Lyme Bay - A case study: measuring recovery of benthic species, assessing potential spill-over effects and socio-economic changes

Objective 1: Identification of indicator species for monitoring the recovery of Lyme Bay

Final version

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Marine and Fisheries Science Unit, Nobel House, London

Author details:

E.L. Jackson
MarLIN Biodiversity and Conservation Science Programme Manager
emma.jackson@mba.ac.uk

O. Langmead
MarLIN Biodiversity and Conservation Science Programme Manager
olla@mba.ac.uk

M. Barnes
MarLIN Information Officer
morrne@pml.ac.uk

H. Tyler-Walters
htw@mba.ac.uk

K. Hiscock
khis@mba.ac.uk

The Marine Life Information Network® for Britain and Ireland (*MarLIN*)

The Marine Biological Association of the United Kingdom
The Laboratory Citadel Hill
Plymouth,
PL1 2PB

www.marlin.ac.uk

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Executive Summary

The work presented in this report is part of a larger project funded by Defra which focuses on assessing the various changes that may ensue as a result of protection of a $60nm^2$ area of Lyme Bay to mobile fishing gear, both in ecological and economic terms. The ecological monitoring includes monitoring of representative indicator species of the reef to examine recoverability and to "*assess the long-term effects of fishery area closures on long lived and sessile benthic species".* The current report outlines the selection of such indicator species for Lyme Bay and the wider application of this and alternative methods to monitoring MPAs.

The method for selecting representative species employed both subjective selection (i.e. species were locked in for perceived reasons of economic value, public interest, ecological role) and a objective assessment of the range biological traits (biological characteristics exhibited by species, relating to life history and mode of life) relevant to recoverability and/or function. For the latter the benthic species list was matched to biological traits information using BIOTIC (Biological Traits Information Catalogue; www.marlin.ac.uk/biotic) and ordination methods employed to identify correlating traits and suggest categorical groupings for the species.

By selecting representatives from the range of biological traits of species found in the area of interest (both relating to recoverability of the individual or population and more general lifestyle traits), the indicators can be used both to assess potential recovery and changes in ecosystem structure. In the latter case this maybe through an increase in structural biogenic/ecosystem engineering species and the secondary settlement of species such as echinoderms and crustaceans or changes in the trophic structure due to a movement from scavengers to suspension feeders. Selecting a range of species representative of different levels of recoverability should also allow short-term and long-term recovery (both in terms of occurrences and growth) to be monitored. Additionally monitoring species with high tolerance and high recoverability to physical disturbance may indicate other natural environmental variations.

The application of these indicators in Lyme Bay and for monitoring other MPAs is discussed and alternative approaches considered. With the exception of the rare and scarce species, the other selected indicator species, where present are likely to be suitable for use in monitoring reef habitats in other Marine Protected Areas in the region using video and diver surveys. However, each MPA will have its own specific environmental conditions and the habitat features for which sites were designated are not always reef, therefore these selected indicator species will not always be the most representative. The wider application of the work presented in this report is in outlining a transferable method for selecting representative indicator species for a specific site. Such a method is particularly valuable in the absence of large amounts of data and of cause and effect studies highlighting which species are key to the functioning and integrity of the system.

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1 Introduction

1.1 Project Background

1.1 Early in 2008 Defra released a Partial Regulatory Impact Assessment and Consultation on "measures to protect biodiversity in Lyme Bay from the impact of fishing with dredges and other towed gear". Following this consultation Defra designated a 60nm^2 closure to mobile fishing gears within Lyme Bay. The primary purpose for establishing the closed area is for the protection of marine biodiversity, namely, to ensure the structure of the reef system is maintained and to aid the recovery of the benthic habitats.

1.2 The work presented in this report is part of a larger project funded by Defra which focuses on assessing the various changes that may ensue as a result of protection, both in ecological and economic terms. In addition to monitoring the marine reef community as a whole, the monitoring of representative indicator species are required to examine recoverability and to "*assess the long-term effects of fishery area closures on long lived and sessile benthic species".* Specifically the purpose of the project is to:

1. Identify and select a number of indicator species that represent the full range of life strategies used by benthic species in the study area[but selection of species should consider their wider application for monitoring of Marine Protected areas (MPA)];
2. To develop a cost-effective sampling design for the monitoring of benthic recovery within the closure of an area of Lyme Bay;
3. To quantify the recovery of the identified species within the closure with the removal of towed gear[1] compared to appropriate control areas;
4. To assess the long-term effects of fishery area closures on long lived and sessile benthic species;
5. To collect and store samples of selected benthic species for future DNA analysis;
6. To quantify and assess any effects on scallops (e.g. increased larval export and spill over) resulting from the area closure; and
7. To assess any socio-economic impacts[2] (e.g. diversification, gear changes, changes to areas fished, effort changes) which result from the closure restrictions.

1.3 This information will be used to assess the effectiveness of marine protected areas in achieving conservation objectives; the socio-economic implications of MPAs; provide further detail on where fisheries management and conservation objectives could be integrated.

[1] Demersal gear and dredgers

[2] Other business operators such as the recreational industry etc should be considered in the scope of this assessment and not merely the fishing industry.

1.2 Methods for selecting indicator species

1.4 When managing a marine protected area it is not possible for managers to measure everything of potential interest within the ecosystem, so indicators of change are invaluable and the choice of what to measure is a critical step in any monitoring programme (Noss *et al.*, 1997). In their review of indicator species selection methods for monitoring ecological integrity, Carignan and Villard (2002) identified both subjective and objective, quantitative methods. Subjective methods primarily involved the selection of indicator species based on their perceived importance (e.g. economic value, public interest, ecological role). If such species were fundamental in a sites designation as "protected" then it is important that these species are monitored irrespective. Carignan and Villard (2002) proposed that the major problem with such an approach was that the species chosen may not necessarily be sensitive to changes in the ecological integrity of the given ecosystem.

1.5 More quantitative methods of selecting indicators have included selection based on a species occurrence in a predefined habitat type using ordination methods, with the view that species specific to certain habitats are better indicators than habitat generalists as they are more susceptible to environmental change (Dufrêne and Legendre, 1997 cited in Carignan and Villard, 2002). Others have used ordination techniques to link species to habitat types under contrasting conditions of human disturbance to identify which species are indicative of certain conditions (Hutto, 1998 cited in Carignan and Villard, 2002). Such techniques have been used to identify indicators of physical disturbance in soft sediment marine habitats (Dayton *et al.*, 1995, Ellis *et al.*, 2000) where there is a wealth of data to support such analyses. For subtidal soft sediment it has also been possible to measure an ecological process such as bioturbation and model the consequences of removing species from the system to examine the effects on this process (Solan *et al.*, 2004). On a larger scale adaptations of such a model could be used to identify key species which are driving the ecological function, which could in turn be used as indicators of ecosystem functioning (Cefas, in prep., see also Jennings *et al.*, 2001).

1.6 For hard substrata this approach is more difficult due to the diversity of the habitats and limited quantitative data comparing disturbance regimes in these habitats. However, information on the responses of some reef species to disturbance does exist and knowledge of the specific traits of the species which result in these responses is available, allowing selection of indicator species by analysing their biological traits (BIOTIC www.marlin.ac.uk/Biotic and references within, Airoldi, 2000, Bevilacqua *et al.*, 2006).

