life history traits, anthropogenic threats, legal enforcement and management measures. The structure comprises introduction and methods, followed by three main chapters- introduction to seahorses, threats to seahorses and overview of applicable laws. Data obtained from the BBN are presented followed by a discussion of findings with reference to scientific literature.

2.0 Method

2.1 Overview

This work evaluates international, European and national laws in relation to their effectiveness at protecting UK seahorses. Inspired by the explanation of the benefits of BBN for conservation within Landscape Logic (2010) and the benefits of combining science with policy and law, this study uses; a systematised literature review, a Bayesian Belief Network and three reference sites with known seahorse populations- Studland Bay, The Essex Estuaries and The Thames Estuary. This allows for comparison of legislation effectiveness, as each site varies in environmental legal protection. The effectiveness of law as a conservation strategy can be evaluated and a determination made about its adequacy in sustaining seahorse populations.

2.2 Systematised literature review

Systematised literature reviews (Grant and Booth 2009) were used both within the BBN diagram process (discussed below) and for the review of applicable international, European and national law. The literature review for the law covered statutes, government policy documents, Lexis+ database and peer reviewed scientific literature.

2.3 Bayesian Belief Network

BBNs create probability models to predict ecological outcomes under uncertain conditions (Landuyt et al. 2013). Within the study, an interaction diagram (Figure 1) was used to present variables, known as *nodes*. Nodes are categorised into: ecological/ biological, management tools, socio/ economic, abiotic, international law, European law and national law. A horrendogram layout is applied to the interaction diagram, with the law nodes on the outer edge, colour coded to indicate international, European and national law (Boyes and Elliott 2014). Direct interactions between the nodes are shown using *edges*, where the influence and confidence of the interaction is defined by colour and thickness (Marcot et al. 2006). Positive interactions (the source node and response node act in the same direction) are shown in green and negative interactions (source

node and response node act in opposing direction) are shown in red (Stafford et al. 2020). The confidence of the interaction increases with line thickness, determined by the IPBES Global Assessment Framework (GAF) (Vanbergen 2016), ranging from ‘inconclusive’ (thinnest) to ‘well established’ (thickest). Nodes and edges were determined using peer reviewed scientific literature, Google Scholar academic books, government reports and The ENDS Report and through expert opinion from a focus group survey (Appendix Ⅰ).

Within the BBN template, nodes are given ‘prior of increasing’ values between 0-1, based on evidence and expert opinion following the literature review, where > 0.5 means the node is likely to increase, < 0.5 it is likely to decrease and 0.5 it has an equal likelihood to increase or decrease (Stafford et al. 2020). If evidence was available for more than one law impacting a node, with different prior of increasing values, the value furthest away from 0.5 was applied. Prior values are provided (Table 3) for reality scenarios which depict how law is currently implemented and extreme scenarios which is how the law could be better implemented. For this study, an approximation of a BBN was used, adapted to simplify necessary interaction parameters, and allow reciprocal interactions and feedback loops. The model was created in Excel as per Stafford et al. (2015), including bootstrapping of parameters using the methods detailed in Stafford et al. (2020). Posterior of increasing results were calculated to provide predictions of how law is currently affecting the three reference sites and to predict possible outcomes if the law was implemented more effectively at each site.

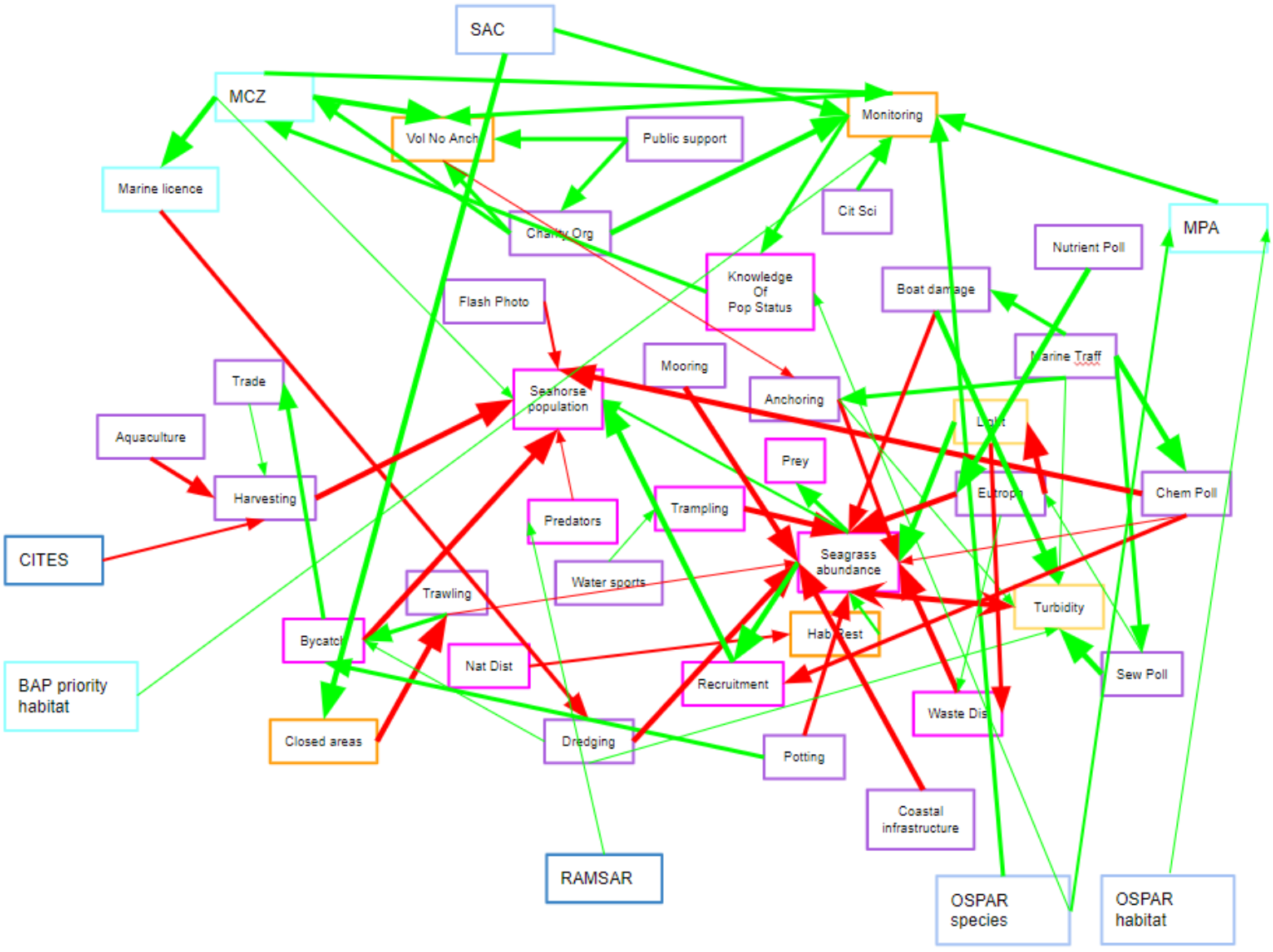

Figure 1: Interaction diagram used for the BBN. Pink nodes indicate ecological/ biological factors, orange nodes indicate management tools, purple nodes indicate social/ economic factors, yellow nodes indicate abiotic factors, dark blue nodes indicate international law, pale blue nodes indicate European law and fluorescent blue nodes indicate national law. Positive interactions are represented by green edges and negative interactions are represented by red edges. The probability of an interaction is depicted by the thickness of the edge, with stronger probability being thicker. See Table 1 below for details of nodes used in the interaction diagram and Appendix I for supporting evidence for each edge.

Table 1: Details of the nodes that appear in the interaction diagram (Figure 1), including the category of node type and the code used for the node in Figure 1.

Node Name	Node Type	Definition/ Examples	Code used in Figure 1
Seahorse population	Ecological/ biological	Number of *Hippocampus hippocampus* and *Hippocampus guttulatus*	Seahorse population
Seagrass abundance	Ecological/ biological	Coverage of *Zostera* sp.	Seagrass abundance
Seahorse recruitment	Ecological/ biological	Number of individuals added to a population eg. by birth or immigration	Recruitment
Predators	Ecological/ biological	Crabs, larger fish, on rare occasions seabirds	Predators
Prey	Ecological/ biological	Mainly consists of amphipoda	Prey
Natural disturbance	Ecological/ biological	Storms, wave abrasion e.c.t.	Nat Dist
Trampling	Ecological/ biological	Disturbance by humans through foot or vehicle degradation	Trampling
Wasting disease	Ecological/ biological	Pathogen *Labyrinthula zosterae* causing the reduction in seagrass abundance	Waste Dis
Knowledge of population status	Ecological/ biological	Knowing the number of individuals in an area eg. through tagging projects	Knowledge Of Pop Status
Bycatch	Ecological/ biological	Non-target fish caught	Bycatch
Light levels	Abiotic	Light available for photosynthesis	Light
Turbidity	Abiotic	Water clarity	Turbidity
Chemical pollution	Social / economic	Contamination of water by eg. heavy metals	Chem Poll
Nutrient pollution	Social / economic	Excessive levels of nitrates and phosphorus in the water	Nutrient Poll
Mooring	Socio/economic	The use of permanent structures to secure boats	Mooring

Anchoring	Social /economic	Securing a boat to the seabed using an anchor which penetrates the seafloor	Anchoring
Boat damage	Social /economic	Propeller scarring, propella swash, boat wake, hull dragging e.t.c.	Boat damage
Bottom trawling	Social /economic	Benthic and demersal fishing technique using a net	Trawling
Dredging	Social /economic	Fishing method using a frame to scrape along the seafloor	Dredging
Potting	Social /economic	Fishing method using stationary, baited traps	Potting
Water sports	Social /economic	Diving, snorkelling, windsurfing, paddle boarding, jet skis e.t.c.	Water sports
Marine traffic	Social /economic	Number of boats in the area	Marine Traff
Eutrophication	Social /economic	Increased levels of nitrogen and phosphorus in the water causing excessive algal growth	Eutroph
Sewage pollution	Social /economic	Wastewater/ effluent entering water	Sew Poll
Harvesting	Social /economic	Removing wild individuals from the environment	Harvesting
Charitable organisations	Social /economic	Work carried out by charitable organisations eg. The Seahorse Trust, The Wildlife Trusts etc.	Charity Org
Public support	Social /economic	Support/ cooperation from the general public	Public support
Citizen science	Social /economic	Public / amateur participation in scientific research eg. data collection	Cit Sci
Trade/ Illegal trading	Social /economic	Sale of wild animals either legally or illegally	Trade
Flash photography	Social /economic	As stated	Flash Photo
Aquaculture	Social /economic	Rearing of individuals for commercial use	Aquaculture
Coastal infrastructure	Social /economic	Structures built along the coast eg. buildings, sea defences, piers	Coastal infrastructure

Habitat restoration	Management tool	Renewing/ enhancing destroyed or damaged habitat	Hab Rest
Closed areas	Management tool + national law	An area closed to certain fishing gears or all fishing activity	Closed areas
Voluntary no anchor zone	Management tool	Marked areas highlighted to public	Vol No Anch
Monitoring	Management tool	Systematic assessments of status	Monitoring
Marine licence	Management tool + national law	Authorisation required to conduct an activity within the UK marine area	Marine licence
CITES Appendix II species	International law	'Trade must be controlled in order to avoid utilisation incompatible with their survival' (CITES 2023)	CITES
RAMSAR site	International law	'Wetlands of international importance designated under the Ramsar Convention' (JNCC 2022)	RAMSAR
Special Area of Conservation	European law	Protected area 'designated to protect habitats and species listed on Annex I and Annex II of the European Habitats Directive.' (JNCC 2020)	SAC
OSPAR Threatened &/or declining species	European law	A list to ' guide the OSPAR Commission in setting priorities for its further work' (OSPAR Commission 2008a)	OSPAR species
OSPAR Threatened &/or declining habitat	European law	A list to 'guide the OSPAR Commission in setting priorities for its further work' ((OSPAR Commission 2008a))	OSPAR habitat
Marine Conservation Zone	National law	A type of Marine Protected Area	MCZ
Marine Protected Area	National law	'Defined geographical areas of the marine environment established and managed to achieve long-term nature conservation and sustainable use' (JNCC 2019a)	MPA
UK BAP list of priority habitat	National law	'Identified as being the most threatened and requiring conservation action under the UK Biodiversity Action Plan' (JNCC 2019b)	BAP priority habitat

2.4 Reference sites

The three reference sites were chosen because they have seahorses present; however, vary in the anthropogenic pressure they face and the laws that can be applied.

2.4.1 Studland Bay

Studland Bay consists of Studland Bay Marine Conservation Zone (MCZ), an inshore site, covering 4km² from the south east corner of Shell Bay to Old Harry Rocks (Natural England 2021; MMO 2022a). Its designated features include the long snouted seahorse and seagrass beds (Sch2 SI 2019/45), classified as 'unfavourable condition' (MMO 2022a), meaning conservation objectives require these to be brought into favourable condition. A voluntary no anchor zone was established as a permanent zone in 2022 (MMO 2022b) and closed fishing areas were introduced with the 2016 Southern IFCA Bottom towed Fishing Gear Byelaw (Smith 2020). The surrounding area (Figure 2) also includes Poole Harbour RAMSAR and Studland - Portland SAC (DEFRA 2022a). In 2022, the Environment Agency classified Studland Knoll bathing water quality as 'excellent' with no sewage pollution noted (Environment Agency 2022a).

Both species of seahorses have been sighted at Studland Bay, however, the long snouted seahorse is more common. South beach provides their preferred seagrass habitat and suitable breeding grounds (Garrick-Maidment 2010; DWT and Seasearch 2015; Garrick-Maidment 2021). The short snouted seahorse is a transient species to the bay (Garrick-Maidment 2021). *Zostera marina* is the primary species of seagrass present (Seastar Survey Ltd 2012; DWT and Seasearch 2015). Studland Bay is a popular site for recreational boat users (Garrick-Maidment 2021) and beach goers.

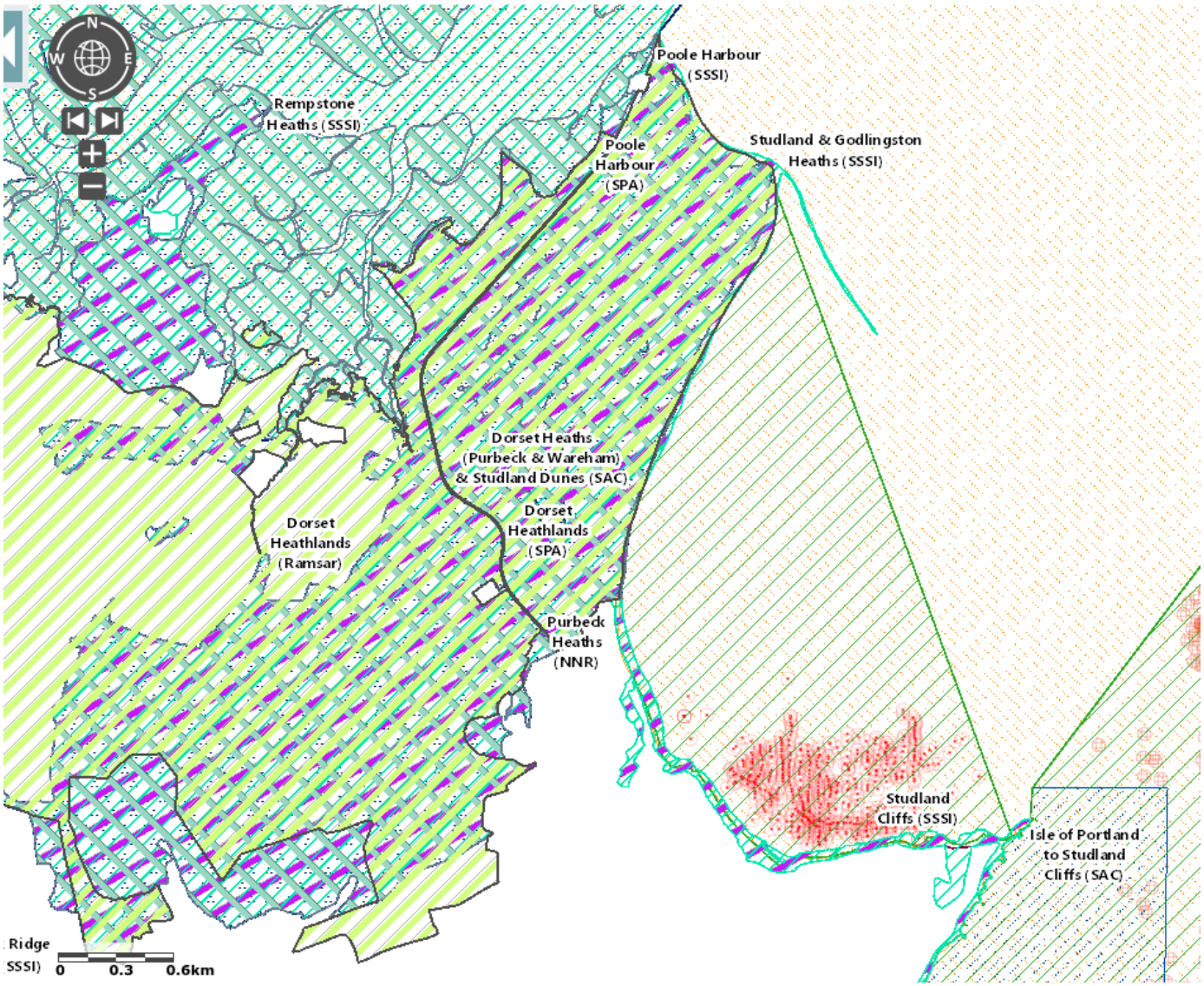

Figure 2: Studland Bay map, colour coded to show designations in the area, produced using MagicMaps (DEFRA 2022a). See Table 2 for the legend.

2.4.2 The Essex Estuaries

The Essex Estuaries (Figure 3) include Blackwater, Colne, Crouch and Roach and the surrounding mudflats. The area includes the Blackwater, Crouch, Roach and Colne Estuaries MCZ covering 284km² (Natural England 2013a), the European Marine Site, the Essex Estuaries SAC, RAMSARs and the Essex Coast Environmentally Sensitive Areas (DEFRA 2022a). The Essex Estuaries SAC saw the implementation of the Bottom Towed Fishing Gear (Prohibited Areas) Byelaw 2016 (KEIFCA 2016).

In 2022, the Environment Agency classified the bathing water quality at West Mersea beach within the Estuaries as ‘excellent’ with no sewage pollution noted; however, the previous two years were ‘good’ and 2018 ‘sufficient’ (Environment Agency 2022b). Both species of seahorse are recorded around the Essex Coast (Garrick-Maidment 2007) with the short snouted seahorse recorded within the estuary (BBAN 2022). The estuaries provide predominantly *Zostera noltei* and smaller areas of z*ostera marina* (Wyer et al. 1977; Jackson et al. 2016). The Essex Estuaries are used for commercial fishing and recreational use such as bait digging, pleasure boats and water sports (Natural England 2015).

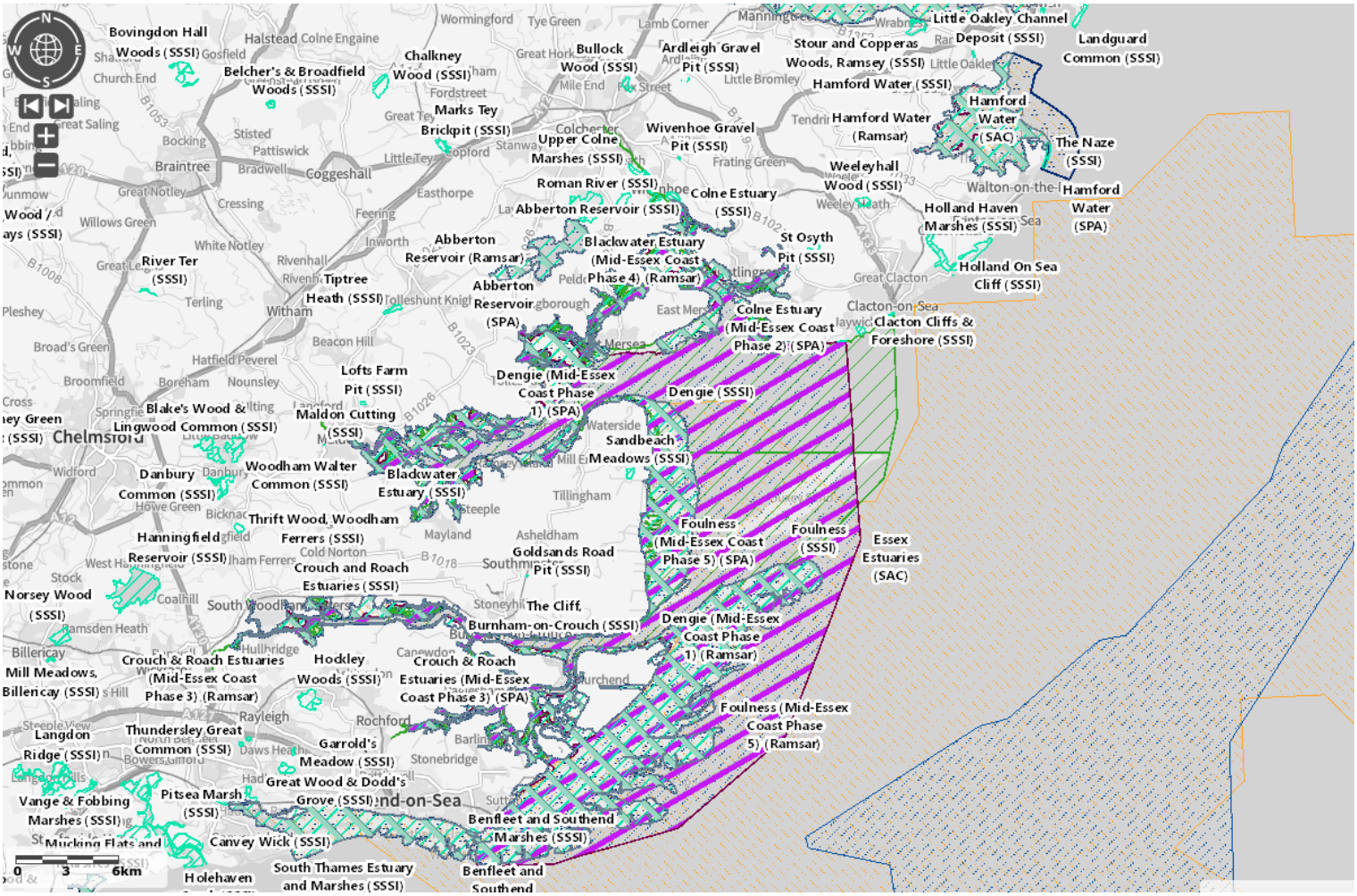

Figure 3: Essex Estuaries map, colour coded to show designations in the area, produced using MagicMaps (DEFRA 2022a). See Table 2 for the legend.

2.4.3 The Thames Estuary

As the Thames Estuary can be defined by various criteria, The Greater Thames Estuary National Character Area has been used as a guideline boundary (Natural England 2013b). Focus is on the outer estuary, opening to the north sea extending upriver to the Swanscombe MCZ. The Thames Estuary (Figure 4), includes the Thames Estuary and Marshes RAMSAR and Swanscombe MCZ (DEFRA 2022a). In 2022, the Environment Agency classified the bath water quality at Southend Jubilee beach as 'good' (Environment Agency 2022c). Both *Zostera marina* and *Zostera noltii* are present in the Thames Estuary (Wyer et al. 1977; Hily et al. 2003) and an extensive bed of *Zostera noltei* is located at Maplin Sands on the northern bank of the estuary (JNCC 2022). This provides suitable habitat for both species of seahorse, which have been reported (Garrick-Maidment 2021; ZSL 2017; ZSL 2022). The Thames Estuary faces many anthropogenic pressures, such as major shipping vessels, commercial fishing, urbanisation, recreational activities and dredging (Natural England 2013b; PLA 2022).

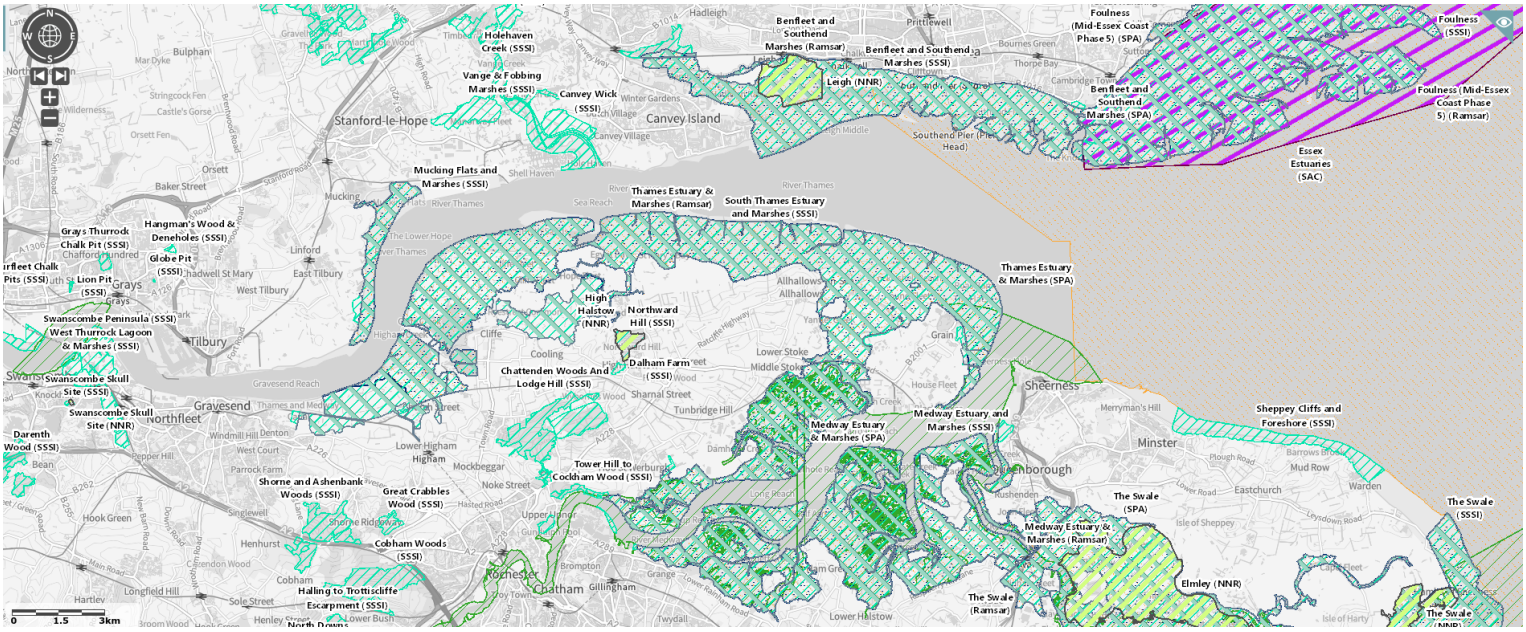

Figure 4: Thames Estuary map, colour coded to show designations in the area, produced using MagicMaps (DEFRA 2022a). See Table 2 for the legend.

Table 2: Legend of the colour codes taken from MagicMaps (DEFRA 2022a), used to produce the maps of Studland Bay, The Essex Estuaries and The Thames Estuary.

Designation	Code
National Nature Reserves (England)	
RAMSAR sites (England)	
Site of Special Scientific Interest (England)	
Special Areas of Conservation (England)	
Special Protection Areas (England)	
Designated Marine Conservation Zones (England)	
Designated Special Areas of Conservation (Marine Components GB)	
Classified Special Protection Areas (Marine Components GB)	
Marine Conservation Zone Designated Features - Habitat Features of Conservation Importance (points). Seagrass beds	

2.5 Key proposed scenarios

Table 3: Key proposed scenarios for each reference site depicting the reality of current protection and extreme possibilities if laws were better implemented. Justifications for model implementations are summarised in appendix Ⅱ.

Scenario number	Name	Model Implementation- Adjust the following nodes:
1	Studland Bay reality	Chemical pollution= 0.3 Eutrophication= 0.3 Trawling = 0.25 Harvesting= 0.4 Trade= 0.2 Voluntary no anchor zone= 0.6 MPA= 0.6
2	Essex Estuaries reality	Chemical pollution= 0.3 Eutrophication= 0.3 Coastal infrastructure = 0.45 Trawling = 0.25 Harvesting= 0.4 Trade= 0.2 MPA= 0.6
3	Thames Estuary reality	Chemical pollution= 0.3 Eutrophication= 0.3 Harvesting= 0.4 Trade= 0.2 MPA= 0.6
4	Studland extreme	Seagrass abundance= 0.6 Anchoring= 0.1 Chemical pollution= 0.1 Eutrophication= 0.15 Monitoring= 0.8 Coastal infrastructure = 0.25 Trawling = 0.1 Harvesting= 0.1 Trade = 0.1 MPA= 0.7 MCZ= 0.8 CITES= 0.9 RAMSAR= 0.8 OSPAR species= 0.8 OSPAR habitat= 0.8
5	Essex Estuaries extreme	Seagrass abundance= 0.6 Anchoring= 0.1 Chemical pollution= 0.1 Eutrophication= 0.15 Monitoring= 0.8

		Coastal infrastructure = 0.2 Trawling = 0.1 Harvesting= 0.1 Trade = 0.1 MPA= 0.7 SAC= 0.9 CITES= 0.9 RAMSAR= 0.8 OSPAR species= 0.8 OSPAR habitat= 0.8
6	Thames Estuary extreme	Seagrass abundance= 0.6 Anchoring= 0.1 Chemical pollution= 0.1 Eutrophication= 0.15 Monitoring= 0.8 Coastal infrastructure = 0.25 Trawling = 0.1 Harvesting= 0.1 Trade = 0.1 MPA= 0.7 CITES= 0.9 RAMSAR= 0.8 OSPAR species= 0.8 OSPAR habitat= 0.8

2.6 Limitations of the research methods

Firstly, literature sourced for the construction of the BBN interaction diagram and for the law review is subject to bias (Grant and Booth 2009). Although several information sources were used, literature produced in English and that was free to access was selected. A lot of seahorse conservation and MPA research has been conducted in the Philippines, despite the vast majority of this work being produced in English, it is possible government documents written in Filipino language were missed that could have provided useful information.

As with any model, BBN has limitations. Although the process of producing the interaction diagram utilised the IPBES GAF, the degrees in confidence of the evidence and the use of expert opinion was subject to knowledge-based bias. Bias can also occur when making the probabilistic judgements for the prior beliefs (Landscape Logic 2010). BBN also depends on the use of expert knowledge of specialist software, assistance was provided by Professor Rick Stafford for this. When discussing BBN results it is also

important to remember that the posterior result of 0.5 does not necessarily mean there would be no increase or decrease; it could be there is lack of evidence to provide a probabilistic outcome (Newton et al. 2007). Furthermore, BBN posterior outcomes do not provide fully quantitative results, therefore the exact scale of the increase or decrease in nodes cannot be determined. The results should be interpreted as providing a model of belief, to support prior knowledge, not as certainty.

Lastly, the use of reference sites will provide a generalised result for seahorse populations within those areas and may not be accurate for populations of seahorses in other areas of the UK. The study could be improved by including a wider range of literature through translation of documents and by differentiating between the application of laws across different UK jurisdictions.

3.0 Chapter 1: Introduction to seahorses

This chapter will introduce seahorse population ecology and will discuss how it makes seahorses vulnerable to anthropogenic pressures.

Seahorses are marine fish belonging to the *Syngnathidae* family (Foster and Vincent 2004). Two species are indigenous to the British Isles: long snouted seahorse *Hippocampus guttulatus* and short snouted seahorse *Hippocampus hippocampus*. Both species are widely distributed in the UK with populations recorded at the three reference sites (Garrick-Maidment 2007; ZSL 2017; Garrick-Maidment 2021). Population densities of both species are low. The long snouted seahorse has a higher dependency on seagrass (Foster and Vincent 2004), whereas the short snouted seahorse is more versatile in its habitat preference recorded in sandy and rocky habitats (Garrick-Maidment 2021). Habitat suitability also depends on holdfast availability, distribution and type (Correia et al. 2018).

Life history factors make seahorses sensitive to anthropogenic pressures (Curd 2009) and, therefore, vulnerable to local extinctions. High site fidelity and small home ranges

(Curtis et al. 2017) means destruction of their habitat can have direct consequences on their population numbers and low population densities put them at risk to allee effects and stochastic events. Seahorses exhibit monogamy/ mate fidelity (Foster and Vincent 2004; Sabatini et al. 2021), meaning removing individuals can reduce reproductive efficiency, negatively impacting reproductive success. Their low mobility makes it difficult to find new partners should individuals be removed and means they are less able to emigrate from degraded habitats or escape threats. Seahorses also have low fecundity, limiting reproductive rate and lengthy male parental care means the survival of the juvenile is dependent on male survival (Foster and Vincent 2004). Seahorses are especially vulnerable to anthropogenic threats as their habitat, transitional waters (estuaries, shallow bays), is often exploited by humans. Seahorses are sensitive to environmental changes, such as habitat loss and increased water temperature, which increases their metabolic rate (Faleiro et al. 2015). Sensitivities means they could act as biological indicators for the marine environment, much like seagrass is (Krause-Jensen et al. 2005). Despite their ecological value, insufficient data means both native species are categorised as Data Deficient on IUCN Red List of Threatened Species (Pollom 2017; Woodall 2017), making it difficult to monitor population trends.

4.0 Chapter 2: Threats to seahorses

This chapter outlines the threats seahorses face, focussing on significance of pressures to UK populations.

Seahorses face many threats relating to direct removal and as a consequence of habitat degradation. The most significant cause of global decline is over-exploitation for wildlife trade, with Traditional Chinese Medicine being the biggest direct market for seahorses (Vincent 1996). For UK populations however, this is arguably the second most significant threat, after habitat degradation, as the UK is not a main contributor to seahorse exports (Vincent 1996). Illegal wildlife trade (IWT) continues to threaten UK wildlife (Wildlife and Countryside LINK 2022) and is illegal, unregulated and unreported meaning, thus its impact on seahorses is unknown (Foster et al. 2019). A more

immediate direct removal threat, however, is bycatch susceptibility (Pollom et al. 2021), especially in non-selective fishing gear such as trawl nets (Pinnegar et al. 2008).

For UK populations, the most significant threat is the increased death rate from the loss of seagrass habitat, especially for long snouted seahorses which depend on seagrass beds (Garrick-Maidment 2021). The UK has lost 44% of seagrass since 1936 (Green et al. 2021), and remaining beds are classified as ‘degraded’ (Wilding et al. 2009). Seagrass meadows at Studland Bay, the Essex Estuaries and the Thames Estuary, therefore, provide valuable habitat for seahorses, yet remain under threat.

Seagrass loss results from physical disturbance such as boating, trampling, static and towed fishing gear (d’Avack et al. 2014) and water quality reduction (Short and Wyllie-Echeverria 1996). Within the UK marine environment, sewage continues to be released into coastal waters (Slack et al. 2022), meaning triple the number of bathing waters were classified as ‘poor’ in 2022 than 2021 (Salvidge and Carpenter 2022). Evidence of poor water quality is also indicated by the 340 water penalties which have resulted in fines (Carpenter 2022). Pollution also arises from eutrophication (Short and Wyllie-Echeverria 1996) causing excessive algal growth to dominate over seagrass and surrounding coastal developments lead to runoff causing sedimentation and nutrient loading (Short and Wyllie-Echeverria 1996). These pressures exacerbate an already decreased seagrass abundance due to the significant loss in the 1930’s as a result of a wasting disease, which killed approximately 90% of seagrass in the Atlantic ocean (Jakobsson-Thor et al. 2018). Populations have failed to recover. Furthermore, seagrass is sensitive to natural disturbance, as roots are disturbed easily, seed bearing stems are detached and sediment smothers plants (Short and Wyllie-Echeverria 1996; Valdemarsen et al. 2010).

Humans can also cause physical disturbance to the seahorses directly. Contact or flash photography can cause stress to individuals, causing dispersal or death (Marine Biological Association 2014). Chemical pollution is likely to be an underestimated threat to seahorses as studies have found bioaccumulative effects of heavy metal uptake in *H*.

guttulatus (Nenciu et al. 2016) and increased mortality rate due to toxic effects of endocrine disrupting substances (D'Alvise et al. 2020; Qin et al. 2020). UK marine ecosystems still face pollution inputs of heavy metals, organobromine and organochlorines, which have effects on marine organisms' immune, reproductive and nervous systems (EEA 2019b). The Greater North Sea is classified as a 'contamination problem area' by the European Environment Agency (EEA 2019b). Toxicity, persistence and bioaccumulation potential of contaminants remains a concern for seahorse populations. As both species have low population densities, the consequences of deleterious threats are likely to be great.

5.0 Chapter 3: Applicable laws to seahorse protection

There is no legislation explicitly dealing with the protection of seahorses; protection comes as a consequence of laws which protect marine species and the environment. Therefore, this chapter discusses relevant international, European and national laws, focussing on implementation and effectiveness. Firstly international law will be discussed, followed by European and national legislation.

International:

Several international Conventions, of which the UK are signatory, can be applied to seahorse protection. Questions arise however, over how much signatory nations can be held accountable to international agreements given the lack of enforcement, monitoring and punishment (Dupuy and Viñuales 2018), suggesting a lack of effectiveness.

1971 Ramsar Convention

This section discusses the Ramsar Convention, in relation to seahorses.

This international law protects wetlands of international importance globally and in Great Britain (JNCC 2019c). Consequently, wetland protection could increase bird abundance, impacting the status of seahorse populations through increased fry predation (Project Seahorse 2021). RAMSARs close to the reference sites include Poole Harbour

RAMSAR, The Crouch and Roach Estuaries RAMSAR and The Thames Estuary and Marshes RAMSAR. Criticism of the Convention however, highlights the lack of precise obligations and enforceable mechanisms holding Contracting Parties accountable (Day and Porter 2021). This weak enforcement minimises its positive impacts on bird populations and combined with evidence of a moderately declining population of UK water birds (DEFRA 2020a), it is highly unlikely the Convention will modify bird populations enough to have direct predation consequences on seahorse populations.

1973 Convention on International Trade in Endangered Species (CITES)

The following section discusses CITES, with regard to seahorses.