1.7 Biological traits analysis (BTA) is receiving increasing attention due to the focus on maintaining functional diversity in marine ecosystems (Bremner *et al.*, 2003, Solan *et al.*, 2004, Bremner *et al.*, 2006, Hiscock *et al.*, 2006) and the ability of this methodology to provide information on the dispersal potential of species, a key consideration in understanding marine connectivity and of use in the planning of MPA networks (e.g. Roberts *et al.*, in prep). BTA has also been used to categorise species by life strategy and to identify indicator species for monitoring impacts and/or recovery in the marine environment. In soft sediments, using trait information. Borja *et al.* (2000) identified five ecological groups related to the degree of sensitivity/tolerance to an environmental stress gradient and, by analysing data from a wide range of soft-bottom benthos in a variety of locations including polluted or disturbed situations, listed a large number of species assigned with their ecological group. This is now widely used as an indicator for Water Framework Directive (WFD) monitoring in soft substratum habitats. Potential indicators for integrated ecosystem assessment includes resilience, the ability to recover from or resist being affected by a disturbance (Hughes *et al.*, 2005). By using biological traits to assign species to different ecological groups you can ensure that the range of expected responses to disturbance can be represented when selecting species as indicators. Similarly traits can be used to ensure that any list incorporates indicator species from all major functional guilds (producers, herbivores, carnivores, decomposers, etc.), so as to ensure that integrity is preserved at every level (di Castri *et al.*, 1992).

1.8 In their review of selecting indicator species (Carignan & Villard, 2002) concluded that, the selection should include:

(i) many species representing various taxa and life histories are included in the monitoring program,
(ii) their selection is primarily based on a sound quantitative database from the focal region, and
(iii) caution is applied when interpreting their population trends to distinguish actual signals from variations that may be unrelated to the deterioration of ecological integrity[3]

(Source: Carignan & Villard, 2002)

1.9 As well as aiming to ensure that the indicators can be used to assess the main impacts from human activities, it is important that the suite of indicators can collectively enable an assessment of the state of the ecosystem component (structure and function). By selecting representatives from the range of biological traits of species found in the area of interest (both relating to recoverability of the individual or population and more general lifestyle traits), the indicators can be used both to assess potential recovery and changes in ecosystem structure. In the latter case this maybe through an increase in structural biogenic/ecosystem engineering species and the secondary settlement of species such as echinoderms and crustaceans or changes in the trophic structure due to a movement from scavengers to suspension feeders. Selecting a range of species representative of different levels of recoverability should also allow short-term and long-term recovery (both in terms of occurrences and growth) to be monitored.

1.10 There are two main criticisms of using indicator species. The first is that in order for any species to be considered as an indicator of a particular stress, its response to that stress must be known, quantifiable *and* independent of local effects. It is very difficult to a priori select species that are totally independent of local effects. However, by monitoring species with a known quantifiable response to physical disturbance (i.e. those highly sensitive to physical disturbance which can be

[3] Ecological integrity is defined here as 'the capacity of an ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar, undisturbed ecosystems in the region' (Karr and Dudley, 1981)

measured by reduced abundance, reduction in size or observable physical damage) and those species with high tolerance and high recoverability to physical disturbance it may be possible to get an indication of natural environmental variations (e.g. natural fluctuations in growth and recruitment related to climate or life cycles or density dependent processes such as competition).

1.11 Finally, if, as in the case of Lyme Bay, there is a large amount of past survey data for specific species then it would be important to consider these species as indicators for monitoring. Long-term time series data (even if the combination of different surveys) have considerable value in examining change, in particular when separating natural versus anthropogenic change.

1.3 Aims and Objective

1.12 The objective of the current study was the selection of a number of indicator species that represent the full range of life strategies used by benthic species in the study area (objective 1 in purpose of overall project as outlined in Introduction). In selecting the indicator species, consideration of the methodology for selection and the species themselves in the context of wider MPA monitoring was required.

1.13 The aims of the work are to:

- Select species representative of a range of life strategies used by benthic species in the study area;
- Consider species previously monitored within the framework of preceding projects;
- Consider structural or functional species which can be used as indicators of condition;
- Ensure that any indicator species are:
    - relatively easy to understand by non-scientists and those deciding on their use;
    - easily and accurately measured, with a low error rate; and
    - measurable over a large proportion of the area in which the indicator is likely to be used;
- Consider species which will show different rates of recovery; and finally,
- Ensure epifauna such as erect sessile species which are long-lived and slow growing are included in the selection.

1.14 The selection of indicator species representative of a range of life strategies used by benthic species in the study area will be conducted by using the outcomes of the biological traits analysis.

2 Methods

2.1 The Lyme Bay Study Area

2.1 Lyme Bay is an open stretch of southerly facing coastline straddling the East Devon and West Dorset border (see Figure 1). The area has been well studied and is currently included in several statutory and non-statutory planning processes, such as the Finding Sanctuary project and investigations for possible Special Areas of Conservation (SACs).

2.2 The study area here is defined as those parts of Lyme Bay contained within a line drawn between Portland Bill in the east (2°27'12W, 50°30'49N) and Start Point in the west 3°38'21W, 50°13'16N. The resulting 2460 km^2 area includes environments ranging from high diversity reefs in the northern section, muddy soft substrata in the west supporting isolated seagrass beds, as well as sandy, gravel and cobble substrata. Depth increases gradually offshore, with maximum depths within Lyme Bay of over 50m.