Seahorses are threatened by international trade, therefore, regulations are needed to control the levels of harvesting. Consequently, all seahorse species have been added to CITES Appendix II, which aims to regulate trade, suggesting that UK seahorse populations should be protected from unsustainable harvesting (CITES 2022a).

Appendix II regulates trade so export levels should not be detrimental to wild populations (CITES Convention 1973) via a non-detriment finding (NDF) assessment and ensures specimens are legally acquired through a legal acquisition finding. Whilst NDF recommendations include a minimum export size of 10cm and suggest specimens caught as bycatch from trawlers in closed areas are not legally acquired and should not be traded (Foster 2008), these are only guidance measures. Absence of evidence that the specimen has been legally acquired is an offence; however, it is through the UK's domestic implementation of CITES, the Control of Trade in Endangered Species (COTES) regulations 2018 that prosecution occurs (Hansard HC Deb., 6 December 2018). Effective national legislation is therefore required for prosecution. CITES specimen trade permits are intended to ensure compliance with the Convention (Hansard HC Deb., 6 December 2018). These will only be effective if enforced by the Animal and Plant Health Authority, UK Border Force (UKBF) and the National Wildlife Crime Unit (NWCU) (Animal and Plant Health Agency and DEFRA 2013). Enforcement is restricted by low prioritisation of IWT and limited funding (Maher and Sollund 2016).

In 2018, 14 seahorse seizures occurred at UK borders, one involving five live specimens with permit errors (Hansard HC Deb., 6 December 2018), suggesting IWT of seahorses does occur in the UK, even if at low levels. Convictions in the UK, however, primarily involved selling products containing seahorse components and illegal importation, not for harvesting native populations. A 2014 case resulting in a fine (UK National Wildlife Crime Unit 2022a), a 2022 case resulting in a suspended sentence (UK National Wildlife Crime Unit 2022b) and almost 75% of 174 cases resulting in non-custodial sentences (Wildlife and Countryside Link 2017), suggest the seahorse IWT could still be perceived as a high profit, low risk crime, implying offenders will not be deterred.

The procedure of 'Review of Significant Trade' (RST), attempts to review implementation of CITES within the UK (CITES 2022b). The RST does suggest the use of seahorses in the UK is now sustainable as prior to CITES, trade surveys reported most live trade was wild sourced native species but between 2013-2018 following the RST, only captive born specimens were traded (Foster et al. 2021). This evidence suggests CITES has significantly reduced global trade of wild specimens, transforming the global trade of live seahorses to captive bred specimens (Foster et al. 2022). Criticisms, however, label CITES as a 'self-policed system', as there is no global enforcement agency to hold Member States accountable (Maher and Sollund 2016). Furthermore, charities argue that regulations on seahorse trade simply fuel IWT (Project Seagrass 2022a). Specifically, concerns arise over IWT of seahorses online, when online sales platforms do not require evidence of CITES compliance and reports of online platforms not responding when concerns of IWT are raised (Hansard HC Deb., 6 December 2018). UK sourced seahorse IWT could also heighten when other seahorse populations have been depleted but demand continues (Maher and Sollund 2016).

It is suggested that the trade of UK seahorses is not posing a threat to current populations. Should however, the demand increase for UK seahorse specimens, weak enforcement of CITES would be inadequate to protect seahorses.

1979 Bern Convention

The section below discusses the Bern Convention with reference to seahorses.

This Convention aims to conserve wild flora and fauna and their habitats (Bern Convention 1979), listing long and short snouted seahorses in appendix II as strictly protected fauna (Council of Europe 1979). The listing, however, only protects Mediterranean populations, therefore, does not offer protection to UK seahorse populations.

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)

The following section discusses OSPAR with regards to seahorses.

OSPAR aims to protect the North-East Atlantic marine environment from eutrophication and pollution (OSPAR Convention 1992). The UK is a Contracting Party (JNCC 2019d), therefore, UK seahorses and their habitat should be protected from pollution. Protection occurs through ecological quality objectives, such as achieving a ‘marine environment where eutrophication does not occur’ (OSPAR Commission 2010), via threatened and/or declining species and habitats lists where both seahorses and seagrasses are listed (OSPAR Commission 2008b; OSPAR Commission 2008c; OSPAR Commission 2008d) and through the MPA network (JNCC 2019d). As listed features, seahorses and seagrass received case reports including a status evaluation, potential threats and management considerations; however, case reports are non-legally binding recommendations. Recommendation documents 2012/3 and 2012/2 (OSPAR Commission 2012a; OSPAR Commission 2012b) include considerations to further the protection of seahorse species, yet, lists of threatened/declining species are an OSPAR ‘Other Agreement’, therefore, Contracting Parties are not legally bound to implement the considerations (OSPAR Commission 2018), thus offering weak protection.

OSPAR relies on national laws for implementation, further weakening protection. In the 2017 implementation report, the UK declared European and national legislation as means of implementing OSPAR (OSPAR Commission 2018), including the

Environmental Impact Assessment Directive, Habitats Directive, Marine Strategy Framework Directive, Wildlife and Countryside Act 1981 and NERC Act. The successful implementation of OSPAR, therefore, relies on the success of national laws.

Evaluation of OSPAR's North-East Atlantic Environment Strategy 2010-2020 highlights its lack of success, such as OSPAR's MPA network only covering 6.5% of the OSPAR Maritime Area (OSPAR Commission 2020a). Human activity that threatens seahorses continues to occur, such as; fishing gear disrupting areas of the English Channel seabed, human-induced eutrophication and concerning levels of pharmaceutical chemicals such as contraceptives occurring (OSPAR Commission 2021). Although heavy metal pollution is falling in the Greater North Sea, background levels have not been achieved (OSPAR Commission 2020a). Latest reports show whilst the majority of the Greater North Sea (location of the three reference sites) is classified as a non-problem area for eutrophication, it still has the largest surface area of approximately 98,000km² classified as 'problem area' (OSPAR Commission 2017a). Specifically for the UK, 'problem areas' are transitional waters (OSPAR Commission 2017b), where seahorses live.

Current assessment shows short snouted seahorses are protected in twelve MPAs in the Greater North Sea but long snouted seahorses are only protected in four (Hennicke et al. 2022). Whilst Studland to Portland, Essex Estuaries and the Thames Estuary and Marshes are declared as OSPAR MPAs, reports do not clarify if seahorses are protected here. This is likely because only 14% of OSPAR MPAs have long-term monitoring programmes (Hennicke et al. 2022). Finally, despite being listed as an OSPAR threatened/ declining habitat and the UK claiming European legislation fulfils their commitment to Recommendation 2012/04 on the protection of *Zostera* beds, seagrass beds remain in poor status as of 2022 (OSPAR Commission 2022a). Finally, fishing, tourism, suspended solids and temperature increase pressures are all increasing within the Greater North Sea (OSPAR Commission 2022a).

The evidence reviewed above suggests that whilst OSPAR has had some success, ultimately threats to transitional waters, seagrass and seahorses are continuing in the

Greater North Sea and protection to reference sites' populations (methods section 2.4) is weak.

European:

The sections below discuss the effectiveness of European laws at protecting seahorses. European law has been very influential to UK environmental protection (Fisher 2019), therefore, European laws have been reviewed in relation to their effectiveness prior to Brexit. Whilst several European laws can be applicable to seahorse protection, Directives only specify objectives, leaving room for Member States to decide their method of achievement (EUR-Lex, 2022), this creates inconsistencies and could weaken the value of Directives.

Conservation of natural habitats and of wild fauna and flora (Habitats Directive)

This section discusses the Habitats Directive with reference to seahorses.

The Habitats Directive's aim of restoring /maintaining biodiversity to favourable condition is implemented through designation-based protection, creating a network of protected sites, forming Natura 2000 (Kingston et al. 2017). Natura 2000 includes Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). SACs aim to protect habitat types in Annex I and habitats of species from Annex II (European Commission 2022a). Although seahorses are not listed as species in Annex II, Estuaries are listed under Annex I habitat types (JNCC 2019e), suggesting the protection of seahorse habitat. Seahorse protection is only weak as it occurs as a consequence of estuary protection.

Within the reference sites, Essex Estuaries SAC has been designated (JNCC 2015a) and whilst seahorses are not qualifying features Estuaries are (Natural England 2018). Despite the Directive requiring Member States to report every 6 years on the status of the habitats (European Commission 2022b), the baseline condition of seagrass within the Essex Estuary SAC was only formally surveyed 9 years after designation (Jackson

et al. 2016). The survey revealed that in 2016, 11 years following the SAC designation, seagrass beds were in unfavourable condition as a consequence of trampling and nutrient enrichment (Jackson et al. 2016), implying the legal designation did not protect seagrass meadows. Furthermore, it was only 12 years after designation when mitigation measures against new development and recreational disturbance were proposed via the The Essex Coast Recreational disturbance Avoidance and Mitigation Strategy. Mitigation measures included restricted access, provision of rangers and monitoring (Essex County Council 2018); however, this strategy only mitigates pressures from new developments, not existing pressures and mainly focuses on reducing pressures for bird species. Furthermore, SACs do not protect against activities occurring outside the zone that still negatively influence the SAC, such as eutrophication.

Whilst the Essex Estuaries trawling byelaw (KEIFCA 2016) could protect seahorses from bycatch and seagrass from destructive fishing gear, a trawling ban over the whole SAC was deemed over precautionary (KEIFCA 2016). A regulatory byelaw which closes certain areas to bottom towed gear was suggested (Chief IFCO 2016). This does include the Crouch, Roach, Colne and Blackwater estuarine rivers (KEIFCA 2016) but does not cover the intertidal seagrass beds below Crouch Estuary (Chief IFCO 2016), which is left exposed to bottom trawling.

The 2012 Review of the Habitats Directive suggested implementation was ‘working well’ and claimed ‘a high level of environmental protection is maintained’ (HM Government 2012a). Despite these claims, it's important to consider how in 2022 the overall assessment of Marine Atlantic Estuaries was Unfavourable-Bad (EEA 2022), 70% of UK habitats were classified as Bad and in 2020 60% of Marine Atlantic habitats were classified Bad (EEA 2020). This suggests the Habitats Directive is ineffective. Two suggested reasons for limited success are insufficient funding to properly implement the Directive (European Commission 2016) and because it falls to Member States’ willingness to engage, rather than legal enforcement (Kingston et al. 2017).

This evidence suggests protection of seahorses via the Habitats Directive is very weak and often a consequence of wider environmental protection.

EU Wildlife Trade Regulations (EU Trade Regulations)

The section below discusses the EU Trade Regulations with regards to seahorses.

Trade of UK wild seahorses is supposedly regulated through the European implementation of CITES, the EU Trade Regulations (European Commission 2010). In line with the CITES Annexes, both UK seahorse species are listed under Annex B (United Nations Environment Programme 2023). Permits are required for importing, exporting and re-exporting seahorses into and from the EU (European Commission 2010), ensuring the specimen is legally obtained in accordance with Member State legislation (TRAFFIC 2015), which for the UK means not caught from UK waters. These permit requirements are stricter than CITES Regulations as import and export permits are required (TRAFFIC 2015). Stricter European law could mean it is more effective at regulating the seahorse trade.

EU Wildlife Trade Enforcement Coordination Workshop highlights however that whilst the EU Enforcement Working Group is responsible for monitoring Member State compliance and making recommendations on enforcement, it is really Member States who are responsible for enforcing the Regulations (Parry-Jones et al. 2005). The UK's implementation report 2015-2017 (DEFRA 2018a) states the UK does not 'typically export wild-taken native fauna' and the overview of seizures of CITES listed species in the EU reports no key seizures of seahorses with the UK as the export country in 2019 (TRAFFIC 2021). This suggests UK seahorses are not at risk from high harvesting levels. The implementation report, however, revealed a decline in performance due to staff availability, along with no development of implementation tools, no equipment purchased for monitoring/ enforcing and the budget for management authorities decreased (DEFRA 2018a). The report also highlights that CITES is not included in the National Biodiversity Strategy and Action Plan, suggesting management of trade in endangered species is not a priority for the UK government. The report suggests as IWT evolves such as with online platforms, enforcement levels and technology may not keep up. The report also highlights how regulation of wildlife trade is implemented through national law of The Control of Trade in Endangered Species Regulations 2018

(COTES), meaning effectiveness of trade regulation relies on strength of national legislation.

The evidence above suggests protection for seahorses through EU Trade Regulations is weakening and compliance is determined by application of national law.

Water Framework Directive 2000/60/EC (WFD)

The following section discusses the WFD in relation to seahorses.

The WFD aims to prevent deterioration of inland surface waters including transitional and coastal waters, impacting the quality of seahorse habitat. The WFD aims to achieve chemically and ecologically ‘good surface water status’ (EFRA 2003) by 2027 (originally 2015). To achieve the Directive’s objectives, specific management plans for each River Basin District (RBD) are produced (The Parliament of the United Kingdom 2012). Whilst it is argued that the WFD implementation has improved and has been responsible for improved ecological status of water bodies (Vermeulen, et al. 2019), it cannot be ignored that the main objective has not been achieved, as in 2015, 47% of EU surface waters had not reached good ecological status (Voulvoulis et al. 2017). In 2020, in England, only 29% of estuaries/ coastal waters classified as ‘good’ (JNCC 2021), therefore, its effectiveness must be questioned. For the reference sites specifically, the 2015 ecological surface water classification for the Anglian RBD, which includes the Essex Estuaries included 13, 106, 419, sites classified as bad, poor and moderate respectively, with only 65 classified good (Environment Agency 2016a). For the Thames RBD, 27, 112, 320, 39 sites were classified bad, poor, moderate and good respectively (Environment Agency 2016b) and for the South West RBD which includes Studland Bay, 21, 94, 420 and 160 sites were classified bad, poor, moderate and good respectively (Environment Agency 2016c). In 2022, Studland Bay was classified as good and The Essex Estuaries and Thames Estuary classified as moderate for ecological status (Environment Agency 2022d), thus good ecological status has only been achieved for one reference site. For chemical status, two measures of priority substance concentrations are taken, one including uPBTs (ubiquitous (present, appearing or found everywhere), persistent, bioaccumulative and toxic), a more specific

set of hazardous substances and one excluding uPBTs (EEA 2018). For Studland Bay and Essex Estuaries, chemical status failed when including uPBTs but classified good when excluding uPBTs and the Thames Estuary failed chemical status on both measures (Environment Agency 2022d). This data implies whilst water quality has partially been achieved for Studland, it has not for Essex and Thames reference sites, indicating pollution impacting seagrass and seahorses is still present.

The Government's 25 Year Environment Improvement Plan (EIP), a requirement of the Environment Act 2021 (HM Government 2018a), intended to translate commitments of the Directive (Gove 2018), such as 'at least three quarters of our waters to be close to their natural state'. The plan has been criticised for lacking specific, measurable, achievable, results-focused, and time-bound targets (EAC 2018; The Parliament of the United Kingdom 2023), demonstrated by the ambiguous wording of 'close to' and 'as soon as is practicable'. Furthermore, as a policy document, it is not legally binding (Fisher et al. 2019).

Full implementation of the Directive has not been achieved mainly due to the costly effort and ecological knowledge required to fulfil the RBD management plans, inadequate funding available (Vermeulen et al. 2019; European Commission 2021a) and lack of clarity due to variation in water types, meaning a European definition of good ecological status cannot be defined (Voulvoulis et al. 2017). Other criticisms include how the Common Implementation Strategy is not legally binding (EFRA Select Committee 2003) and incompatibility between the Directive's deadlines and ecological timeframes, as the recovery of ecological aspects that's needed to achieve good ecological status could take centuries (Voulvoulis et al. 2017). The 2019 fitness check (European Commission 2019) highlighted how enforcement of the Directive was largely down to Member States carrying out national review procedures, highlighting lack of EU level enforcement. Lastly, Keessen et al. (2010) emphasises the lack of punishment for Member States for not achieving Good status, which is in part due to ambiguity over whether the WFD objective is an obligation of result or obligation of best efforts, as the obligation of the Directive is only to 'aim' to achieve good water status.

One consequence of the Directive is that seagrass is used as a biological quality element (BQE) in defining a water body's ecological status (Foden et al. 2010). As a BQE seagrass abundance is monitored and there should be no changes in abundance due to anthropogenic activities. This should indirectly provide seahorse habitat protection; however, evidence that water quality has still not reached good status shows this is not the case.

This evidence suggests, despite the ambition of the WFD, ultimately it provides weak protection due to weak wording and implementation occurring through non-legally binding policy documents.

The Marine Strategy Framework Directive 2008/56/EC (MSFD)

This section discusses the MSFD in reference to seahorses.

The MSFD aims to protect European marine environments by requiring Member States to have strategies for achieving ‘good environmental status (GES) by 2020’. This should ensure the quality of seahorse habitat. To help with interpretation of the Directive, eleven descriptors have been described to show what GES should look like (European Commission 2022c). Four are important to seahorse protection- maintaining biodiversity, minimising eutrophication, protecting the seafloor and minimising contaminants (European Commission 2021b). Although the Directive includes the North-east Atlantic Ocean (Nesbit and Watkins 2018), it applies to Coastal Waters but not Transitional Waters, i.e., estuaries, as defined by the WFD (DEFRA 2014a). The MSFD, therefore, affords protection to Studland Bay seahorse populations but not populations at the Essex Estuaries or Thames Estuaries, as confirmed by Professor Ross Hill (personal communication 15 February 2023).

A 2020 implementation report reveals, for the descriptors relating to seahorse protection biodiversity loss continued, benthic environments remained under threat and eutrophication impacted EU coastal environments (European Commission 2020). This suggests the Directive has been unsuccessful at protecting marine waters. Furthermore, Alexander et al. (2015) emphasises four main issues that will affect the descriptors,

including variability in the ecosystems, uncertainty of and limited guidance on how to minimise cumulative effects of pressures, lack of knowledge of human impacts on ecosystem resilience and conflicts between policy and economic sectors. Furthermore, the descriptors used and the definition of GES are qualitative, demonstrated by ‘ecologically diverse’ and ‘clean, healthy and productive’ (DEFRA 2022b). This induces concern as it could fail to set clear goals which can be quantitatively evaluated for progress (European Commission 2020). Ultimately, the MSFD has not set clear targets, does not include protection of all environments where seahorses are found (transitional waters) and the goal for GES has not been achieved.

National

The following sections review applicable national laws. Many of the international and European laws discussed above, have been incorporated into national legislation. It is important to consider, however, that seahorses do not have a specific national law solely for their protection. It could also be argued that UK wildlife laws primarily involve apprehending an offender, instead of preventing crime, however, reliance on punishment instead of prevention will not protect species such as seahorses from extinction.

Wildlife and Countryside Act 1981 (WCA)

The section below discusses the WCA with reference to seahorses.

The primary piece of legislation protecting British wildlife is the WCA, which lists seahorses. Since 2008, both species have been protected under Schedule 5 Section 9, which should ‘prohibit intentionally killing, injuring or taking them from the wild’ and importantly, prohibits intentional/ reckless damage to place of shelter (sch5 s9 WCA1981). This legislation should offer protection to all three reference site populations. Enforcement is difficult however, as offences in remote locations such as underwater are hard to detect (Nurse 2012).

Furthermore, although convictions at magistrate court level could result in up to six months imprisonment and/or an unlimited fine (Quinn 2017), legislation terminology makes conviction difficult. Specifically, ‘intention’ does not have a consistent meaning (LexisNexis 2022a) and it can be hard to prove ‘intention’ or ‘recklessness’ as simply failing to consider risks does not constitute recklessness (LexisNexis 2022b). Furthermore, if substantial damage occurs resulting in population declines or local extinction, fines and prison time will not rectify the ecological damage. Shortcomings of implementation also arise due to lack of resources and species-specific knowledge among police officers and the Crown Prosecution Service and the lack of perceived importance around wildlife crime (Nurse 2012). Low prioritisation of wildlife offences results in underdetection, underreporting and low prosecution (Nurse 2012). Underreporting and lack of detection of offenders could be why, as of 2023, the MMO have confirmed there have been no prosecutions relating to seahorses, seagrass or MPAs (personal communication 17 January 2023). It could be, therefore, that offences are happening but not being detected.

Furthermore, protection via the WCA is often the result of NGOs (Nurse 2012), implying a weaker enforcement approach is taken by authorities. This is evidenced through the Seahorse Trust founder Neil Garrick-Maidment who succeeded in challenging the government through a judicial review over the oil rig drilling exploration in Poole Bay which would damage important breeding grounds of seahorses (personal communication 4 January 2023). This also implies weakness of the Environmental Impact Assessment process. Weak enforcement is further demonstrated by how anchoring is allowed to continue at the reference sites despite the damage it causes to seahorses ‘place of shelter’. Despite Studland Bay being a known seahorse breeding location, authorities have opted for a Voluntary No Anchor Zone, which is widely ignored. A similarly weak approach is being taken at the proposed Bradwell B nuclear power station, located at the Essex reference site. Despite reports of seahorses in the estuaries and the negative effects of the proposed Bradwell B power station, the application has not been rejected. As confirmed by Graham Farley from Mersea Island Environmental Alliance, Greenpeace Research Laboratories have reported that not all

Priority List Substances were screened for during tests (personal communication 30 January 2023). The possibility exists, therefore, that these hazards might be introduced to the environment and harm seahorses. Assessments also did not include testing for changes to turbidity, salinity or temperature as a result of groundwater discharges from the station which could result in damage to seahorse's place of shelter, the seagrass, yet the Bradwell B proposal has not been rejected.

The evidence suggests activities destructive to seagrass are allowed to continue where seahorse populations have been recorded, therefore the WCA cannot be deemed effective at protecting seahorse populations.

Natural Environment and Rural Communities Act 2006 (NERC)

The following section discusses Section 40 and 41 of NERC, regarding seahorses.

Both species of seahorse are listed in NERC as Species of Principal Importance and seagrass as a Habitat of Principal Importance (s40 NERC2006; DEFRA 2022c). NERC should further the conservation of seahorses (s41 NERC2006) and provide guidance around development and management of marine environments (DEFRA 2014b). This is relevant to coastal management planning and the fishing industry, which have the potential to harm seahorse populations.

NERC supersedes the 1994 UK Biodiversity Action Plan (BAP) (JNCC 2019f), where seagrass was first listed, seahorses were later added in 2007. To achieve the UKBAP at Studland management was carried out via the 2003 Dorset Biodiversity Strategy (Dorset Biodiversity Partnership 2003). Seahorses were not highlighted as species with a local level plan in Dorset as at this point they were not a priority species. The Dorset Biodiversity Partnership (2010) mid-term review highlighted however, implementation of BAP was unsuccessful as only 8% of actions against marine and coastal issues were completed. Since then Natural England did initiate a seagrass monitoring study (Seastar Survey Ltd 2012). For The Essex BAP 1999 (EBAPSG 1999), monitoring of seagrass and seahorses occurs only when areas have been designated as MCZ or SACs, when initiated by NGOs or during ad hoc research.

Following the enactment of NERC, in 2011, Natural England identified that both species of seahorse required additional conservation measures, such as site management and monitoring. Specifically, highlighting the need to protect breeding populations at Studland Bay (Hiscock et al. 2011). Site management included ‘strict regulations on placement of anchors, and fishing gear types’ (Hiscock et al. 2011); however, implementation seems to have failed because 12 years later anchoring damage continues to occur at Studland Bay and within the Essex Estuaries (Griffiths et al. 2017; MMO 2021).

The 2020 review of biodiversity shows listing of priority species/ habitats provided little protection (DEFRA 2020b) as ‘over 40% of priority habitats and 30% of priority species were declining in the most recent analysis’. The fact the most recent analysis was 2008 (JNCC 2008), also shows weakness of implementation. Furthermore, there are no Action Plans for species added to the list in 2007, which includes seahorses, making it difficult to further their conservation.

Although NERC requires a ‘biodiversity duty’ of public bodies to have regard to biodiversity conservation (s41 NERC2006; Natural England and DEFRA 2014), a 2010 review (Webbon and McHardy 2010) highlighted how public authorities taking action on their biodiversity duty was often not a result of commitment to Section 41. The review also emphasised lack of money, resources and awareness of duty as barriers to implementation (Webbon and McHardy 2010). A recent review (NERC Select Committee 2018) also supports the conclusion that species priority lists in Section 40 have done little to enhance protection of wildlife. Specifically, weak wording such as ‘have regard’ is unclear and unenforceable. Lack of reporting obligations and lack of enforcement measures such as penalties for not implementing the duty means there is little incentive for authorities and no consequences for not adhering. This is evidenced through the Bradwell B nuclear power station proposal. Although NERC calls for steps to further the conservation of species and habitats, damaging activities continue due to weak enforceability.

Marine and Coastal Access Act 2009 (MCAA)

This section reviews the MCAA, relating to seahorses.

The most significant aspect of the MCAA for seahorse protection is Part 5 providing designation of MCZs. Despite MCZs being designated at all reference sites, seahorses and seagrass are only designated features of the Studland MCZ, therefore, should receive specific protection measures.

Although MCZ designation does not automatically restrict all harmful anthropogenic activities, they do induce obligations to further the Conservation Objectives (pt5 MCAA2009). For Studland, this includes bringing seahorses and seagrass into favourable condition and restricting activities and development which may hinder this. Pressures to seagrass (MMO 2022a), however, suggest restrictions are not occuring. This is likely due to lack of enforcement/ surveillance and cost of policing (EAC 2014). The MCAA does provide for byelaws to protect against damaging anthropogenic activities. Whilst byelaws could include prohibiting anchoring for Studland Bay, no such byelaw exists, only a voluntary no anchor zone which provides no legal protection.

MCAA does establish the Inshore Fisheries and Conservation Authorities (IFCA), providing IFCA power to make byelaws, such as for Studland Bay the Southern IFCA Bottom towed Fishing Gear Byelaw 2016 (Smith 2020) which protects seagrass beds within the MCZ from damaging fishing. Management measures for Swanscombe MCZ are still being developed (Kent and Essex IFCA 2023a) therefore, there are no specific byelaws in place. MCAA also allows for byelaws within SACs. For the Essex SACs, a Bottom Towed Fishing Gear Byelaw has been introduced (Kent and Essex IFCA 2023b). Whilst intended to protect the designated habitats, this would extend protection to seahorse populations from bycatch and seagrass from damage (Gravestock 2015). Breaching byelaws within MCZs does carry fines up to £5,000 and fixed financial penalties of £200 (s139 MCAA2009), which could deter people. Offences, however, only occur when deliberate or reckless damage has ‘significantly’ hindered a protected feature. It might be argued that one boat anchoring would not significantly hinder the seagrass, however, this does not account for cumulative effects. MCAA also requires

authorities to report on the extent that Conservation Objectives have been achieved (s124 MCAA2009), however, no documentation can be found on this.

MCAA also establishes planning in marine waters (POST 2011). Studland Bay is included in the South Inshore Marine Plan Area and Essex Estuaries and The Thames Estuary in the South East Inshore Marine Plan Area (HM Government 2021a). The plans have, however, been criticised for lacking detail (Blue Marine Foundation 2015) and ambiguous terminology (Lexis+UK 2020).

As seahorses and seagrass are only designated features in one of the reference sites MCZs, protection is limited. Furthermore, management of Studland Bay MCZ does not appear adequate to achieve the conservation objectives and lack of enforcement means reports of trawlers in closed areas go uninvestigated (Blue Marine Foundation 2015). As of 2021 the seagrass beds and seahorses were still in unfavourable condition (DCF 2021), showing the MCZ designation has not yet fulfilled its obligation to seahorses.

Marine Strategy Regulations 2010 SI 2010/1627

The following section reviews the Marine Strategy Regulations with regards to seahorses.

The Marine Strategy Regulations have the potential to improve UK water bodies by aiming for ‘good environmental status’ (GES) by 2020 (Essential Environment Online 2023). As the UK’s implementation of the MSFD, the same four descriptors (see page 40) are important to seahorse protection (European Commission 2021b).

To achieve GES, the Secretary of State was obligated to develop a Marine Strategy (MS). The MS Part 1 covers initial assessment of environmental status, determination of GES and establishes targets (HM Government 2012b). Environmental pressures such as leisure and recreation, fishing, navigational dredging and waste disposal were recognised as being ill-managed (HM Government 2012b). These pressures affect seahorses and their habitat.

As Part 2 establishes monitoring programmes (DEFRA 2022b), effectiveness of the Strategy can be assessed. Monitoring states that GES in 2018 had not been achieved

for 7 of the descriptors. Specific to seahorse protection, GES is uncertain for intertidal/ soft sediment benthic habitats, and although GES is described as being ‘largely achieved’ for eutrophication levels, it remained a problem in some coastal and estuarine areas (DEFRA 2019a) and despite levels of contaminants being ‘largely achieved’, persistent chemicals were causing some coastal areas to fail (DEFRA 2019a). Seahorse habitats, therefore, still saw pollution pressures (DEFRA 2019a). Language such as ‘largely’ and ‘generally’ in the 2022 update of achievement of GES, is worrying as it does not suggest complete achievement.

Finally, Part 3 presents the programme of measures (PoM), which is how the government plans on achieving GES (DEFRA 2015a). The PoM, however, is strictly speaking not legally binding and there are no means of punishing the government if the PoM is not achieved (Fisher et al. 2019). Furthermore, despite the 2015 PoM declaring a required update by March 2022, the update has only reached the consultation phase and has not been finally published. Response to the PoM Consultation in 2021 (Environment Links UK 2021) suggests even the proposed changes are insufficient to reach GES.

Success of the Marine Strategy Regulations at protecting the marine environment and marine species such as seahorses is mixed. Whilst some descriptors have achieved GES, the ones most relating to protection of seahorses, have not.

Conservation of Habitats and Species Regulations 2017 SI 2017/1012 (2017 Regulations)

The section below discusses the 2017 Regulations, in relation to seahorses.

Under the 2017 Regulations, SACs and SPAs are designated along with European protected animal and plant species. Seahorses or seagrass are not stated as European Protected Species (sch2 SI 2017/1012), therefore, direct protection is limited. Through the designation of SACs, however, there is potential for seahorse protection via general protection of the area or via sub-feature categorisation of seagrass under the Estuaries

designated feature habitat category. Within the reference sites, SACs include Studland - Portland SAC (however the bay itself is not included, therefore, is not discussed further), no SACs have been designated for the Thames Estuary and so the Essex Estuaries SAC is the focus of this discussion.

The 2017 Regulations aim to control damaging operations through issuing Special Nature Conservation Orders and Restoration Orders (DEFRA 2015c) and by a Management Scheme for each site (reg 38 SI 2017/1012). For the Essex Estuaries SAC, Conservation Objectives included maintaining the qualifying features in favourable condition (one of which is 'Estuaries') (Natural England 2018) and a Site Improvement Plan was issued which suggested monitoring, management plans and byelaws in order to mitigate threats (Natural England 2015). No actual management plan, however, was issued (JNCC 2015b). In 2015, threats affecting the 'Estuaries' Qualifying Feature were identified as coastal squeeze, fisheries, invasive species and nitrogen deposition (Natural England 2015), however, it was only in 2020 the 'Essex Coast Recreational disturbance Avoidance and Mitigation Strategy' was drafted (Birds Aware Essex Coast 2020).

Furthermore, local planning authorities are required to ensure planning decisions do not hinder SAC objectives (Birds Aware Essex Coast 2020), through a Habitats Regulations Assessment (HRA). Despite SAC designation, Bradwell B nuclear power plant construction has been proposed at the Essex Estuaries site. A HRA has not been conducted for Bradwell B yet but the HRA report from the original Bradwell Power station raises potential problems with water quality, water abstraction and return, coastal squeeze and habitat loss affecting the Essex Estuaries SAC (DECC 2010). If Bradwell B is granted consent, the 2017 Regulations have failed to protect seagrass and seahorses.

Whilst it could be argued there is no legal obligation through the 2017 Regulations to provide direct protection to seahorses, it seems even the designation of SACs does not extend them protection.

Control of Trade in Endangered Species Regulations 2018 SI 2018/703 (COTES)

The section below reviews COTES, in relation to seahorses.

As seahorses are listed under COTES, it should control their sale, keeping and import/ export (FAO 2022). COTES is the most direct way the UK can prevent damaging levels of seahorse harvesting; effective enforcement, therefore, is crucial.

COTES 2018 updated the Control of Trade in Endangered Species (Enforcement) Regulations 1997 (DEFRA 2018b), as criticisms of enforcement were raised by NGOs, police and The Environmental Audit Committee (EAC 2012). Consultation on proposed changes in 2015 (DEFRA 2015b), highlighted how enforcement was often slow and difficult, which resulted in failure of investigation (EAC 2012). Amendments such as not requiring a vet present for non-invasive sampling and police having powers of seizure will hopefully improve enforcement of COTES. Although the suggestion for more designated import and export ports was proposed, some respondents of the consultation highlighted how this could result in resources and trained staff being spread too thinly. This highlights again how lack of resources often restricts enforcement of legislation. Respondents of the consultation highlighted the need for more trained customs officers with the ability to carry out examinations on various species at each port, along with facilities to inspect live animals and greater priority given to CITES species by UKBF (Wildlife and Countryside Link 2015). Currently, out of the 38 points of entry and exit in the UK for CITES listed species, only four airports have Border Control Posts designated to handle live fish specimens (HM Government 2021b), suggesting investigation of fish specimens, such as seahorses is being under prioritised.

Whilst there is no evidence of the UK being the country of origin for wild caught exported seahorses between 2003-2019 (CITES Trade Database report 12), UKBF continues to uncover deliberate and repeat offenders of IWT of other species (DEFRA 2018b). This demonstrates the prevalence of IWT and how offenders have not been

deterred by legislation. Although the scale of COTES breaches appears to be low with an average of 10 convictions a year between 2012-2016 (DEFRA 2018b), NGOs state how monitoring and recording of wildlife crimes in the UK is inadequate (Wildlife and Countryside Link 2018). The reality, therefore, of the scale of seahorse IWT could be higher. Between 2010-2018, the number of CITES prosecutions in the UK decreased and throughout 2018 total seizures decreased, however, the reason behind this is unknown (Wildlife and Countryside Link 2018), therefore cannot be attributed to effectiveness of law. Ambiguity of recording of COTES breaches means the effectiveness of the Regulations can not be investigated (Wildlife and Countryside Link 2018). Between 2012-2016 penalties were also usually lenient as only 19 offences resulted in prison sentences opposed to 22 fines (DEFRA 2018b). As long as penalties are deemed low, and application of COTES is weak (Reid and Haenlein 2022), legislation will not deter IWT offenders. Should the pressure of trade of UK seahorses increase, it is unlikely COTES would provide effective protection.

The laws reviewed in chapter 3, suggest neither international, European or national law is providing strong protection to seahorses. The next section presents the results of the BBN.

6.0 Results

Data obtained from the BBN as described in the methods section are presented for all three reference sites. Figure 5 depicts reality and extreme scenarios with all nodes presented. Figures 6 and 7 are used to highlight the nodes which had posterior changes for reality and extreme scenarios. Figures 8.1-8.3 are used to easily compare reality and extreme scenarios for each reference site for nodes that had posterior changes.

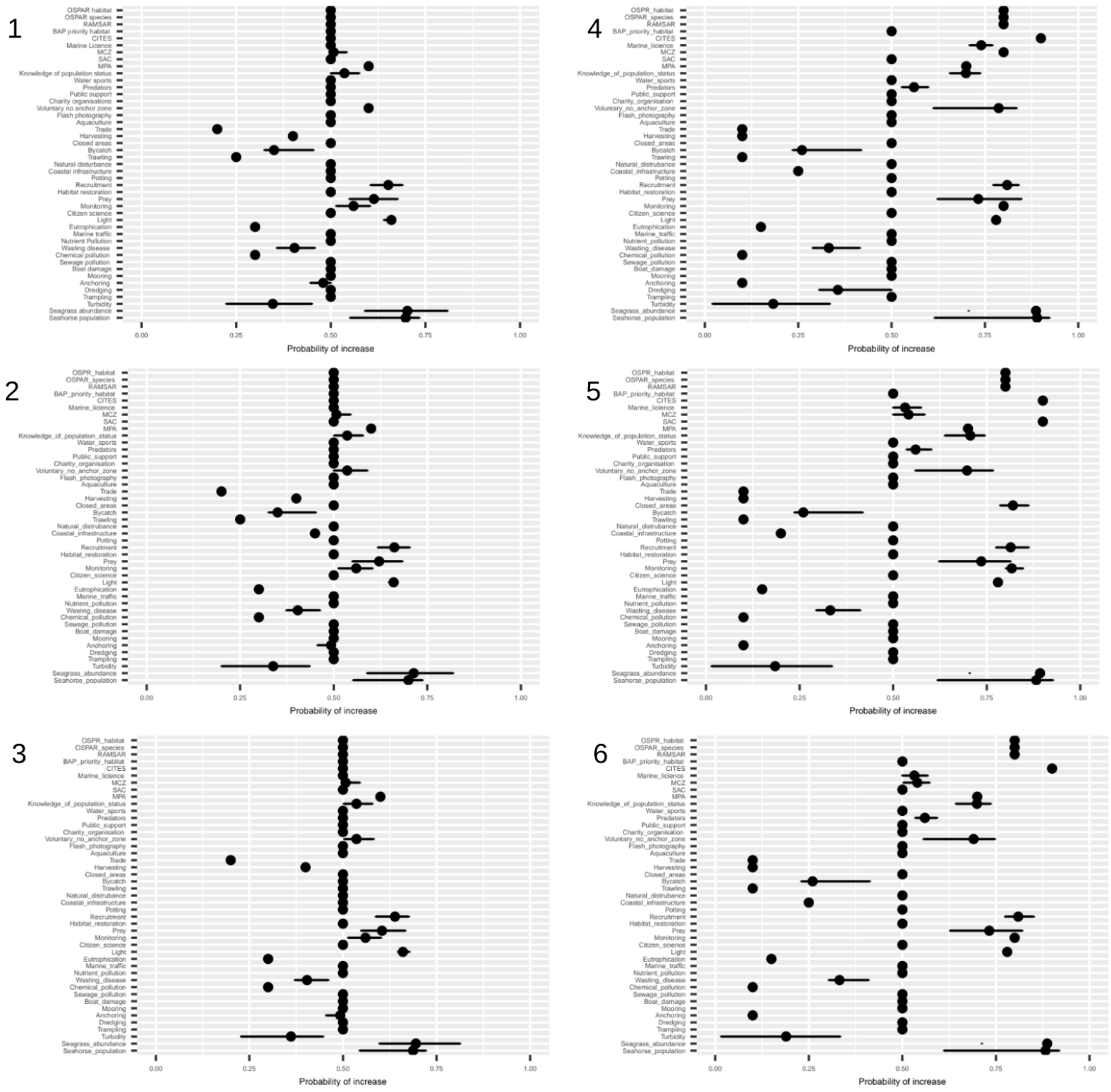

Figure 5: Calculated probability of increase (+/- 95 % confidence intervals) in nodes for reality scenarios 1, 2 and 3 (Studland Bay, The Essex Estuaries and The Thames Estuary) and extreme scenarios 4, 5 and

6. Values of > 0.5 are likely to increase and values of < 0.5 are likely to decrease. Model implementation details are given in Table 3.