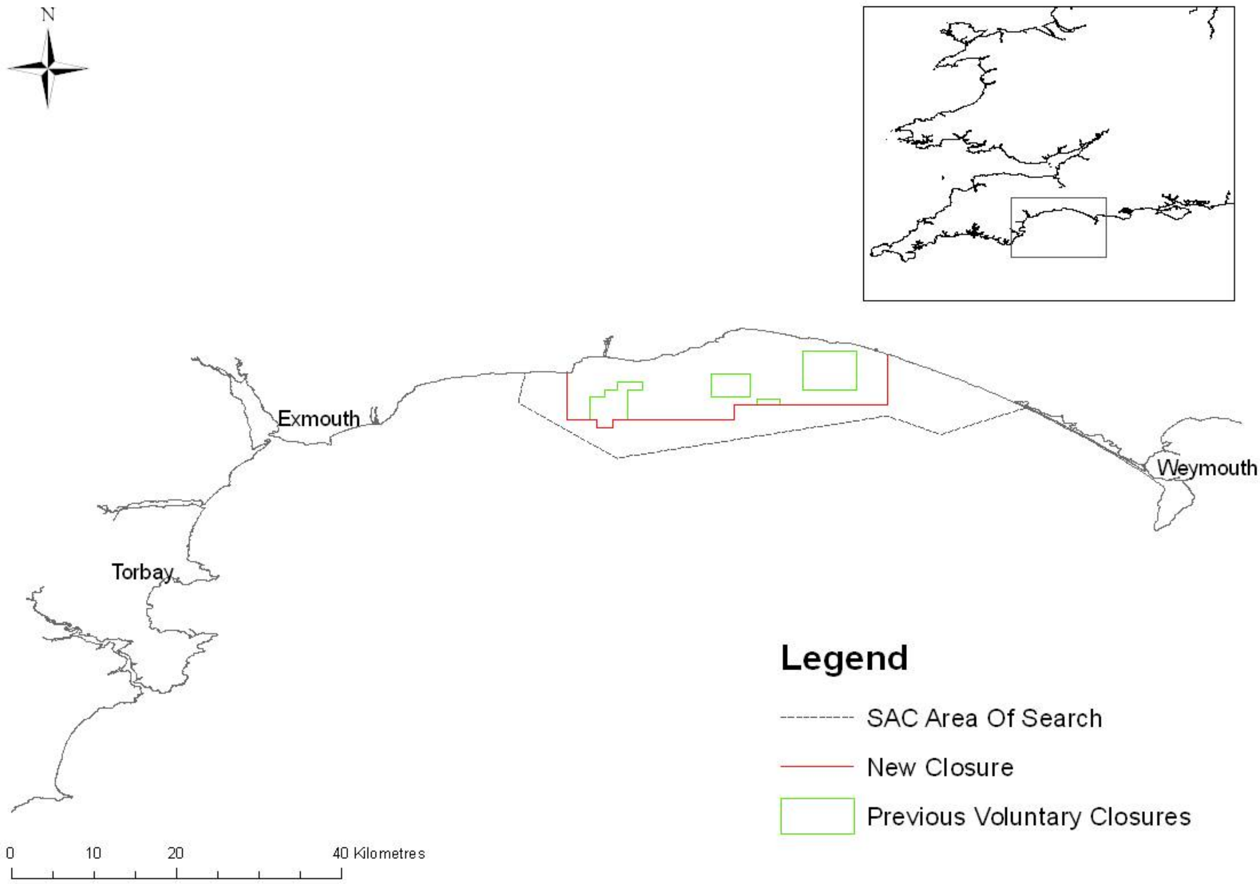

Figure 1: Location of Lyme Bay, the area closed to mobile gear and previous voluntary closed areas.

2.1.1 Lyme Bay Reef

2.3 It is Lyme Bay's rocky reefs that are the focus of the current work, defined under the Habitats Directive Annex 1 Habitats as being where animal and plant communities develop on rock or stable boulders and cobbles. Sublittoral rock reefs are mainly fished using static gear (especially pots/creels) for crustaceans. However reefs may be affected by mobile fishing gear where they are low-lying and do not pose a threat to the gear. In Lyme Bay, fishing has had a substantial impact on reef communities including populations of pink sea fans (*Eunicella verrucosa*). This is particularly the case if the rock is relatively soft, making them vulnerable to structural damage thus changing the substratum and, potentially the communities, as well as removal of epifauna, as found in Lyme Bay (Devon Wildlife Trust, 1993, Hiscock, 2007, Hiddink *et al.*, 2008). There is a large body of information describing effects of mobile fishing gear (see, for instance, the volume edited by (see, for instance, the volume edited by Kaiser & de Groot, 2000a, Sewell & Hiscock, 2005). In their review Sewell and Hiscock (2005) summarized the following potential impacts of mobile fishing gears on reef habitats:

- Relatively soft rocky outcrops can be subject to physical damage;
- Reduce structural complexity of habitats and reduce biodiversity;
- May cause damage to large algae such as kelp;
- Remove erect epifaunal species and large sessile species;
- Physical damage may be caused to fragile structures; and
- Large, fragile and long-lived species may be directly killed or selectively removed, whilst smaller robust organisms are generally unharmed.

2.4 In selecting indicators of change for such habitats it is therefore important to select both structurally important species, species that are more or less vulnerable to physical damage and species which will recover at different rates once disturbance has been removed. In order to establish whether the functionality of the system has altered it is also important to select species from a range of functional groups (for example based on feeding method, habit and mobility).

2.2 Data collation

2.1 The first step in selecting a representative list of indicator species for monitoring was to examine the species which had been recorded in the area by examining national species records and survey data.

2.2 An up-to-date species list for benthic species recorded in the Lyme Bay study area was compiled using data from the following sources:

- National Biodiversity Network (NBN)/ JNCC snapshot of Marine Recorder (taken 10th December 2007);
- Marine Nature Conservation Review (MNCR);
- Data Archive for Seabed Species (DASSH, held at the MBA)/MarLIN (accessed 13th March 2008);
- Royal Haskoning biological records collected for marine SAC study;
- Devon Biodiversity Records Centre (DBRC);
- SeaSearch (including the August 2008 survey, via personal communications);
- University of Plymouth towed video surveys (Stevens et al. 2007);
- School of Ocean Sciences, Bangor datasets.

2.3 All records where collated within a geodatabase so that the information could be queried using GIS. All survey data sources used are listed in Annex 1.

2.3 Filtering species

2.4 1855 different marine species were found to be resident in Lyme Bay on examination of the above data sources and as such a filtering process was employed prior to further analysis to remove those species not relevant to the study at hand, (i.e. are not appropriate due to the sampling methodology employed, are not associated with reef habitats). The following species were locked-in to the selection process prior to any filtering: The king scallop (*Pecten maximus*), the sea squirt *Phallusia mammillata*, the orange pumice bryozoan (*Cellepora pumicosa*), Ross coral (*Pentapora foliacea*), Trumpet anemone (*Aiptasia mutabilis*), Dead man's fingers (*Alcyonium digitatum*) and the Pink Sea Fan (*Eunicella verrucosa*); due to their conservation interest, structural importance and/or the large amount of historical survey data already available.

2.5 The process adopted for the filtering of species is outlined in Figure 1. Mammals, birds and reptiles were removed from the list given they whey were considered outside the scope of the current project. Fish species were included where they had a close association with the benthos (benthic, demersal and benthopelagic). Predominately inter-tidal species and those species with a maximum dimension of less than 2cm (excluding colonial species) were then removed on the basis that the focus was on subtidal habitats and that organisms less than 2 cm in size could not be seen using video techniques). Species less than 10cm in size were removed unless they were highly abundant (>50 individuals recorded), important species (in terms of conservation interest) or in underrepresented phyla (fewer than 4 individuals). All of the remaining species were classified as largely "independent" of others (either in terms of symbiosis, mutualism, commensalisms, or in terms of their larval settlement preferences, where this is known), which reduces the chance that population trends in the species are confounded by those of another species.

2.6 The distributions of species were then plotted against the Devon Wildlife Trust (DWT) substrata maps. All species found only on soft substrata (sand and mud) were removed, to select for those species with a strong association with reef (bedrock and mixed ground substrata). Finally, similar species in overrepresented phyla, (where in situ identification would be problematic were subjectively removed).