6.1 Reality for the three reference sites (scenarios 1, 2 and 3)

Following from Figure 5, this section will discuss the results based on current implementation of law. Having changed the prior beliefs based on evidence of the effectiveness of current legislation (Table 3- scenarios 1, 2 and 3), Figure 6, below, compares the posterior increases for the three reference sites' reality scenarios.

Most importantly, scenarios 1, 2 and 3 all produced a potential increase for *seahorse populations* and *seagrass abundance* (posterior increases of > 0.5) (Figure 5). Albeit moderate positive effects, this suggests seahorse populations and their habitat could increase at all three reference sites under current implementation of legislation. Out of the three reference sites, Studland Bay produced the potentially biggest increase in *seahorse populations* (0.67), followed equally by the Essex Estuaries and the Thames Estuary (0.66) (Figure 6). The difference between these sites, however, is very minor. *Seagrass abundance* was most likely to increase at The Thames Estuary (0.64), followed by Studland Bay and the Essex Estuaries respectively (0.62 and 0.61); again the difference is minor. Large confidence intervals seen in Figure 5 mean weaker posterior increases for both *seahorse populations* and *seagrass abundance* than depicted in Figure 6 are possible. Results in Figure 6 also show potential for moderate increases in: *light*, *monitoring*, *prey*, *recruitment*, *voluntary no anchor zone*, *knowledge of population status*, *MPA*s, *MCZ*s and *marine licences* at all three sites.

There is potential for moderate decreases in: *turbidity*, *anchoring*, *chemical pollution*, *wasting disease*, *eutrophication* and *harvesting* at all three sites. At the Essex Estuaries site, there is moderate potential for a decrease in *coastal infrastructure* and at both Studland Bay and the Essex Estuaries there is moderate decrease in *trawling* and *bycatch*. For *trade,* the decline is moderate at the Thames site but major for Studland Bay and Essex populations. Therefore, under current legislation some anthropogenic pressures that are harmful to seahorses have the potential to decrease.

Nodes that remained at 0.5 posterior increase (equal chance of increasing or decreasing) for the three reality scenarios were: *trampling*, *dredging*, *mooring*, *boat damage*, *sewage pollution*, *nutrient pollution*, *marine traffic*, *citizen science*, *habitat restoration*, *potting*, *natural disturbance*, *closed areas*, *aquaculture*, *flash photography*, *charity organisations*, *public support*, *predators*, *water sports*, *SAC*s, *CITES*, *BAP priority habitat*, *RAMSAR*, *OSPAR species* and *OSPAR habitat* (Figure 5). These are not depicted in Figure 6.

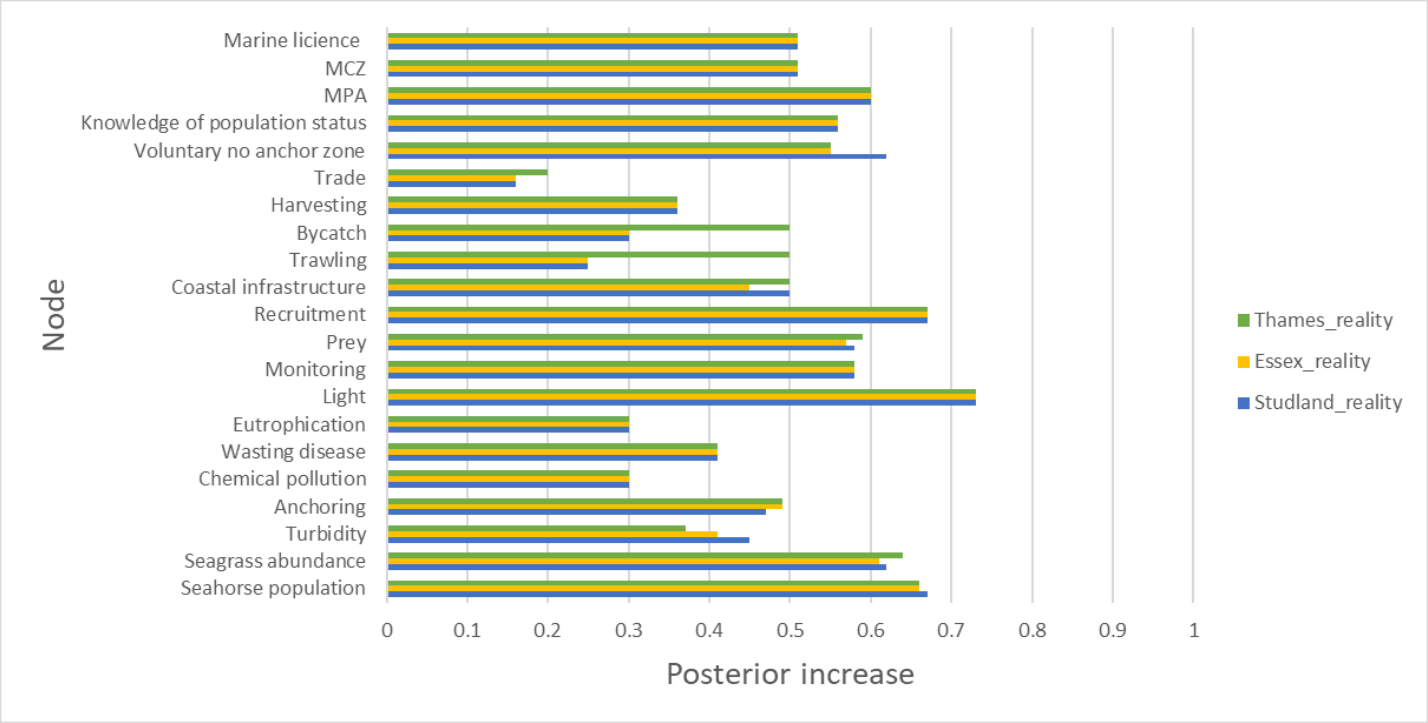

Figure 6: The calculated probability of posterior increase at all three reference sites, in relation to current legislation. Values of > 0.5 depict nodes likely to increase and values of < 0.5 are likely to decrease

6.2 Extreme possibilities for the three reference sites (scenarios 4, 5 and 6)

This section discusses the results for if laws were better implemented. These are referred to as extreme scenarios as they are intended to represent a world where laws are functioning effectively to achieve the aims set out within them; however, unfortunately this does not happen in reality. The prior beliefs were changed to

represent an improved, although still not 100% perfect, implementation of the law, as different prioritisation of environmental protection means it is unlikely a faultless implementation of law would ever be achieved (Table 3- scenarios 4, 5 and 6). Figure 7, below, compares the potential posterior increases for the three reference sites.

Most importantly, scenarios 4, 5 and 6 all produced a potentially moderate increase for *seahorse populations* and *seagrass abundance* (Figure 5). Out of the three reference sites, the Essex Estuaries and the Thames Estuary produced the potentially biggest increase in seahorse populations (0.79), whilst Studland Bay had a smaller increase (0.75) (Figure 7). *Seagrass abundance* was most likely to increase at the Essex Estuaries (0.75); however, this was only a minor difference to Studland Bay and the Thames Estuary (0.74). It is worth noting, large confidence intervals on the *seahorse population* nodes in scenarios 4, 5 and 6 (Figure 5) show that whilst there is potential for a bigger increase in seahorse populations in the extreme scenarios compared to reality, there is still a chance for only a small increase.

The results show at the three reference sites, *dredging*, *closed areas*, *predators*, *SAC*, *CITES*, *RAMSAR*, *OSPAR species* and *OSPAR habitat* nodes were now showing a likely increase or decrease so were included in Figure 7. Results in Figure 7 show potential for moderate increases in: *prey, recruitment*, *voluntary no anchor zone*, *predators*, *knowledge of population status*, *MPA*s, *RAMSAR, OSPAR species* and *OSPAR habitat* and major increases in: *light*, *monitoring* and *CITES* for all reference sites. For *MCZ*s and *marine licence* nodes, Studland Bay showed major increases but Essex and Thames Estuary had only moderate increases. There is potential for moderate decreases in *turbidity*, *dredging*, *wasting disease* and *coastal infrastructure* and major decreases in *chemical pollution*, *anchoring*, *eutrophication, trawling*, *harvesting* and *trade* for all three reference sites. For *bycatch,* decreases were moderate at Studland Bay but major at the Essex and Thames Estuaries. Figure 7 also depicts a major increase in the *closed areas* and *SAC* nodes for the Essex Estuaries.

Nodes that remained at 0.5 posterior increase (equal chance of increasing or decreasing) for the extreme scenario for all reference sites were: *trampling*, *mooring*, *boat damage*, *sewage pollution*, *nutrient pollution*, *marine traffic*, *citizen science*, *habitat restoration*, *potting*, *natural disturbance*, *aquaculture*, *flash photography*, *charity organisation*, *public support*, *water sports* and *BAP priority habitat* (Figure 5). These, therefore, are not depicted in Figure 7.

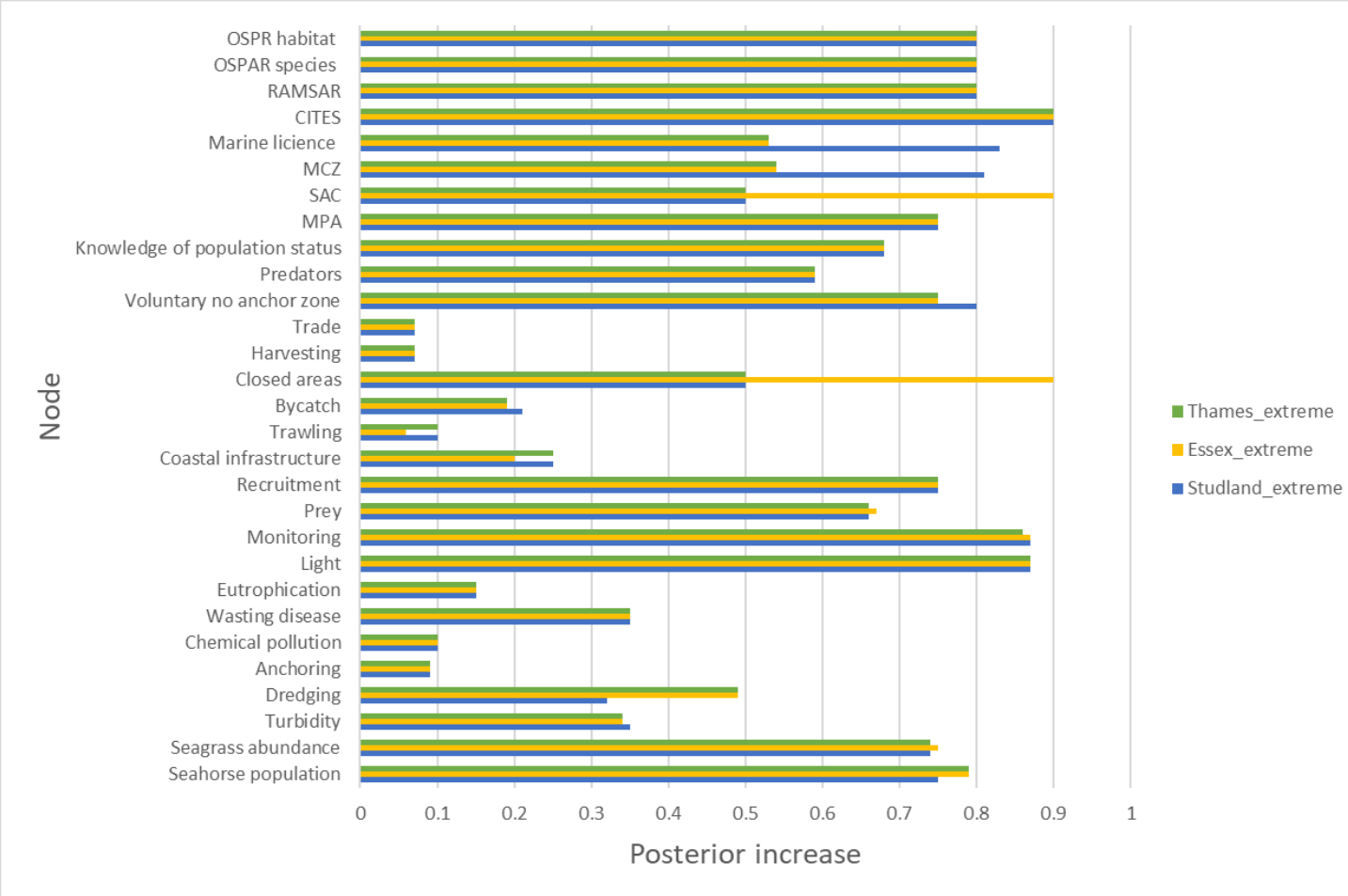

Figure 7: The calculated probability of posterior increase at all three reference sites, in relation to extreme scenarios. Values of > 0.5 depict nodes likely to increase and values of < 0.5 are likely to decrease.

6.3 Reality compared to extreme scenarios for the three reference sites

This section of the results is used to present the data for easy comparison between reality and extreme scenarios for each reference site. Figures 8.1, 8.2 and 8.3, below, show how at all sites, seahorse populations and their seagrass habitat have potential for a greater increase in the extreme scenarios. Extreme scenarios also have the strongest effect on decreasing harmful activities to seahorses, such as harvesting and bycatch. Out of all the scenarios, 5 and 6 (Essex Estuaries and Thames Estuary extreme scenarios, method section 2.5) produced the potentially biggest increase in seahorse populations.

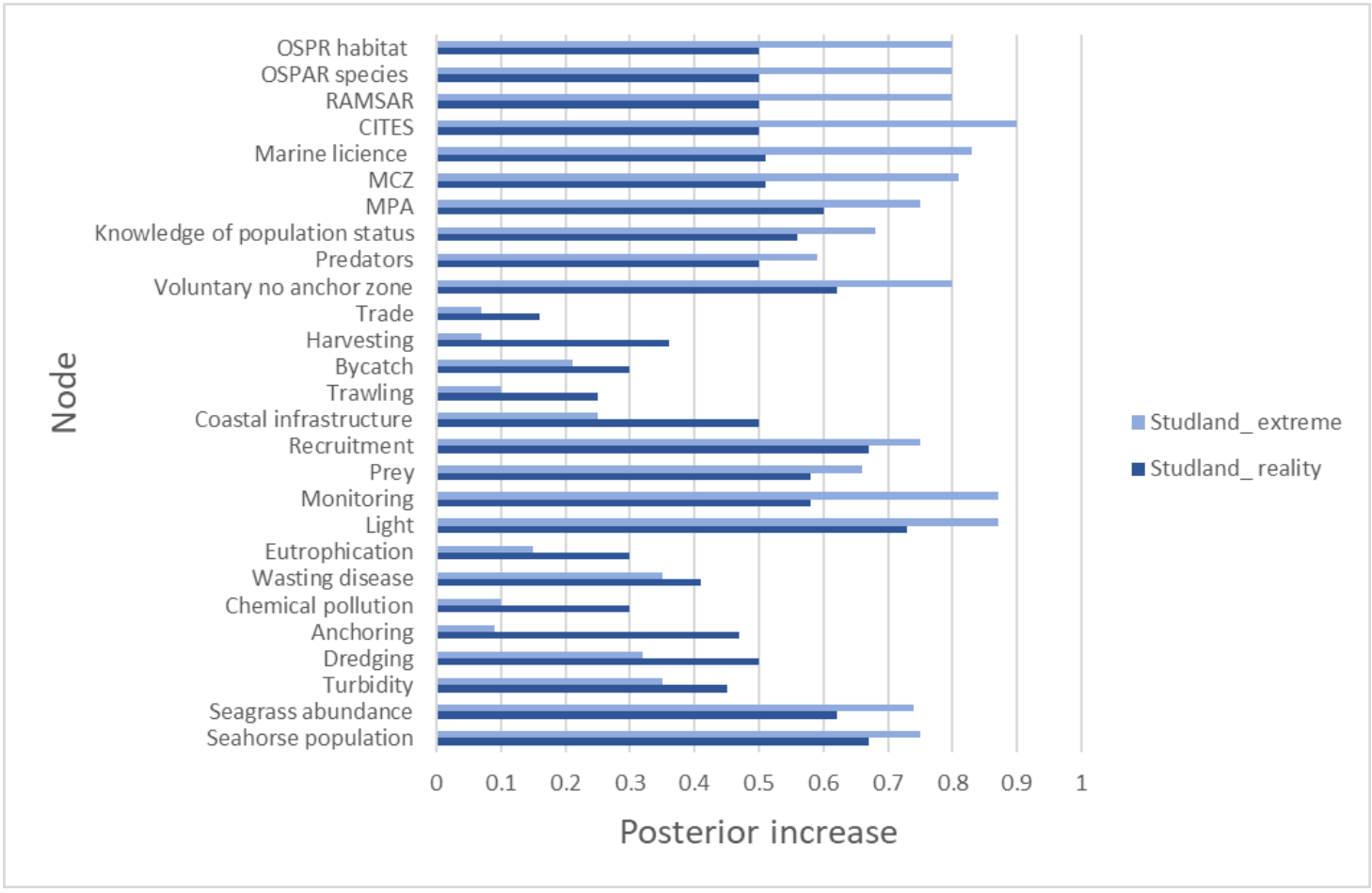

Figure 8.1: The calculated probability of posterior increase at Studland Bay, for the reality and extreme scenarios. Values of > 0.5 depict nodes likely to increase and values of < 0.5 are likely to decrease.