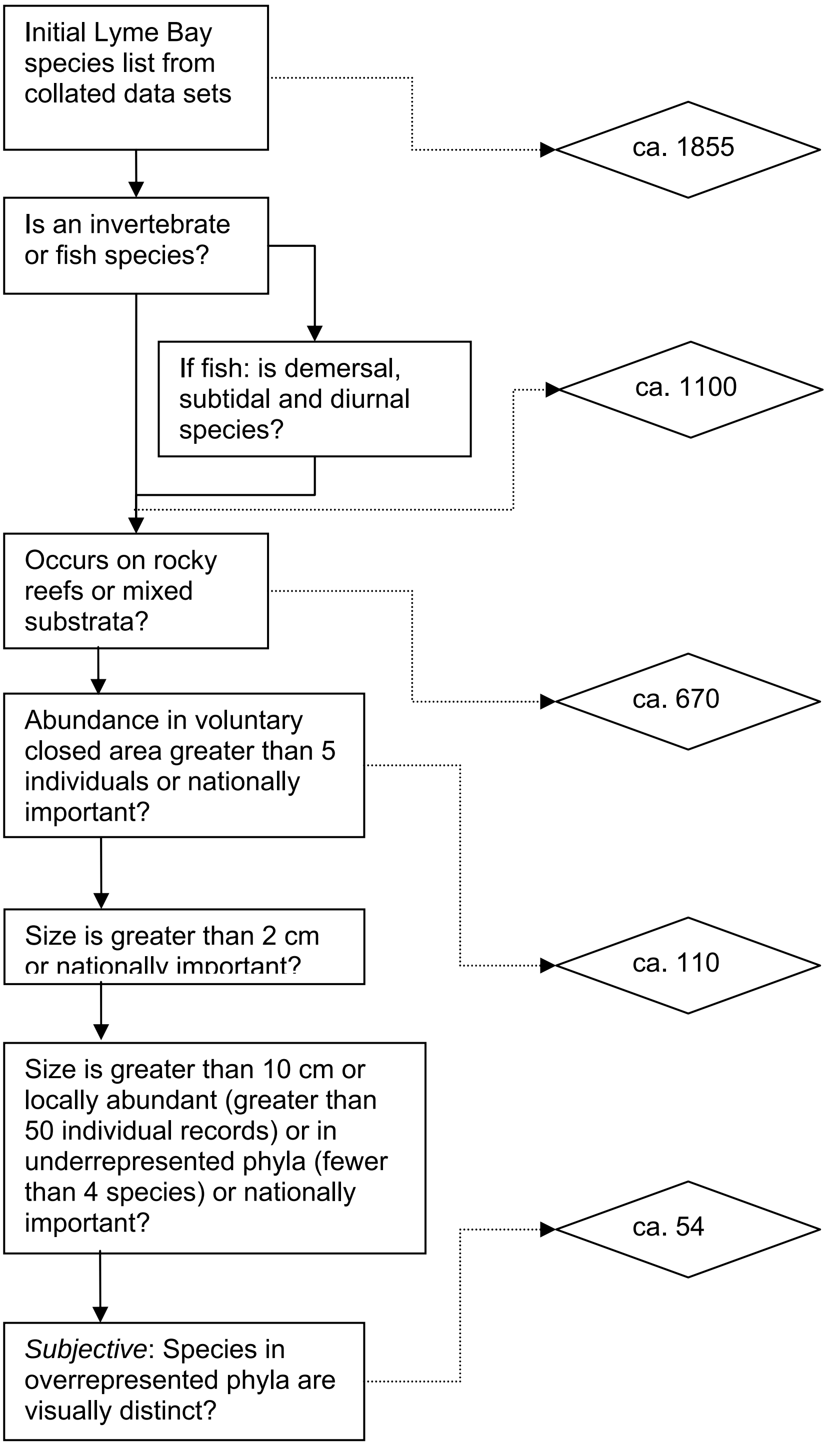

Figure 2: Species filtering procedure and the number of species left after each step

2.4 Traits analysis

2.7 On completion of the filtering process a short list of 54 species was identified. The benthic species list was next matched to biological traits information using BIOTIC

(Biological Traits Information Catalogue; www.marlin.ac.uk/biotic) where available[4]. The BIOTIC database contains information on over 40 biological trait categories (including traits relating to reproduction, mobility, preferred substrata/ habitat/ abiotic factors and food/ prey type) for over 200 selected benthic species, together with a bibliography of source literature. The emphasis is on benthic invertebrates and plants. In addition, MarLIN holds further traits information at generic level. Any gaps in species coverage were researched to enable traits information for most species to be included in analyses. Table 1 illustrates the traits used in the current study and their definition. These traits were chosen to reflect different levels of recoverability potential and to allow species to be selected to represent this range and also the range of functional groups (e.g. feeding methods) within the community being monitored.

Table 1 The definition of analysed traits (source: www.marlin.ac.uk/biotic)

Trait*	**Definition**
Fragility	The propensity to suffer damage from a physical impact.
Regeneration	The capacity for partial or whole regrowth or regeneration.
Maturity	The time taken to reach reproductive maturity from birth.
Fecundity	The average number of offspring per reproductive episode.
DispPotLarvae	The potential horizontal distance larvae may travel before settling.
DispPotAdult	The potential horizontal distance adults may travel from birth to death (mobility and territoriality).
Size	The maximum width or length reached by a fully-grown adult.
Lifespan	The potential maximum time from birth to death.
Growth rate	The average increase in width/ length per unit time over the whole lifespan.
Sociability	The relative tendency or disposition to associate intraspecifically.
Habit	Characteristic appearance, form, or manner of growth (e.g. attached, bed-forming, burrow dwelling, free living, sessile, encrusting, erect)
Feeding method	The process by which food is usually obtained (e.g. predator, suspension feeder, deposit feeder, grazer).

*As labelled in the BIOTIC database

2.8 In order to assess whether the filtered species list fell into distinct groups with similar trait characteristics, an ordination [Principal Components Analysis[5] (PCA)] was carried out using PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) with species listed as “samples” and scores for each of the traits as “measurements” scored as shown in Table 2. The same analyses were repeated for

[4] Prior to the current study BIOTIC database contains information on over 40 biological trait categories for over 200 selected benthic species, together with a bibliography of source literature. The emphasis is on benthic invertebrates and plants. In addition, MarLIN holds further traits information at a generic level. All additional traits researched during the current contract will be made available on the BIOTIC online database.

[5] The basic principle of Principal Components Analysis to express two or more correlated variables by a single factor.

the free living and sessile species separately due to the inherent differences in the susceptibility of these two groups to physical disturbances and to the different sampling methods employed to record them[6] (See Annex 5). The PCA identifies closely correlating traits (see Figure 3), for example dispersal potential of adults and feeding mechanism, sociability and size.

Table 2: Codes and categories for the traits used in the analysis

	Coded scores for analysis				
	1	***2***	***3***	***4***	***5***
"Recoverability" traits					
Fragility	Fragile	Intermediate	Robust		
Regeneration	No	Yes			
Maturity (years)	< 1	1 - 2	3 – 5	6 – 10	
Fecundity	< 2 k	2 k – 200 k	> 200 k		
DispPotLarvae	< 0.1 km	0.1 – 1 km	1 – 10 km	> 10 km	
DispPotAdult	None	< 0.1 km	0.1 – 10 km	> 10 km	
"Lifestyle" traits					
Size (cm)	≤ 2	3 - 10	11 - 20	21 – 50	> 50
Lifespan (years)	< 1	1 - 2	3 – 5	6 – 10	≥ 11
Growth rate	≤ 1 cm/yr	1 – 3 cm/yr	3 – 5 cm/yr	> 5 cm/yr	
Sociability	Solitary	Gregarious	Colonial		
Feeding method	Photoautotroph	Passive suspension	Active suspension	Deposit/ omnivore	Predator/ Scavenger

2.9 Ordination (see Figure 3) showed no distinct groupings, but rather a spread across the continuum in the levels of different traits, with many overlapping groupings according to recoverability potential, size and feeding methods etc. An additional step was therefore employed to ensure selection of representatives across the range of life history strategies found within the Lyme Bay reefs. Traits were separated into what we have termed "recoverability" traits and "lifestyle traits", for the purposes of this work (see Table 1). The lifestyle traits are used to ensure selected target species encompass the range of functional roles of species within the Lyme Bay reef area. The recoverability traits are used to assess how rapidly individuals and populations are likely to recover from extensive physical disturbance.

[6] *Antedon bifida* (the rosy feather star) was categorised as sessile. Although this species is not truly sessile (it can crawl and swim) its ability to avoid mobile gears is limited.

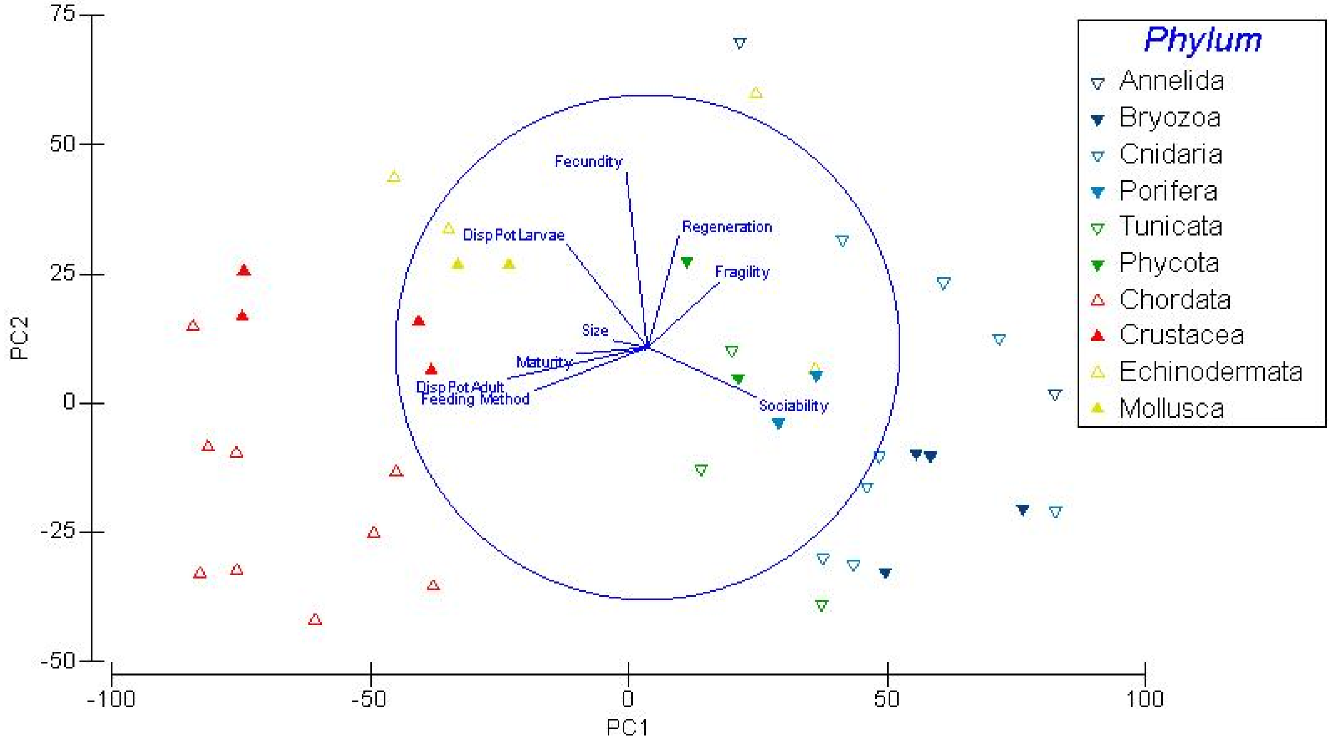

Figure 3: Principal Component Analysis of the traits recorded for different species in Lyme Bay.

2.5 Recoverability traits

2.10 At an individual level, the ability to recover is determined by the sensitivity of that species (Tyler-Walters & Jackson, 1999). In terms of the physical disturbance of mobile fishing gears (the focus of the current study), this is primarily linked to fragility and the regenerative ability of the species. In the grouping below this is termed “survival ability”. If an individual is lost from a site, the ability to recover will depend on the reproductive ability of the species (a combination primarily of the time taken to reach maturity and the fecundity), whether there are still members of the population at the site or, if not, the ability to repopulate the site from adjacent or distant populations. Rare and scarce species with limited populations will have a very low chance of repopulating. For all species the ability to repopulate a site will primarily depend on the potential of larvae and/or adults to disperse[7] either from distant or adjacent populations. Using the flow charts from (Tyler-Walters & Jackson, 1999) as a framework (see Annex 2) species were scored based on their “recoverability” traits against three categories:

- **Survival ability**: how likely an individual from the species is to survive an event of physical disturbance. Species which are either able to withstand physical impacts in the short-term or heal from them stand a better chance of

[7] The ability of a species to recolonise an area may also be dependent on settlement cues and or the presence of other species or conditions. In this study settlement processes have not been addressed as it is assumed that the rocky reef environment has not been removed, and the species identified do not have known strong dependencies on other species. The limits of scientific research on this subject for certain species, mean that it is still a possibility.

surviving to reproduce and contribute to the survival of the population as a whole. Fragility and regenerative potential are given equal weighting:

Low – fragile species with no regenerative abilities
Medium – either fragile species than regenerate or intermediate species with no regenerative abilities
High – intermediate species with regenerative abilities

- **Reproductive ability**: a measurement of how quickly dwindling populations will be able to re-establish themselves in the wild. It is a product of the average fecundity of a mature individual and the time to reach maturity. Species with a high fecundity that have a low age-at-maturity will be able to recolonise much more rapidly than slowly maturing species that produce fewer offspring. This is weighted so that species which reach maturity at a considerable age will have a low 'reproductive ability' regardless of their fecundity whereas species which mature within a year of birth will have a high to medium 'reproductive ability':

Low – fecundity minus maturity trait scores is negative
Medium – fecundity minus maturity trait scores is 0
High – fecundity minus maturity trait scores is positive

- **Repopulation ability**: a measurement of to what spatial extent a species will be able to recolonise new areas and the ability of geographically distinct populations to mix. It is a product of potential larvae dispersal and adult dispersal across the seabed. It is weighted so that mobile adults in particular have a high 'repopulation ability', while sessile species where only the larvae are able to disperse have a medium to low 'repopulation ability'.