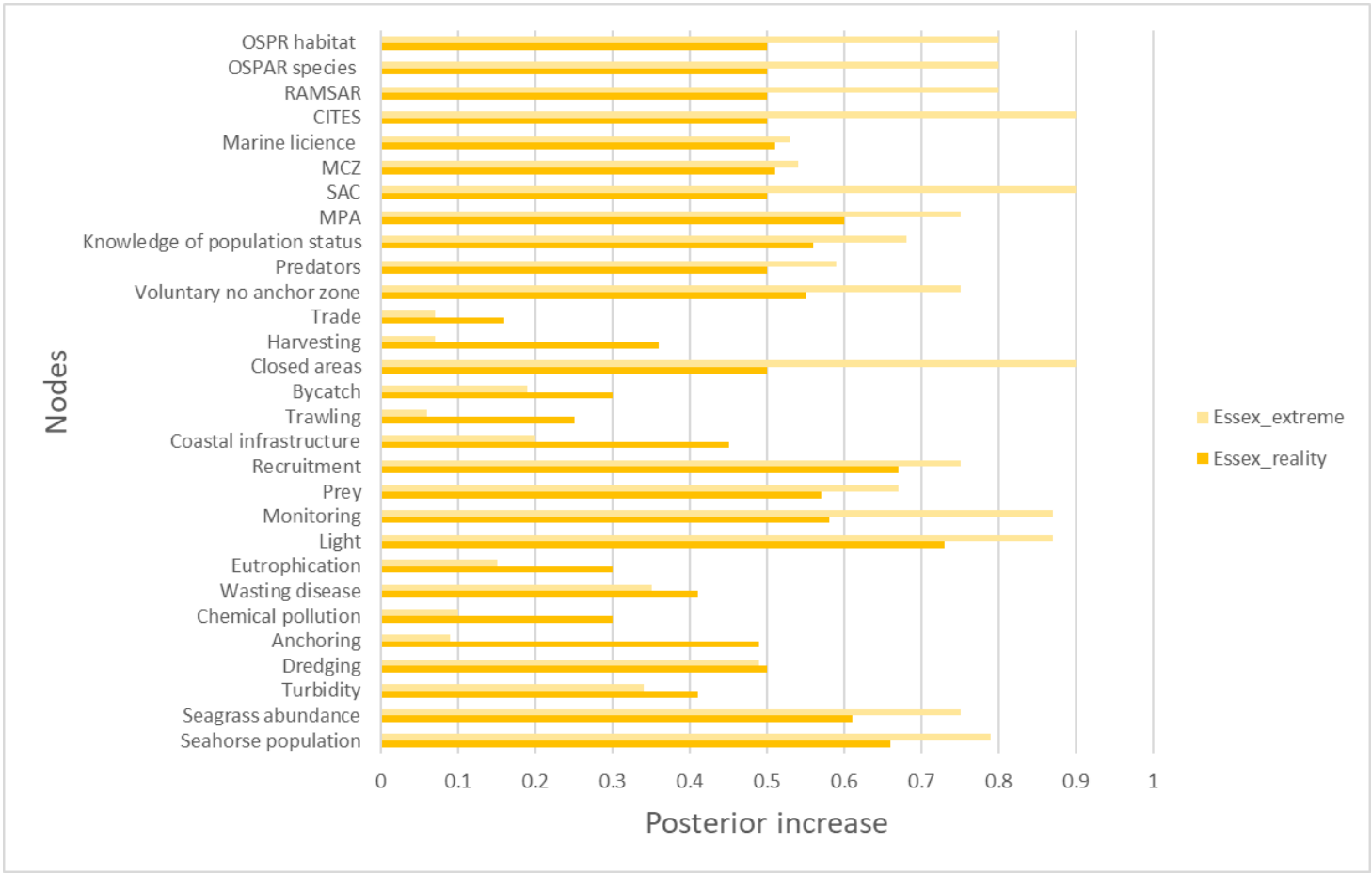

Figure 8.2: The calculated probability of posterior increase at the Essex Estuaries, for the reality and extreme scenarios. Values of > 0.5 depict nodes likely to increase and values of < 0.5 are likely to decrease.

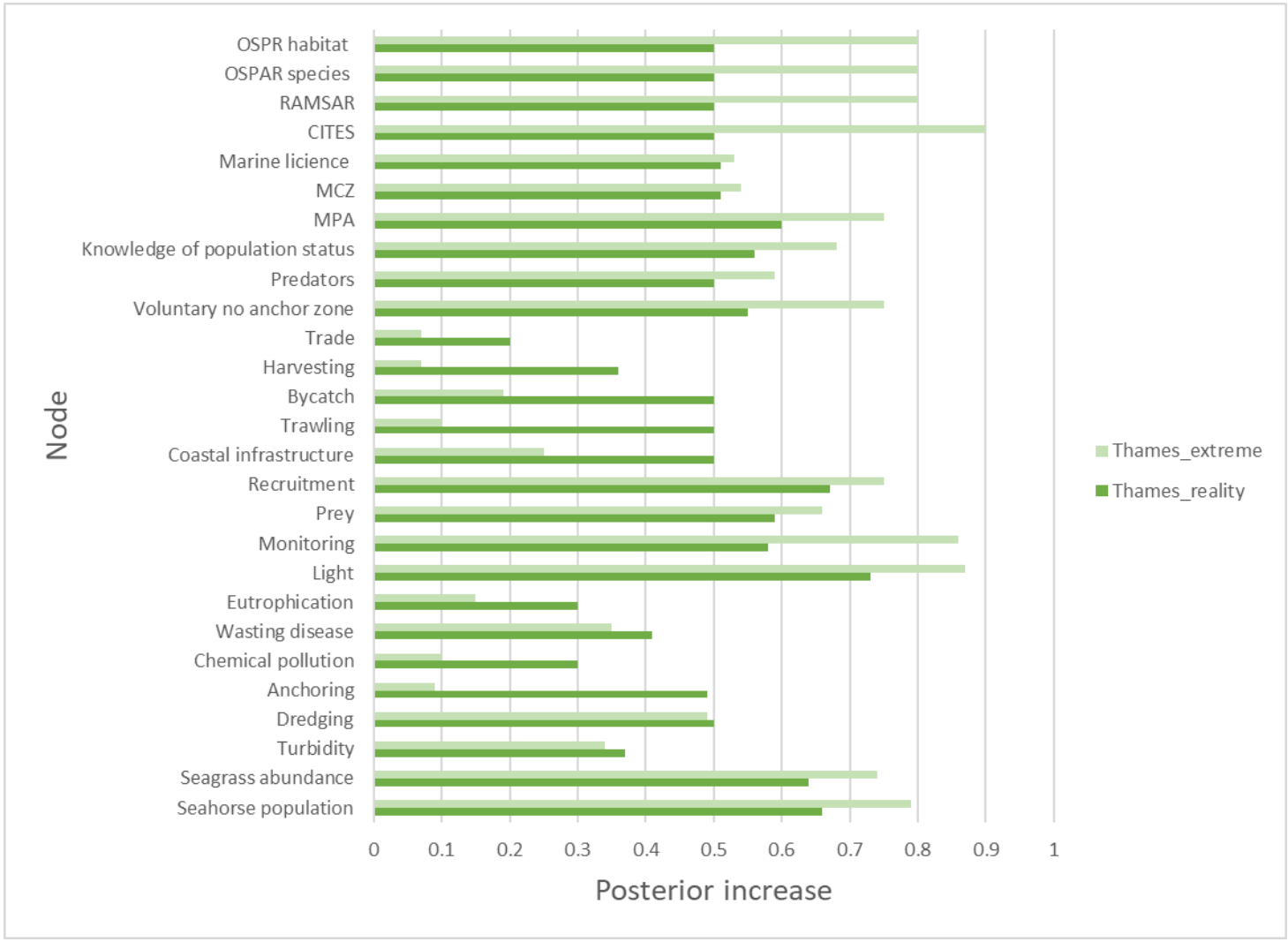

Figure 8.3: The calculated probability of posterior increase at the Thames Estuary, for the reality and extreme scenarios. Values of > 0.5 depict nodes likely to increase and values of < 0.5 are likely to decrease.

7.0 Discussion

To fulfil the aim and final objective of this study, this chapter discusses the data obtained from the BBN presented in section 6, with reference to site specific factors, seahorse ecology and legal frameworks (section 2.4, chapter 1 and chapter 3). This is achieved through considering how laws are applied in reality, how laws could be applied in an extreme scenario and finally through recommendations. To promote clarity, BBN probability data is converted into descriptive terms using a scale adapted from Landscape Logic (2010). To add further understanding and provide weight to descriptive terms, indications of moderate (values of 0.80- 0.51 and 0.49- 0.2) and major (values of 1- 0.81 and 0.19 - 0) probabilities have been given.

7.1 Application of laws in reality

The results show overall that under current implementation of law, seahorse populations and their seagrass habitat at all reference sites have a moderate probability of increasing. This implies the protection given by international, European and national law needs strengthening. Considering seahorses' low population densities and low fecundity, an only moderately probable increase means it is possible seahorses will not reach stable numbers. Under current legal implementation, out of the three sites, seahorse populations are best protected at Studland Bay, showing the biggest posterior increase (Figure 6). Seahorses at Studland Bay, however, still only have a moderate probability of increasing. The stronger probability of seahorse increase seen at Studland Bay could result from Studland currently being the only reference site to have seahorses as designated features of the MCZ under the MCAA. Although the other reference sites have MCZs, the slightly more substantial increase at Studland suggests it could be the specific designated feature allocation that provides them protection, not just the area-based conservation. This raises the question of whether having legislation that relies on an area-based conservation offers adequate protection to seahorses or whether conservation needs to be species specific. The ineffectiveness of area-based conservation such as that which the MCAA and Habitats and Species Regulations provide, has been highlighted as a result of inefficient management and poor funding for

surveillance and policing of MPAs (Gill et al. 2017; Maxwell et al. 2020). This supports the idea that area-based approaches will not provide strong protection for seahorses. This is important as an area-based approach is a primary approach taken by the government within the new Environment Act 2021 (HM Government 2023), with a focus on MPAs through 30-by-30 (protecting 30% of the ocean by 2030) and by creating Highly Protected Marine Areas (HM Government 2023). This study, however, suggests the focus of MPAs, under current management and enforcement, is unlikely to have a significant impact on reducing surrounding pressures. The Environmental Audit Committee (EAC 2021) also suggests MPAs are poorly managed and enforced, supporting the idea that under current application, MPAs would not protect biodiversity. Another consideration is the level of protection area-based conservation provides when climate change is affecting the survival rate and distribution of marine species through ocean warming and ocean acidification. This is an important consideration for future seahorses populations due to the medium sensitivity their seagrass bed habitats have to global warming (d'Avack et al. 2022). If sea temperature change or ocean acidification causes an increased death rate or range shift in seahorse species specifically or in seagrass, areas designated for their protection would become climatically unsuitable and thus even designating seahorses as protected features within the area would not lead to their protection. The study by Gillingham et al. (2015) (although terrestrial based), suggests there is potential for protected areas to help in species retention. Faleiro et al. (2015), however, suggests seahorses *Hippocampus guttulatus* experienced negative behavioural changes when faced with ocean acidification, supporting the idea that designation of protected areas in climatically unfavourable conditions would not protect seahorses.

As area-based conservation can not be relied upon to protect seahorses, it would be beneficial to have additional targeted protection, for example through the new Species conservation strategies implemented by the Environment Act 2021. It could, however, be concluded that even designating species will lead only to weak protection, as seahorses at the Studland Bay MCZ are a designated feature and so should have received targeted conservation, yet their populations are still only set to see a moderate

probability of increasing. When we consider the even weaker probable increase at Studland, through the 95% confidence intervals seen in Figure 5, model 1, it further implies even identifying seahorses as designated features in MCZs does not provide adequate protection. The fact that MCZs are not providing adequate protection at sites where seahorses are designated features and where they are not means the legal framework which provides MCZs needs to be urgently addressed to ensure MCZ better management. This argument is also raised by the Environmental Audit Committee (EAC 2021), who suggest that lack of enforcement of MPA's protected status will lead to 'paper parks'. Whilst the 2023 EIP is calling for 70% of designated features in (MPAs) to be in favourable condition by 2042 (HM Government 2023), this will only help seahorse populations that are designated features for which they are not in two out of the three reference sites. Yasué et al. (2012) also supports the idea that area-based conservation such as MPAs does not provide seahorses strong protection as the density of seahorses over time did not increase more inside the MPA than outside. For species such as seahorses that are vulnerable to threats that do not know the boundaries of MPAs, such as pollution, area-based conservation will not protect them. It is important to consider that the MCZ designation for Studland Bay has been in place only since 2019. Life history traits of seahorses, such as low fecundity, may mean it will take longer to see the positive effects of MCZ protection on seahorses when the species is a designated feature. The discussion above, however, suggests it will unlikely improve over time if implementation of laws stays the same. Furthermore, despite Studland Bay MCZ having seagrass as a designated feature, habitat restoration remained at 0.5, implying laws are not actively improving conditions of seahorse habitat despite the MCZ conservation objective of bringing seagrass into favourable condition. This provides further evidence that MCZ designations do not provide seahorses effective protection.

Under current legislation, seahorses at Essex were less likely to increase than at Studland. The difference in designations between the two sites implies the SAC at Essex provides less protection to seahorses than the Studland Bay MCZ (where seahorses are a designated feature). This could be due to SACs only designating estuaries, not specifically seahorses, as features, therefore protection of seahorses is

incidental and weaker, further supporting the argument that seahorses require targeted conservation measures. The results also suggest having a SAC present makes no changes to the seahorse populations as the seahorse posterior node was the same for the Thames Estuary where there is no SAC. These results could therefore be used to help guide authorities on the conservation approach needed and the type of MPA required depending on the targeted species.

Due to seahorses' dependence on seagrass (especially the long snouted), it is also important to consider the posterior increase of seagrass. Under current implementation of laws, seagrass at all reference sites has only a moderate probability of increasing but has the strongest probability within the Thames Estuary. This is surprising as the Thames Estuary arguably faces the most intense amount of threats but the weakest protection. This implies the laws in place to protect seagrass at Studland Bay and Essex Estuaries, such as bottom-towed gear byelaws and designation of seagrass as a feature of the MCZ, do not provide protection, otherwise the seagrass posterior nodes at Studland and Essex would have been greater. This highlights again that if the practical application of the laws are not upheld, they merely provide protection on paper. It is worth considering the importance of seagrass to the two native species, as although seagrass abundance increase was least probable in the Essex Estuaries (Figure 6), it is here that the short snouted seahorse has been recorded the most. As this species does not rely on seagrass as heavily, this difference may not be such an issue. This is not to take away from the fact that the short snouted seahorses within the Essex Estuary will still require seagrass.

Arguably, one of the most significant threats to seahorse populations at Studland Bay is the destruction of seagrass beds via anchoring. Under current legislation, anchoring at Studland Bay only has a moderate probability of decreasing (Figure 6), suggesting the biggest pressure for the area has not been mitigated by law. Important threats to Essex Estuaries seahorse populations include damage to the seagrass from commercial fishing and recreational boats. For boat related threats, anchoring has a moderate probability of decreasing and mooring, boat damage and marine traffic had an even

chance of increasing or decreasing (Figure 5 and 6), again suggesting the most significant pressures for the area have not been alleviated by legislation. Despite the implementation of the Essex SAC, protection from fishing was weak. Although trawling had a moderate probability of decreasing, static fishing gear which can cause cumulative stress from pot placement, remained at 0.5, along with closed areas. This implies fishing pressure will remain an issue for seagrass beds and thus seahorses within the Essex Estuaries. The seahorse populations within the Thames Estuary face the most substantial amount of threats, including from major shipping vessels, fishing and urbanisation. Coastal infrastructure, boat damage and trawling, however, remained at 0.5 and so it cannot be said these will decrease under current legislation. Furthermore, as the Thames Estuary has the greatest level of anthropogenic pressures it would be logical to assume the Thames site might require the biggest increase in seahorse populations just in order to survive, but the reality models suggest a joint smallest increase (Figure 6). Should global populations of seahorses become depleted and UK populations become more targeted, the threat of harvesting could become more detrimental to UK populations. For all three reference sites, however, harvesting had only a moderate probability of decreasing. This suggests the current application of laws, which aim to control trade (CITES, EU Trade Regulations and COTES) only offers weak protection.

For all sites, the chemical pollution threat was more likely than sewage or nutrient pollution to decrease, suggesting the laws governing pollution were more effective at suppressing chemical pollution than nutrient pollution. Knowing seagrass sensitivity to eutrophication and water quality reduction, any positive effect of reduced chemical pollution to seahorses may be counteracted by the continued loss of seagrass habitat from consequences of sewage and nutrient pollution. To ensure viable populations, recruitment is an important node that should be increasing, especially as fry can have a high predation rate (Project Seahorse 2021). If pressures to seahorses were being effectively regulated, the posterior increase for recruitment would likely show a major probability of increasing but in reality the models show a moderate probability of increasing. Although seahorse populations have naturally low densities (Project

Seahorse 2021), when combined with the levels of pressures we are currently seeing, it is important recruitment remains high to support current populations.

The highest probable decrease in the reality models is trade. This suggests that out of applicable legislation, trade regulations are most effective at mitigating the related pressure. It is possible trade regulations are most effective because the legislation specifically lists seahorses or because trade is regulated across different levels of legal frameworks, i.e., international, European and national. This concept insinuates the more legislation in place to provide protection, the better the outcome will be, such as when the concept is applied to governance measures for MPAs (Professor Rick Stafford personal communication 25 March 2023).

Ultimately, current application of policy and law does not sufficiently minimise the threats to UK seahorses. Without adequate protection, the survival of viable populations within the three reference sites cannot be ensured.

7.2 Extreme application of laws

More extreme prior values were applied to assess the consequences of laws being better implemented. The results suggest that even though better implementation would lead to a stronger probability of seahorse populations and seagrass abundance increasing (Figure 8.1, 8.2, 8.3), the effect would still not result in a major probability of increasing for any site. The fact that implementing the current applicable laws almost perfectly still only leads to a moderate probability of seahorses and seagrass increasing is very concerning as it implies there is currently no legal framework that can provide seahorses strong protection. With better implementation, seahorse populations at Essex Estuaries and Thames Estuary would see the highest probable increase (Figure 7). This suggests even if laws were better implemented to improve MCZ management at Studland Bay, it still wouldn't offer the best protection to seahorses, further suggesting area-based conservation will not be suitable for seahorses. These results suggest we need stronger species specific protection alongside the government’s focus on MCZs in their 25 Year EIP. Within the extreme scenarios, the Essex Estuary seahorse

populations had the joint highest possible increase (with Thames Estuary), suggesting it is the SAC designation that would provide the most protection if the laws were better implemented. This protection given by the SAC in the extreme scenarios would, however, still result in only moderately probable increases in seahorses. It is the Essex site which also sees the highest probable increase in seagrass when laws are better implemented, suggesting again how the use of SACs would provide better protection to seahorses than MCZs.

Within the extreme scenarios, the application of the RAMSAR Convention means predators would also likely increase. This increase, however, is only moderate and as reports of birds predating Syngnathidae are opportunistic (Kleiber et al. 2011), it is unlikely that better application of RAMSAR would be harmful to seahorses. Even under better implementation of legislation, several posterior nodes remained at 0.5, suggesting laws would not cause a decrease in these harmful effects. Several important nodes which did not decrease at any reference sites are sewage pollution, trampling and boat damage, which is important, as we know seagrass is sensitive to decreases in water quality and easily harmed by physical disturbance.

Better application of the law will provide stronger protection, seen by a larger proportion of nodes having a posterior increase or decrease but also the stronger effect seen on the nodes. It is important to consider, however, that stronger implementation of these laws is likely to be in contrast with national economic pursuit, so the chances of seeing the implementation of these laws as extreme as depicted in models 4, 5 and 6 is unlikely.

7.3 Law amendment recommendations

It is apparent from these results that no current legislation is effective at protecting UK seahorse populations. It is crucial, therefore, to consider amendments that could be made. In order to strengthen laws which are already in place, it is recommended that seahorses be added as designated features to any MCZs in the vicinity of where seahorses are located. This would strengthen the MCAA's responsibility to protect

seahorses because the act requires maintaining or bringing designated features into favourable condition and reporting on the success of Conservation objectives. Seahorses and seagrass should also be added to the list of European Protected Species under the Habitats and Species Regulations 2017, so that they can be qualifying features of SACs and so are required to be maintained in favourable condition. Furthermore, to keep up with pressures of harvesting for international trade purposes, seahorses should be listed under appendix I for CITES and COTES. Change from controlling trade to prohibiting trade of these species could increase the deterrent for harvesting.

Additionally, although the concept of strict liability is built into some of the UK's environmental legislation, it should also apply to wildlife crimes under Schedule 5 Section 9 of the Wildlife and Countryside Act. This would strengthen the Act and allow prosecution of offenders for damaging seahorse habitat (seagrass beds) even if intent or recklessness (from a legal point of view) cannot be proven. This would require the terminology of 'reckless' to be removed for the Act, meaning it is not an offence to say you were not aware of the seagrass habitat.

It is also important to consider how the European legislation was reviewed in relation to its impacts prior to Brexit. Whilst it could be argued the reality scenarios depict a weak protection of seahorses, suggesting European legislation did not provide strong seahorse protection anyway, now European legislation is being repealed, we must ensure new legislation such as the Environment Act 2021 exceeds protection that was previously provided before Brexit.

Whilst these amendments could bring improvement to the protection of seahorses, if we take into consideration how even extreme implementation of the current laws did not lead to adequate protection, it is likely that these amendments alone would be insufficient. It is necessary to consider then how we ensure seahorse populations do not face extinction in the future. It is likely that protection is weak because current legislation either offers only incidental protection or because seahorses are listed within certain

laws, instead of having a specific law for just seahorses. It could be argued that having several legal frameworks all advocating for roughly the same thing, either the protection of biodiversity or to promote a higher level of water quality, could heighten the protection species receive and provide backup protection if one law is not working to full potential, as discussed at the end of section 7.1. Whilst this might work for legislation such as trade regulations that lists specific species, when it comes to protection of environmental status, such as MSFD and Marine Strategy Regulations, the protection remains weak. The next recommendation, therefore, is a legislative proposal for a Conservation of Seahorses Act. This domestic legislation would provide specific protection, much like the Conservation of Seals Act 1970 and Protection of Badgers Act 1992. This would prevent killing, injuring or taking seahorses and destruction of their place of shelter. This would ensure more species specific conservation. Alternatively, to ensure species targeted conservation, seahorses could receive targeted conservation through the new Species Survival Fund laid out in the 2023 EIP. The EIP, however, offers little detail on how the fund will operate (Fair 2023), only that it is 'targeted at protecting our rarest species' (HM Government 2023), which seahouses arguably are. Due to the lack of detail on this option and the concern of the timeframe for funding available, it could be argued that instating a specific law as discussed above would be the preferable option.

Protection can be further strengthened by taking an adaptive law approach. By realising that laws are often written for the problems we face in the here and now, this leaves room for laws to become outdated, to struggle with scientific uncertainty and to not support newly emerging scientific evidence. By having a built-in adaptation mechanism within the law, it can be adapted in line with the latest scientific evidence (Dr Iain Green personal communication 22 March 2023). This will be important for seahorse conservation as current threats to their populations, such as the effect of endocrine disrupting chemicals are still being researched. The Secretary of State for Environment, Food and Rural Affairs must, therefore, have the power and importantly the duty, to biennially review the environmental law and make new provisions if required. This would also give a better opportunity to invoke the precautionary principle should it be needed.

For example, the adaptive law approach would strengthen the protection given by laws governing the regulation of pollution such as the Water Framework Directive and the The Marine Strategy Framework Directive as it would allow adaptation according to the latest evidence on toxic chemicals. Although it is likely this approach would be opposed by those who have an anthropocentric light green environmental ethic, it is possible this approach could be accepted for seahorses as their charismatic nature evokes public support. This would leverage huge changes for environmental law.

In a broader context, seahorse protection could be strengthened by supporting the concept of ecocide, as coined by Professor Arthur W. Galston. Ecocide is defined as ‘unlawful or wanton acts committed with knowledge that there is a substantial likelihood of severe and either widespread or long-term damage to the environment…’ (Stop Ecocide International 2023). Elements of ecocide that could be applied to seahorses include transboundary pollution of the marine environment, which impacts seagrass beds such as pollution impacting across OSPAR region boundaries and climate change increasing temperature stress and storm severity which could impact seagrass beds. Polly Higgins and Jojo Mehta, founders of the Stop Ecocide International, call for ecocide to be recognised as a crime, suggesting amendment to the Rome Statute of the International Criminal Court (ICC) to make ecocide an arrestable offence, therefore holding polluters responsible. The concept of ecocide has been adopted through domestic legislation by a small number of countries, e.g., Ukraine, who define ecocide in Article 441 of its criminal code, which came into force in 2001 (The Criminal Code of Ukraine, art 441). As ecocide has not yet been internationally recognised as a crime by the ICC, the UK could take inspiration from Ukraine and adopt it into their national legislation.

8.0 Conclusion

This study provides an important evidence-based analysis of environmental legal frameworks used to protect biodiversity in order to review and understand their

effectiveness particularly related to seahorses. The use of BBN has allowed the shortcomings of international, European and national laws to be highlighted in order to understand the consequences for UK seahorse populations. Ultimately, the study concludes that current implementation of the law does not offer seahorses adequate protection. This is alarming because the plethora of existing legislation gives the misconception that biodiversity is being legally protected, when in reality it is not. Seahorses warrant the best possible protection due to their potential indicator species status and their ability to act as flagship species for important seagrass habitats. The use of extreme scenarios of legal implementation does, however, provide an opportunity for evidence-based amendments to be made in order to enhance policy and law to ensure legal protection is more robust and effective.

As conservation often requires prioritisation of efforts, due to finite funding and resources, BBNs such as this study can be useful tools to help prioritise necessary changes. Protecting threatened species such as seahorses, requires an urgent response as cumulative effects of anthropogenic pressures risk pushing these species to extinction. BBNs give the opportunity to provide scientific, targeted responses. BBNs can, therefore, be useful tools for decision makers and regulators to ensure laws stay effective through time and are adapted to changing environments and knowledge.

9.0 References

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Natural Environment and Rural Communities Act 2006

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10.0 Appendices

Appendix I

Table 4 : Supporting evidence for the direction and weight of each edge in Figure 1.

From (node)	To (node)	Type	Weight	Citations for reference
Seagrass abundance	Seahorse recruitment	+	4	Focus group survey
Seagrass abundance	Turbidity	-	4	de Boer, W.F., 2007 Madsen et al. 2001 Widdows et al. 2008
Turbidity	Seagrass abundance	-	4	Brodersen et al. 2017 d'Avack et al. 2014 Li et al. 2021 van der Heide et al. 2007
Seagrass abundance	Seahorse populations	+	2	Correia et al. 2018 Curtis and Vincent 2005 Garrick-Maidment 2020 JNCC 2002 Neish 2007 Woodall et al. 2018
Mooring	Seagrass abundance	-	4	Jackson et al. 2013 Johnston and Telsnig 2020 Luff et al. 2019 MarineSpace Ltd and Orcades Marine Ltd 2018 Sagerman et al. 2020 Unsworth et al. 2017
Anchoring	Seagrass abundance	-	3	Collins et al. 2010 Garrick-Maidment 2020 Seastar Survey Ltd 2012
Anchoring	Turbidity	+	1	Collins et al. 2010 UKMPA Centre 2001
Seagrass abundance	Prey	+	3	Bowden et al. 2001 Cullen-Unsworth et al. 2018 Kitsos et al. 2008

				Woodall et al. 2018
Charitable organisations	Monitoring	+	4	Dorset Wildlife Trust 2022 Pollom et al. 2021 Seastar Survey Ltd 2012
Citizen science	Monitoring	+	3	Dalby et al. 2021 Garrick-Maidment 2020 Jones et al. 2018 Project Seagrass 2022b Project Seahorse 2022b Zooniverse 2022
Light levels	Seagrass abundance	+	4	Greve and Binzer 2004 Hauxwell et al. 2003 Li et al. 2021
Harvesting	Seahorse populations	-	4	Focus group survey JNCC 2002 OSPAR Commission 2008c
Dredging	Seagrass abundance	-	4	Cole 2016 d'Avack et al. 2014 Erftemeijer and Lewis 2006 Perkins 1988
Dredging	Bycatch	+	1	Lawson et al. 2017
Habitat restoration	Seagrass abundance	+	2	Cunha et al. 2012 MMO 2019a Paulo et al. 2019 Unsworth et al. 2019 Unsworth et al. 2022
Voluntary no anchor zone	Anchoring	-	1	Seastar Survey Ltd 2012
Monitoring	Voluntary no anchor zone	+	3	MMO 2022b MMO 2022c
Public support	Voluntary no anchor zone	+	3	DCF 2021 Seastar Survey Ltd 2012
Boat damage	Seagrass abundance	-	3	Hiscock et al. 2005 Reynolds et al. 2018 Short et al. 2001 Short and Wyllie-Echeverria 1996

Boat damage	Turbidity	+	4	d'Avack et al. 2014 Hilton and Phillips 1982 Sagerman et al. 2020
Charitable organisations	MCZ	+	3	Garrick-Maidment 2010. Garrick-Maidment 2020
Closed areas	Bottom trawling	-	4	KEIFCA 2016 MMO 2014
Charitable organisations	Voluntary no anchor zone	+	3	MMO 2022a
Eutrophication	Light levels	-	4	Burkholder et al. 2007 Hauxwell et al. 2001 Hauxwell et al. 2003
Dredging	Turbidity	+	1	Erftemeijer and Lewis 2006 Miró et al. 2021
Bottom trawling	Bycatch	+	3	Hiscock et al. 2005 Lawson 2017 Lawson et al. 2017 Pinnegar et al. 2008
Trampling	Seagrass abundance	-	4	Boyes et al. 2008 Garmendia et al. 2017 Jackson et al. 2013 Jackson et al. 2016 Milazzo et al. 2002
Monitoring	Knowledge of population status	+	3	Garrick-Maidment 2020 Jackson et al. 2016
Bottom trawling	Seagrass abundance	-	1	Eno et al. 2013 Jackson et al. 2013
Water sports	Trampling	+	1	Jackson et al. 2016
Natural disturbance	Habitat restoration	-	2	Paulo et al. 2019 Van Katwijk et al. 2009
Light levels	Wasting disease	-	3	Jakobsson-Thor et al. 2020 Vergeer et al. 1995
Eutrophication	Wasting disease	+	1	Beets et al. 2014 Hughes et al. 2018

Aquaculture	Harvesting	-	3	Tlusty 2002 Vincent and Koldewey 2006 Watson and Stokes 2004
Flash photography	Seahorse populations	-	2	De Brauwer et al. 2019 Garrick-Maidment 2020 Marine Biological Association 2014
Potting	Bycatch	+	3	Garrick-Maidment 2004 JNCC 2002 Vasconcelos et al. 2019
Potting	Seagrass abundance	-	3	d'Avack et al. 2014 Eno et al. 2013
Seahorse recruitment	Seahorse populations	+	4	Focus group survey
Marine Traffic	Chemical pollution	+	4	Egardt et al. 2018 Garrick-Maidment 2020 Lloret et al. 2008 Saunders et al. 2000
Chemical pollution	Seagrass abundance	-	1	Lewis and Devereux 2009 Ralph et al. 2007
Chemical pollution	Seahorse populations	-	4	D'Alvise et al. 2020 Nenciu et al. 2016 Qin et al. 2020
Chemical pollution	Seahorse recruitment	-	3	D'Alvise et al. 2020 Qin et al. 2020
Marine Traffic	Sewage pollution	+	3	Carreño and Lloret 2021 Cottrell and Graefe 1997 Garrick-Maidment 2020 Saunders et al. 2000
Marine Traffic	Boating damage	+	3	Asplund and Cook 1997 Murphy and Eaton 1983 Saunders et al. 2000
Marine Traffic	Turbidity	+	1	Murphy and Eaton 1983 Saunders et al. 2000
Eutrophication	Seagrass abundance	-	4	Burkholder et al. 1992

				Brun et al. 2008 Van Katwijk et al. 1997
Seagrass wasting disease	Seagrass abundance	-	4	Graham et al. 2021 Muehlstein 1989 Ralph and Short 2002 Short and Wyllie-Echeverria 1996
Bycatch	Trade	+	3	Foster et al. 2019 OSPAR Commission 2008b Vincent et al. 2011a
CITES listing	Harvesting	-	2	Foster et al. 2019 Foster et al. 2022
Sewage pollution	Eutrophication	+	1	Holmer et al. 2016
Eutrophication	Wasting disease	+	1	Hughes et al. 2018 Sullivan et al. 2018
Predators	Seahorse population	-	1	Harris et al. 2007 Kleiber et al. 2011
MCZ	Seahorse population	+	1	DEFRA 2019b Standing 2020 Yasué et al. 2012
RAMSAR	predators	+	1	Kleijn et al. 2014
Trade	Harvesting	+	1	Louw and Bürgener 2020 Vincent 2011a
MCZ	Voluntary no anchor zone	+	4	Johnston et al. 2020 MMO 2022a MMO 2022d
SAC	Closed areas	+	4	Kent and Essex IFCA 2023b MMO 2016 Natural England 2015
Bycatch	Seahorse populations	-	4	Focus group survey
Marine traffic	Anchoring	+	3	Focus group survey
Sewage pollution	Turbidity	+	4	Focus group survey

Public support	Charitable organisations	+	3	Focus group survey
MCZ	Marine licence	+	4	MMO 2013 MMO 2019b
Marine licence	Dredging	-	3	MMO 2019c
Knowledge of population status	MCZ	+	3	DEFRA 2019b
SAC	Monitoring	+	3	Essex Estuaries Initiative 2004. Natural England 2022
OSPAR species	Monitoring	+	3	OSPAR Commission 2012a OSPAR Commission 2022b
OSPAR species	Knowledge of population status	+	1	Curd 2009
OSPAR habitat	MPA	+	1	Emmerson 2021 OSPAR Commission 2019. OSPAR Commission 2020b
OSPAR species	MPA	+	2	Hennicke et al. 2022 OSPAR Commission, 2020b
MPA	Monitoring	+	3	JNCC 2019g OSPAR Commission 2019
MCZ	Monitoring	+	3	DEFRA 2013 MMO 2016
BAP priority habitat	Monitoring	+	1	JNCC 2011 Wildlife and Countryside Link 2005
Nutrient pollution	Eutrophication	+	4	Andersen et al. 2006 Painting et al. 2007
Coastal infrastructure	Seagrass abundance	-	4	Danovaro et al. 2020 Duarte et al. 2004 Short and Wyllie-Echeverria 1996

Appendix Ⅱ

Notes of the justifications of prior values given to each scenario for the BBN (Table 3). These justifications are a consequence of the discussion given in chapter 3.

Reference number for below of law that has been applied:
1. RAMSAR
2. CITES
3. Bern
4. OSPAR
5. Habitats Directive
6. EU Trade regs
7. Water Framework Directive
8. Marine Strategy Framework Directive
9. WCA
10.NERC
11.Habitats and Species Regs
12.MCAA
13.Marine strategy regs
14.COTES

1a. Studland Bay- reality

1. RAMSAR -0.5 (is not increasing or decreasing)
2. CITES- 0.5 (law is not increasing or decreasing the CITES appendix)
3. Bern- is having no effect on UK populations
4. OSPAR species-0.5 (law isn't increasing or decreasing this designation, also they are only recommendations not law)
4. OSPAR habitat-0.5 (law isn't increasing or decreasing this designation, also they are only recommendations not law)
4- MPAs-0.6 (OSPAR sets out to implement a network of MPAs. Studland Bay is included in the network but the overall OSPAR network only covers 6.5% of the OSPAR Maritime Area so hasn't added many MPAs)
4- Eutrophication- 0.45 (Latest reports show majority of the Greater North Sea = non-problem area for eutrophication but transitional waters are still problem areas)
13. Eutrophication- 0.3- ('largely achieved' for eutrophication levels but it remained a problem in some coastal and estuarine areas)
So- 0.3
6- Trade node- 0.3- (requires a permit to say not wild caught in the UK. In 2019 there were no key seizures of seahorses with the UK as the export country- suggesting trade is being controlled. But performance of implementation is declining and regulation of trade is primarily through domestic law really)
14. Trade node- 0.2- (no evidence of the UK being the country of origin for wild caught exported seahorses between 2003-2019 but only 4 airports have CITES points for live specimens with Border Control Posts designated to handle fish specimens so investigation unlikely to be completely thorough)
So- 0.2
7- chem pollution node- 0.35 (Studland chemical status failed 2022 when including uPBTs but passed when not included so some progress made but not completely deceased. Also not completely reduced because Gov's plan to implement directive lacks SMART targets)

13. Chem pollution - 0.3 (levels of contaminants being ‘largely achieved’, persistent chemicals were causing some coastal areas to fail)
So- 0.3
8. Change nothing as not been achieved
9- Harvesting node- 0.4 (although UK doesn’t appear to be a main source of exported seahorses, breeches are hard to detect and underreported therefore could still be occurring. Terminology of law aka ‘intentional’ means hard to prosecute, therefore not a major deterrent)
10. Seahorse abundance- 0.5 (still the same as no action plan for seahorses means nothing done even though species of principal importance)
12.- MCZ node- 0.5 (law isn't increasing or decreasing the MCZ designation)
12. vol no anchor - 0.6 (management of MCZ includes a voluntary no anchor zone, but this is only voluntary so provides no legal protection and is often ignored.)
12- Trawling- 0.25 (provides IFCA to make byelaws- studland trawling byelaw but lack of enforcement means reports of trawlers in closed areas go uninvestigated)

1b. Essex Estuaries- reality
1. RAMSAR -0.5 (is not increasing or decreasing)
2. CITES- 0.5 (law is not increasing or decreasing the CITES appendix)
3. Bern- is having no effect on UK populations
4. OSPAR species-0.5 (law isn't increasing or decreasing this designation, also they are only recommendations not law)
4. OSPAR habitat-0.5 (law isn't increasing or decreasing this designation, also they are only recommendations not law)
4- MPAs- 0.6 (OSPAR sets out to implement a network of MPAs. ESsex Estuaries is included in the network but the overall OSPAR network only covers 6.5% of the OSPAR Maritime Area so hasn’t added many MPAs)
4- Eutrophication- 0.45 (Latest reports show majority of the Greater North Sea = non-problem area for eutrophication but transitional waters are still problem areas)
13. Eutrophication- 0.3- (‘largely achieved’ for eutrophication levels but it remained a problem in some coastal and estuarine areas)
So- 0.3
5. SAC node- 0.5 law is not increasing or decreasing that designation)
6- Trade node- 0.3- (requires a permit to say not wild caught in the UK. In 2019 there were no key seizures of seahorses with the UK as the export country- suggesting trade is being controlled. But performance of implementation is declining and regulation of trade is primarily through domestic law really)
14. Trade node- 0.2- (no evidence of the UK being the country of origin for wild caught exported seahorses between 2003-2019 but only 4 airports have CITES points for live specimens with Border Control Posts designated to handle fish specimens so investigation unlikely to be completely thorough)
So- 0.2
7- chem pollution node- 0.35 (Essex chemical status failed 2022 when including uPBTs but passed when not included so some progress made but not completely deceased.Also not completely reduced because Gov’s plan to implement directive lacks SMART targets)
13. Chem pollution - 0.3 (levels of contaminants being ‘largely achieved’, persistent chemicals were causing some coastal areas to fail)
So- 0.3
9- Harvesting node- 0.4- (although UK doesn’t appear to be a main source of exported seahorses, breeches are hard to detect and underreported therefore could still be occurring. Terminology of law aka ‘intentional’ means hard to prosecute, therefore not a major deterrent)