Low – Larvae dispersal < 1km and adult dispersal < 100m
Medium – Larvae dispersal > 1km and adult dispersal < 100m (or larval < 1km and adult > 100m)
High – Larvae dispersal > 1km and adult dispersal > 100m

2.11 The scores for each of these trait groupings were combined and the species were divided into three groups according to their recoverability. By attributing a score of 1 for low, 2 for medium and 3 for high, the recoverability of each species is determined by the sum of each of the scores for survival, reproductive and repopulation abilities. This provides an equally balanced measurement of how well species will be able to recover from either sustained or episodic events of physical damage: from the short-term recovery of an individual to the rapidity of repopulation of a species through spawning, through to the potential repopulation of an area by a species from other geographically distinct populations (see Box 1).

Box 1. Descriptions of recoverability classes

- **High Recoverability:** Species with high recoverability are rapid recolonisers able to quickly repopulate areas either with a high adult mobility (swimmers and rapid crawlers) or with high larval dispersal for sessile species or both. The sessile species in particular will reach maturity at an early age, often within 1 or 2 years, whereas the free-living, mobile species will have a particularly high fecundity of up to several million offspring. Individuals may be more or less robust and may show regenerative abilities. Species with high recoverability will be able to rapidly recolonise extensive areas.
- **Medium Recoverability:** Sessile species with medium recoverability are moderately slow recolonisers usually with a low larval dispersal potential but often take a short time (less than a year) to reach maturity and have a relatively high fecundity. They are more suited to rapid and not extensive recovery. Individuals may be more or less robust and may show regenerative abilities.
- **Low Recoverability:** Species with low recoverability have greatly reduced larvae dispersal potential with often rapid larval settlement. Adult dispersal if any is extremely small. Maturity is only reached after a year or more, and those that do reach maturity sooner have a limited fecundity. Individuals tend to be fragile or unable to regenerate and a very vulnerable to physical disturbance. Recovery is usually slow and rarely extensive.

2.6 Additional “lifestyle” traits

2.12 However in addition to those traits which primarily influence a species resilience to disturbance and its ability to recover or re-colonise, there are additional traits which relate to the lifestyle and habit of the species and which influence the functional and/or structural role within the ecosystem. Habit, feeding method, sociability and size of each species was therefore also identified for each species.

2.13 In terms of habit, free living and sessile species were separated due to the inherent differences in the susceptibility of these two groups to physical disturbances and to the different sampling methods employed to record them. Habit related traits such as whether the species is for example erect, tube or burrow dwelling, reef building or encrusting will describe the species physical structural role in a community.

2.14 Feeding method (see Box 2) influences a species position within a food web and its role in the flow of energy and nutrients within a system. Previous studies have illustrated how human and environmental factors can result in a shift in the predominance of certain feeding methods and alteration in the food web (Kaiser & De Groot, 2000b, Moline *et al.*, 2004), for example an increase in scavengers after periods of which can have significant implications for the functioning and integrity of the ecosystem.

2.15 During the selection of species from each level of recoverability, representatives from the range of different functional types based on "lifestyle" traits were chosen.

Box 2. Characteristic feeding method definitions from BIOTIC database

Trait		*Definition*
Suspension feeder: Any organism which feeds on particulate organic matter, including plankton, suspended in the water column (from Lincoln *et al.*, 1998).	Active	Catching food on a filter from water by actively sweeping or pumping (e.g. sea squirts, many bivalve molluscs).
	Passive	Catching food on a filter held into flowing water (e.g. hydroids, sea fans, sea pens), or collecting the 'rain' of detritus on sticky apparatus other than a filter (e.g. *Cucumaria frondosa*).
Deposit feeder: Any organism which feeds on fragmented particulate organic matter from the substratum; detritivores (from Lincoln, *et al.,* 1998).	Surface	Obtaining food from the surface of the substratum (e.g. *Corophium volutator*).
	Sub-surface	Obtaining food from within the substratum (e.g. *Echinocardium cordatum*).
Omnivore		Animal which feeds on a mixed diet including plant and animal material.
Herbivore		An organism which feeds on plants, including phytoplankton.
Scavenger		Any organism that actively feeds on dead organic material (e.g. crabs, whelks).
Symbiont contribution		Where some dietary component(s) are provided by symbiotic organisms (e.g. *Anemonia* with zooxanthellae).
Planktotroph		Feeding at least in part on materials captured from the plankton.
Predator		An organism that feeds by preying on other organisms, killing them for food.
Interface feeder		An organism that feeds at the interface between the water column and underlying substratum.
Grazer (grains / particles)		Animals which rasp benthic algae (or sessile animals, such as bryozoan crusts) from inorganicparticles e.g. sand grains.
Grazer (fronds / blades)		Animals which rasp benthic algae (or sessile animals, such as bryozoan crusts) from the surface of macroalgal fronds and blades.
Grazer (surface / substratum)		Animals which rasp benthic algae (or sessile animals, such as bryozoan crusts) from the substratum.
Detritivore		An organism that feeds on fragmented particulate organic matter (detritus).

3 Selected representative indicator species

3.1. On completion of this assessment forty-one of the fifty-four species were found to have all traits information available (See Annex 3 and Annex 4). Six rare and scarce species were identified as occurring within the reefs in Lyme Bay but trait information was not available for these species (with the exception of the sunset cup coral *Leptopsammia pruvoti*). These rare and scarce species will be recorded during monitoring because of their conservation value and their very low recoverability potential. These were the southern cup coral (*Caryophyllia inornata)*, the Weymouth carpet coral (*Hoplangia durotrix)*, the chocolate tiny anemone *Isozoanthus sulcatus*, the sponge *Dysidea pallescens*, the sunset cup coral *(Leptopsammia pruvoti),* the coral *Thymosia guernei* and the sponge *Adreus fascicularis*.

3.2. For each recoverability category (split into sessile and free living) a minimum of three species were selected and where possible to equally represent the range of observed functional "lifestyle" traits. In selecting these species the ease with which these species could be identified in the field was taken account of (through communications with divers that have surveyed Lyme Bay previously) and recorded occurrences within the different areas to be sampled (the voluntary closed areas, the 60nm^2 closure, the proposed SAC and the whole of Lyme Bay, see Annex 6). Sessile and free living representatives of each recoverability group were selected.

3.3. Of the key species locked-in to the indicator selection process all but two were representative of low recoverability (*Cellepora pumicosa*, *Pentapora foliacea*, *Aiptasia mutabilis*, *Alcyonium digitatum* and *Eunicella verrucosa*, see Table 3). The king scallop *Pecten maximus* has high recoverability potential and the sea squirt *Phallusia mammillata* has medium recovery potential. All the key species with low recoverability potential were sessile and had similar "lifestyle" traits therefore we selected additional species to represent this recoverability group. The selected species are shown in Table 3 and described below:

- **High Recoverability:** Suggested representatives for this group are the sponge *Tethya aurantium* (a small relatively robust active suspension feeder), the hydroid *Halecium halecium* (a delicate species with short maturity), the annelid *Chaetopterus variopedatus* (a fecund passive suspension feeder with extensive larvae dispersal), the scallop *Pecten maximus* (a slow-growing but fecund species with a long larval stage), the starfish *Asterias rubens* (a predatory scavenger feeder with a high dispersal potential), the lobster *Homarus gammarus* (a slow-growing but fecund scavenger with a long larval stage), and the pollack *Pollachius pollachius* (a large, long-lived predator);
- **Medium Recoverability:** Suggested sessile representatives for this group are the sea squirt *Phallusia mammillata* (a fast-growing active suspension feeder with limited dispersal potential), the anemone *Actinothoe sphyrodeta* (a rapidly maturing passive suspension feeder with a low fecundity), the hydroid *Hydrallmania falcata* (a fecund species with limited dispersal); Suggested free-living representatives for this group are the crab *Necora puber* (a small scavenger with a large dispersal potential), the wrasse *Labrus bergylta* (a long-

lived highly mobile[8] predator with low fecundity), edible crab *Cancer pagurus* (a large active predator with high fecundity but slow growing) and the goby *Thorogobius ephippiatus* (a solitary omnivore with a low reproductive potential); and

- **Low Recoverability:** Suggested representatives for this group are the bryozoans *Cellopora pumicosa* (a short-lived colonial species with a low dispersal potential) and *Pentapora foliacea* (a potentially large and long-lived but fragile species), the anemone *Aiptasia mutabilis* (a gregarious rapidly maturing species with low fecundity), the sea fan *Eunicella verrucosa* (a long-lived fragile species with low reproductive and dispersal abilities), the corals *Leptopsammia pruvoti* (a long-lived suspension feeder with extremely short larval stage) and *Alcyonium digitatum* (a fragile, slow-growing species with a high larval dispersal potential) and the sponge *Cliona celata* (a relatively robust and large but slow-maturing species).

Maps for each of the selected indicators based on existing data are available in

[8] N.B. Territoriality is considered as part of adult dispersal potential.

3.4. Annex 7 to inform the subsequent survey and monitoring programme. It is important to note that these occurrences are biased by previous sampling objectives (for example sampling intensity is higher in the voluntary closed areas) and are therefore not indicative of the true distributions of these species.

3.5. In addition to the 20 species selected, one species complex was chosen. Erect branching sponges are an important group (highly sensitive to damage by mobile gears) but no traits information is available for them, so traits analysis was not possible. However it is important to include these as a species complex and therefore all erect branching sponges will be considered together although it is likely that these will be represented primarily by *Axinella dissimilis*, *Haliclona oculata* and *Raspailia ramosa* due to their ease of identification using video techniques, compared to some of the other erect branching sponges. It is hoped that by monitoring these species we will improve our knowledge of the recoverability of this group.

3.6. Amongst the free living species selected three commercially important species, Pollack, edible crab and lobster, were selected which would continue to be commercially exploited in the area following the mobile gear closure (via potting and pelagic gear respectively). These species will be key indicators to assess the relative effectiveness of the closure to species that will not be directly impacted versus those that potentially will still be fished. Indeed there may be no changes in these species, even the opposite if there is a shift in fishing effort, but alternatively the protection of the structural sessile may provide increased prey availability and refugia and structure encouraging these species - they will be secondarily affected by scallop dredging (so even with continued fishing, there could still potentially be increases in protected areas). Additionally, it is not possible to avoid the selection of commercially exploited species if the full range of traits is to be represented in the selected species.

3.7. Finally, as mentioned previously, seven rare and scarce species (see paragraph 3.1) were identified. It is not practical to include these in the monitoring programme since their rarity means that they are unlikely to be encountered regularly enough for use in terms of identifying differences in population trends or growth rates between different areas. Given their conservation importance, they should however be recorded if seen in order to continue to gather further information on their distribution and abundance.

Table 3: List of indicator species for rock and mixed substrata for Lyme Bay

Species name	Common name	Phylum	Lifespan	Growth rate (cm yr^1)	Survivorability	Reproduction	Repopulation	Recoverability
Key species locked in to analysis								
Pecten maximus	Great scallop	Mollusca	> 11 yrs	3-5	Medium	Medium	High	High
Phallusia mammillata	A sea squirt	Tunicata	1-2 yrs	3-5	Medium	High	Low	Medium
Cellepora pumicosa	A sea mat	Bryozoa	1-2 yrs	1-2	Low	High	Low	Low
Pentapora foliacea	Ross coral	Bryozoa	6-10 yrs	1-2	Low	Medium	Low	Low
Aiptasia mutabilis	Trumpet anemone	Cnidaria	1-2 yrs	3-5	Low	Medium	Medium	Low
Alcyonium digitatum	Dead man's fingers	Cnidaria	> 11 yrs	< 1	Medium	Low	Medium	Low
Eunicella verrucosa	Pink sea fan	Cnidaria	> 11 yrs	< 1	Low	Low	Low	Low
Sessile Species								
Chaetopterus variopedatus	Parchment worm	Annelida	1-2 yrs	> 5	Medium	High	Medium	High
Tethya aurantium	Golf ball sponge	Porifera	3-5 yrs	1-2	High	Medium	Medium	High
Halecium halecinum	Herring-bone hydroid	Cnidaria	1-2 yrs	> 5	Medium	High	Medium	High
Actinothoe sphyrodeta	Sandalled anemone	Cnidaria	1-2 yrs	< 1	Medium	Medium	Medium	Medium
Hydrallmania falcata	A hydroid	Cnidaria	3-5 yrs	> 5	Medium	High	Low	Medium
Cliona celata	A boring sponge	Porifera	> 11 yrs	3-5	High	Low	Low	Low
*Erect branching sponges**		Porifera			no traits information available			
Free Living Species								
Asterias rubens	Starfish	Echinodermata	6-10 yrs	1-2	High	High	High	High
Homarus gammarus	Common lobster	Crustacea	> 11 yrs	3-5	High	Low	High	High
Pollachius pollachius	Pollack	Chordata	> 11 yrs	3-5	Medium	Medium	High	High
Necora puber	Velvet swimming crab	Crustacea	6-10 yrs	1-2	Low	Medium	High	Medium
Cancer pagurus	Edible crab	Crustacea	> 11 yrs	<1	Medium	Low	High	Medium
Labrus bergylta	Ballan wrasse	Chordata	> 11 yrs	> 5	Medium	Low	High	Medium
Thorogobius ephippiatus	Leopard-spotted goby	Chordata	6-10 yrs	1-2	Medium	Low	High	Medium
Rare and scare species with traits								
Leptopsammia pruvoti	Sunset cup coral	Cnidaria	> 11 yrs	< 1 cm/yr	Low	Low	Low	Low

*Since there are no biological traits available for this group, three representative species (*Axinella dissimilis*, *Haliclona oculata* and *Raspailia ramosa*) are considered together as a species complex.

4 Discussion

4.1 Approach and selected indicators species

4.1. The method described in the current report uses a combination of biological trait analysis and experience based selection (knowledge and past data on important species) to choose a list of indicator species representative of the species found within Lyme Bay. As well as aiming to ensure that the indicators can be used to assess the main impacts from the use of mobile gears and rate of recoverability after the cessation of those activities, it is important that the suite of indicators can collectively enable an assessment of the state of the ecosystem component (structure and function).