10. Seahorse abundance- 0.5 (still the same as no action plan for seahorses means nothing done even though species of principal importance)
11. SAC node- 0.5 (law isn't increasing or decreasing this designation)
11-Coastal infrastructure- 0.45- (Habitats Regulations Assessment meant to ensure planning decisions do not hinder objectives of SAC but Bradwell example shows how this did not stop damaging construction)
12. Trawling - 0.25 (provides IFCA to make byelaws for SAC- trawling byelaw but lack of enforcement means reports of trawlers in closed areas go uninvestigated)

1c. Thames Estuary- reality

1. RAMSAR -0.5 (is not increasing or decreasing)
2. CITES- 0.5 (law is not increasing or decreasing the CITES appendix)
3. Bern- is having no effect on UK populations
4. OSPAR species-0.5 (law isn't increasing or decreasing this designation, also they are only recommendations not law)
4. OSPAR habitat-0.5 (law isn't increasing or decreasing this designation, also they are only recommendations not law)
4- MPAs- 0.6 (OSPAR sets out to implement a network of MPAs. Thames is included in the network but the overall OSPAR network only covers 6.5% of the OSPAR Maritime Area so hasn't added many MPAs)
4- Eutrophication- 0.45 (Latest reports show majority of the Greater North Sea = non-problem area for eutrophication but transitional waters are still problem areas)
13. Eutrophication- 0.3- ('largely achieved' for eutrophication levels but it remained a problem in some coastal and estuarine areas)
So- 0.3
6- Trade node- 0.3- (requires a permit to say not wild caught in the UK. In 2019 there were no key seizures of seahorses with the UK as the export country- suggesting trade is being controlled. But performance of implementation is declining and regulation of trade is primarily through domestic law really)
14. Trade node- 0.2- (no evidence of the UK being the country of origin for wild caught exported seahorses between 2003-2019 but only 4 airports have CITES points for live specimens with Border Control Posts designated to handle fish specimens so investigation unlikely to be completely thorough)
So- 0.2
7- chem pollution node- 0.45 (Thames failed chemical status with and without uPBTs so no real progress made. Also not reduced because Gov's plan to implement directive lacks SMART targets).
13. Chem pollution - 0.3 (levels of contaminants being 'largely achieved', persistent chemicals were causing some coastal areas to fail)
So-0.3
9- Harvesting node- 0.4- (although UK doesn't appear to be a main source of exported seahorses, breeches are hard to detect and underreported therefore could still be occurring. Terminology of law aka 'intentional' means hard to prosecute, therefore not a major deterrent)
10. Seahorse abundance- 0.5 (still the same as no action plan for seahorses means nothing done even though species of principal importance)

2a. Studland Bay- extreme

1. RAMSAR- 0.8 (if better managed might increase bird population but allowance for not 100% perfection)
2- CITES node- 0.9 (if we increased seahorses to CITES listing I)
4- OSPAR species- 0.8 (if 'recommendations' became 'law')
4- OSPAR habitats- 0.8 (if 'recommendations' became 'law')
4- MPAs- 0.7 (if MPAs covered more area and therefore were more ecologically coherent)

4- Eutrophication - 0.2 (if OSPAR was better implemented to achieve the goal of a ‘marine environment where eutrophication does not occur’)
13. Eutrophication- 0.15- (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
8- Eutrophication node- 0.15 (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
So- 0.15
4- Chem pollution - 0.2 (if OSPAR was better implemented to achieve the goal of reducing chemical pollution)
7- chem pollution node- 0.1 (if we got chem status to good with and without uPBTs. If we changed wording of law from ‘aiming’ to ‘to achieve’)
8- chem pollution node- 0.15 (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
13. Chem pollution - 0.15- (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
So-0.1
6- Trade- 0.1- (if money was given to ensure implementation)
14. Trade node- 0.1- (all airports have CITES points for live specimens with Border Control Posts designated to handle fish specimens so investigation more thorough)
So- 0.1
7- Seagrass abundance- 0.6 (as seagrass is used as a biological indicator it should not decrease due to anthro pressures- so although directive does not necessarily work to increase seagrass, it should at least not decrease)
9- Seagrass abundance -0.6 (better enforcement to stop damage to ‘place of shelter’ eg. boat anchoring. Seagrass won’t necessarily increase lots but won't at least won't be destroyed)
So- 0.6
8- Trawling node- 0.15 (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
10. Trawling node- 0.1 (better implementation of following site management of strict regulations on allowed fishing gear types)
12- Trawling- 0.1 if trawling byelaw was better enforced)
13. Trawling - 0.15 (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
So- 0.1
8. Monitoring- 0.8 (better implementation of monitoring plans)
10. Monitoring node- 0.8 (as a species of prinicpal importance should- produce action plan for species added in 2007 (which includes seahorses) which following examples of other species action plans eg. Allis Shad would include monitoring programmes)
So- 0.8
9- Harvesting node- 0.1 (if wildlife crime was prioritised, investigated thoroughly)
10. Anchoring node- 0.1 (better implementation of following site management of strict regulations on anchor placement)
12. Anchoring- 0.1 (change vol no anchor zone to byelaw)
So- 0.1
10. Coastal infra node - 0.25 (change ‘have regard’ to stronger wording in biodiversity duty)
12. MCZ- 0.8 (better management measures)

2b. Essex Estuaries- extreme

1. RAMSAR- 0.8 (if better managed might increase bird population but allowance for not 100% perfection)
2- CITES node- 0.9 (if we increased seahorses to CITES listing I)
4- OSPAR species- 0.8 (if 'recommendations' became 'law')
4- OSPAR habitats- 0.8 (if 'recommendations' became 'law')
4- MPAs- 0.7 (if MPAs covered more area and therefore were more ecologically coherent)
4- Eutrophication - 0.2 (if OSPAR was better implemented to achieve the goal of a 'marine environment where eutrophication does not occur')
13. Eutrophication- 0.15- (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
So- 0.15
4- Chem pollution - 0.2 (if OSPAR was better implemented to achieve the goal of reducing chemical pollution)
7- chem pollution node- 0.1 (if we got chem status to good with and without uPBTs. If we changed wording of law from 'aiming' to 'to achieve')
13. Chem pollution - 0.15- (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
So- 0.1
5- SAC node- 0.9 (if management plan for SAC was actually issued and seen through to 'restore estuaries' and enforcement was better)
11. SAC node- 0.9 (if management plan for for SAC was actually issued and seen through to 'restore estuaries' and enforcement was better)
So- 0.9
6- Trade- 0.1- (if money was given to ensure implementation)
14. Trade node- 0.1- (all airports have CITES points for live specimens with Border Control Posts designated to handle fish specimens so investigation more thorough)
So- 0.1
7- Seagrass abundance- 0.6 (as seagrass is used as a biological indicator it should not decrease due to anthro pressures- so although directive does not necessarily work to increase seagrass, it should at least not decrease)
9- seagrass abundance -0.6 (better enforcement to stop damage to 'place of shelter'. Seagrass won't necessarily increase lots but won't at least won't be destroyed)
So-0.6
10. Monitoring node- 0.8 (as a species of prinicpal importance should- produce action plan for species added in 2007 (which includes seahorses) which following examples of other species action plans eg. Allis Shad would include monitoring programmes)
9- Harvesting node- 0.1 (if wildlife crime was prioritized, investigated thoroughly)
10. Anchoring node- 0.1 (better implementation of following site management of strict regulations on anchor placement)
10. Trawling node- 0.1 (better implementation of following site management of strict regulations on allowed fishing gear types)
13. Trawling - 0.15 (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
So-0.1
10. Coastal infra node - 0.25 (change 'have regard' to stronger wording in biodiversity duty)
11. Coastal infra node- 0.2 (if Habitats Regulations Assessments were actually taken into consideration)
So-0.2

2c. Thames Estuary- extreme

1. RAMSAR- 0.8 (if better managed might increase bird population but allowance for not 100% perfection)
2- CITES node- 0.9 (if we increased seahorses to CITES listing I)
4- OSPAR species- 0.8 (if 'recommendations' became 'law')
4- OSPAR habitats- 0.8 (if 'recommendations' became 'law')
4- MPAs- 0.7 (if MPAs covered more area and therefore were more ecologically coherent)
4- Eutrophication - 0.2 (if OSPAR was better implemented to achieve the goal of a 'marine environment where
eutrophication does not occur')
13. Eutrophication- 0.15- (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
So- 0.15
4- Chem pollution - 0.2 (if OSPAR was better implemented to achieve the goal of reducing chemical pollution)
7- chem pollution node- 0.1 (if we got chem status to good with and without uPBTs. If we changed wording of law from 'aiming' to 'to achieve')
13. Chem pollution - 0.15- (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
So-0.1
6- Trade- 0.1- (if money was given to ensure implementation)
14. Trade node- 0.1- (all airports have CITES points for live specimens with Border Control Posts designated to handle fish specimens so investigation more thorough)
So- 0.1
7- seagrass abundance- 0.6 (as seagrass is used as a biological indicator it should not decrease due to anthro pressures- so although directive does not necessarily work to increase seagrass, it should at least not decrease)
9- Seagrass abundance -0.6 (better enforcement to stop damage to 'place of shelter'. Seagrass won't necessarily increase lots but won't at least won't be destroyed)
So- 0.6
9- Harvesting node- 0.1 (if wildlife crime was prioritised, investigated thoroughly)
10. Anchoring node- 0.1 (better implementation of following site management of strict regulations on anchor placement)
10. Trawling node- 0.1 (better implementation of following site management of strict regulations on allowed fishing gear types)
13. Trawling - 0.15 (if action plans were better implemented to ensure descriptors are achieved but still not perfect due to variability of ecosystems across EU waters)
So- 0.1
10. Coastal infra node - 0.25 (change 'have regard' to stronger wording in biodiversity duty)
10. Monitoring node- 0.8 (as a species of prinicpal importance should- produce action plan for species added in 2007 (which includes seahorses) which following examples of other species action plans eg. Allis Shad would include monitoring programmes)

Appendix Ⅲ: Learning contract

LEARNING CONTRACT:
INDEPENDENT RESEARCH PROJECT

The learning contract is an agreement between student and supervisor: it should clearly indicate what is expected from both sides. The text in Sections 2 and 3 provides guidance and can be modified to give more details reflecting what has been agreed, such as deadlines for submission of drafts and provision of feedback, word count limits/exclusions and number/timing of meetings. **Importantly, the document checklist helps students to follow the required procedures (e.g. ethical approval and risk assessment) and communicate what has been done to the supervisor.** **The student should submit a draft of the completed form to the supervisor and request a meeting to discuss and finalise the content. Both the student and the supervisor are responsible for keeping a signed copy of this document and following what has been mutually agreed.**
1. YOUR DETAILS
Student name: Natalie Harris
Degree Programme: Ecology and Wildlife Conservation
Proposed IRP Title or Set Project: Can the law really protect Seahorses
Supervisor name: Tilak Ginige
2. As the student undertaking the above project I agree to:
• E-mail my supervisor on a fortnightly basis with a progress report • Meet with my supervisor at least once a month to discuss progress and I understand that it is my responsibility to organise these meetings • Comply with the terms of this learning contract and the guidance set out in the Guide to Independent Research Projects • I understand that this is an *independent* project and that I am solely responsible for its completion • I agree to comply with all ethical, laboratory and fieldwork protocols established by the Faculty.
3. As the supervisor of this project I agree to:
• Meet with the student undertaking this project on at least a monthly basis and to respond to the progress e-mails as appropriate • To meet formally with the student during the first week in November to undertake the interim interview • To provide guidance and support to the student undertaking this project bearing in mind that it is an *independent* research project. This is inclusive of commenting on drafts of the final report in a timely fashion.
3. DOCUMENT CHECKLIST
Research Proposal or Plan Attached? ☐ **NO** - to be completed after meeting with Tilak
☐ **NO** **Risk Assessment for fieldwork and evidence of COSSH assessment for all laboratory procedures (online risk assessment completed)**

☐ NO **Completed booking for all field equipment**

☐ NO **Letters of permission where appropriate providing evidence of access to such things as field sites and/or museum archives**

☐ NO **Completed Ethics Checklist**

4. INTERIM INTERVIEW – Progress evaluation

Add here the key points of discussion and what has been agreed, particularly if different from Sections 2 and 3. Please indicate the date of your Interim Review (preferably in October within a month of starting Level 6).

To be confirmed after meeting with Tilak

Interim Review Date:

5. Variance from the Independent Research Project Guide

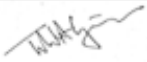
The IRP assessment is normally governed by the guidance provided in the Independent Research Project Guide. Any variance in terms of format (e.g. technical report, scientific paper) and word limit should be agreed and specified here. Submission date cannot be changed unless evidence of mitigating circumstances is provided in accordance with the standard BU Guidelines.

Any changes? ☐ **YES** ☐ **NO** If YES please provide details below:

Yes:

- Word limit to be extended to 15,000 due to study including scientific and legal elements
- References written in BU Harvard format and presented under headings of OSCOLA style due to the amount of legislation referenced

Both of the undersigned parties agree to be bound by this learning contract:	
Student Signature:	
PRINT NAME:	NATALIE HARRIS
Date:	21 June 2022

Supervisor Signature:	
PRINT NAME:	Tilak A. Ginige
Date:	14 June 2022

Appendix Ⅳ: Interim meeting form

Independent Research Project

Interim Interview - Agreed Comments Form

Student Name: Natalie Harris	Programme: Ecology and Wildlife Conservation
Date: 21st October 2022	IRP Title: Evaluating the effectiveness of law protecting UK seahorse populations
Supervisor Name: Tilak Ginige	

Agreed comments – to include progress and plans for completion:

By the 18th of November- have the table of contents and method section completed.

Contact Christine Maggs and Natural England regarding protection of my three case study sites.

Use Lexis and Ends Report in the subject resources section of the library to investigate the laws

Email J.J. Metah on the concept of 'ecoside'

By the 16th December- finish introduction

Word count- 10,000- 15,000 words

Draft deadline = 26th Feb

IRP deadline = 24th April 2023

Two copies of this form are needed – student to retain one copy and include in the appendices of the dissertation the other is to be emailed to the supervisor.

Student Signature:	Supervisor Signature:

Appendix Ⅴ: Proposal form

Research Proposal

Student name: Natalie Harris

Title: Does the law protect seahorses?

Summary

Biodiversity loss leads to negative impacts for humanity such as loss of ecosystem services and ecosystem stability. Anthropogenic threats are a cause of biodiversity decline. UK biodiversity is also under threat, including the two native species of seahorse *Hippocampus guttulatus* long snouted seahorse and *Hippocampus hippocampus* short snouted seahorse.Seahorse populations are vulnerable to overexploitation, fishing, bycatch and habitat degradation (Vincent 1996; d'Avack et al. 2014). Several international, European and national laws can be applicable to seahorse conservation. As important native species and their designation as 'flag species' meaning they are used to secure support and funding for marine conservation which benefits the whole ecosystem such as seagrass, it is vital their legal protection is effective. This study investigate the effectiveness of policy and law protecting UK seahorse populations at three reference sites through the use of literature review and a Bayesian Belief Network

Background

There is increasing concern over biodiversity loss and its negative impacts, with Steffen et al. (2015) stating biodiversity loss as a core planetary boundary which has been surpassed beyond the zone of uncertainty. The urgency, therefore, to protect threatened species before extinction is well recognised (Pollom et al. 2021)

There are 46 recognised species of seahorse, 14 of these species have been categorised by the IUCN as Threatened (IUCN 2022a), suggesting a need for their conservation. Seahorse populations are vulnerable due to the many threats they face, including consumption and trade which is driven by use in traditional medicine, curiosities and aquarium displays (Vincent et al. 2011). Fishing practices, particularly shrimp trawlers which are susceptible to seahorse by-catch (Vincent et al. 2011). Habitat change which arises from physical damage to habitats as well as chemical pollutants, eutrophication, changes in water quality and noise pollution (Vincent et al. 2011). Invasive species and climate change inducing sea temperature change are also stressors to seahorse populations (Vincent et al. 2011).

Two species of seahorse are found in the UK *Hippocampus guttulatus* long snouted seahorse and *Hippocampus hippocampus* short snouted seahorse (Garrick-Maidment 2012). Although categorised as Data Deficient on the IUCN Red list, insufficient data does not mean they are not threatened but that lack of data means the IUCN is unable to 'properly assess extinction risk' (IUCN 2022b). It could be argued that the two UK seahorse species are likely threatened due to the fishing overexploitation and habitat degradation occurring in UK waters (Collins et al. 2010). Efforts to protect these two species increased in the past couple of decades with the commencement of legislation around marine

protection. Protection occurs on a global level, European level and UK level. In 2002, seahorses became the first fully marine species of commercial value to be listed on the The Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora, Appendix II list. Both *Hippocampus guttulatus* and *Hippocampus hippocampus* and their habitat have been protected by the Wildlife and Countryside Act 1981*,* since 2008. *Hippocampus hippocampus* is also on the OSPAR priority list of threatened and endangered species (2003). The vital seagrass habitat is protected as a priority habitat as required under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006 (England) and both the seagrass habitat and the seahorses are on the List of UK BAP Priority Habitats and Species.

As seahorses are often described as flagship species, they are used to gain support and funding for marine conservation that is likely to benefit the whole ecosystem (Yasué et al. 2012). Studland Bay, south coast UK, has resident seahorse populations. An inshore Marine Conservation Zone (MCZ) was announced on 31 May 2019 with the long-snouted seahorse being a designated feature of the MCZ (MMO 2022). Studland Bay is highlighted as being an important breeding ground for seahorses (Garrick-Maidment et al. 2010). The Essex Estuaries also has seahorse populations present. ESsex Estuaries includes the Blackwater, Crouch, Roach and Colne Estuaries MCZ covering 284km² (Natural England 2013), the European Marine Site and the Essex Estuaries SAC. The Thames Estuary has also had reports of seahorses (ZSL 2017). All three sites face varying threats and have different applicable laws. Furthermore, previous studies have suggested that implementation of Marine Protected Areas can cause a decrease in seahorse numbers as numbers of their predators increases (Harasti et al. 2014). Using Studland Bay, the Essex Estuaries and the Thames Estuary as reference sites, this study looks to assess whether laws relating seahorses and their habitats are sufficient enough to provide full protection for seahorses, allowing their populations to stabilise.

Aims and objectives

To critically evaluate using a Bayesian belief network model, the effectiveness of law protecting UK seahorse populations at three reference sites.

Objectives:

1. Assess the scientific importance of UK seahorses populations and assess current population status.
2. Critically analyse the scientific literature related to the anthropogenic pressures faced by UK seahorses.
3. Conduct an evaluation of current international, European and national laws protecting seahorses, including what laws are in place and their enforcement measures. Conducted using Studland Bay, The Essex Estuaries and The Thames Estuary as reference sites.

4. Critically discuss the BBN data obtained with reference to science, policy and law to determine/ understand effectiveness of the legal protection given to seahorse populations within the reference sites.

Overview of the methods (300 words max)

Literature review will be conducted on current laws surrounding the protection of seahorses

Data will be presented using the bayesian belief network

Milestones and timelines (200 words maximum)

Build interaction diagram - October 2022

Conduct a literature review of legislation- December 2022

Construct Bayesian Belief Network model- January 2023

Write up of results and discussion - February 2023

Submission of draft- 26th February

Final submission- 20th April or before

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