4.2. Reviews of the impact of mobile fishing gear on benthic habitats show similar effects (Auster, 1998, Kaiser *et al.*, 2006), primarily that mobile fishing gear reduced habitat complexity (by removing plants and animals which provide three-dimensional structure), changed community structure (shift from longer lived and slow reproducing species to shorter lived and more rapidly reproducing species), and consequently affected ecosystem processes. By selecting representatives from the range of biological traits of species found in the area of interest (both relating to recoverability of the individual or population and more general lifestyle traits), the indicators can be used both to assess potential recovery and changes in ecosystem structure. In the latter case this maybe through an increase structural biogenic/ecosystem engineering species and the secondary settlement of species such as echinoderms and crustaceans or changes in the trophic structure due to a movement from scavengers to suspension feeders. Selecting a range of species representative of different levels of recoverability should also allow short-term and long-term recovery (both in terms of occurrences and growth) to be monitored. Additionally monitoring species with high tolerance and high recoverability to physical disturbance may indicate other natural environmental variations.

4.3. A good indicator species should be sensitive to a manageable human activity[9], the selected species therefore include species sensitive to physical disturbances associated with the use of mobile gear, including the erect branching sponges and the erect and fragile Pink sea fan.

4.4. Good indicators should be relatively tightly linked in space and time to the activity[9]. Sessile, slow growing and long lived species (such as the Pink sea fan, Dead men's fingers *Alcyonium digitatum* and the sponge *Cliona celata*) are likely therefore to show the effects of past disturbances more than free living fast growing species. However, in terms of monitoring recovery changes may take a long time to manifest. Figure 4 illustrates the time taken to reach maturity for the selected

[9] **Hiscock K., Langmead O. & Warwick R.** (2004). Identification of seabed indicator species from time-series and other studies to support implementation of the EU Habitats and Water Framework Directives. *Report to the Joint Nature Conservation Committee from the Marine Biological Association. Marine Biological Association, Plymouth,* 109 pp pp. , **Hiscock K., Langmead O., Warwick R. & Smith A.** (2005). Indicator species to support implementation of the EU Habitats and Water Framework Directives. Second edition. *Report to the Joint Nature Conservation Committee and the Environment Agency from the Marine Biological Association. Marine Biological Association,, Plymouth,* 77 pp. pp. , **Langmead O., Mieszkowska N., Ellis R. & Hiscock K.** (2008). Rock and biogenic reef habitats: Review of indicators and identification of gaps. *Report to the Joint Nature Conservation Committee from the Marine Biological Association. Plymouth, Marine Biological Association. ,* 201 pp.

indicator species. Species such as *Aiptasia mutabilis* and *Tethya aurantium* are also sessile and sensitive to physical disturbance, but with faster growth rates and a shorter time to maturity may show a faster recovery.

4.5. In addition to representing species which are sensitive to physical disturbance it is also important that those species which may respond in a positive way (for example scavengers) to the activity are monitored, as such species may be indicative of continued disturbance in an area.

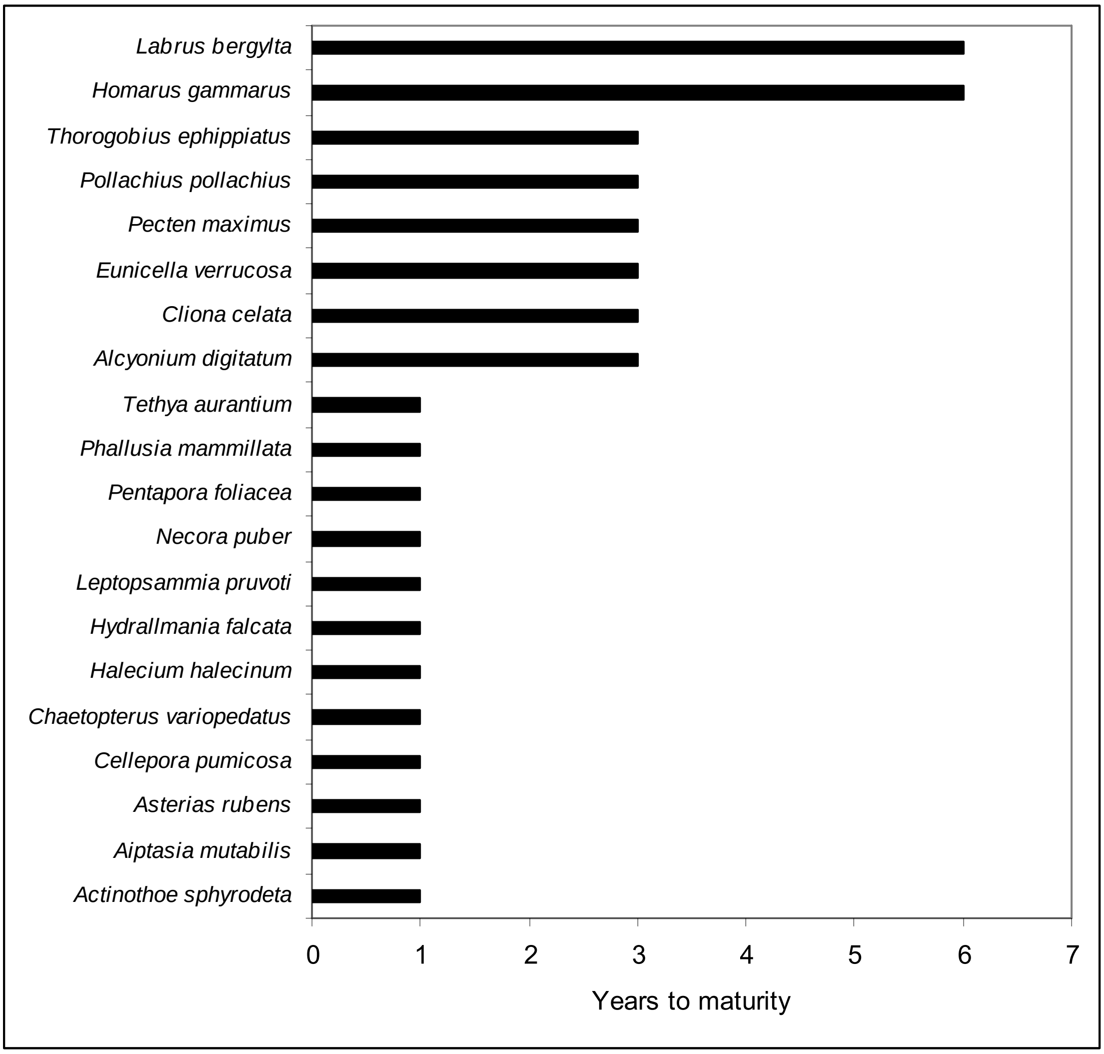

Figure 4 Time taken for selected species to reach maturity.

4.6. Similarly, monitoring only sessile species may mean that important knock on effects on mobile species inhabiting the area (species that can avoid dredges and move to another area if the habitat becomes unsuitable, but may feed on the sessile fauna and or seek refuge in the structures they create).

4.7. Ideally species indicators for monitoring should not only be responsive primarily to human activity but also have low responsiveness to other causes of change[9]. The species classified as low survivability here are those who are primarily impacted by physical disturbance. Many are susceptible to other pressures. Commercially extracted species which are collected by non mobile gears are one example but others may relate to changes in water chemistry, for example the pink sea fan is highly sensitive to changes in salinity and oxygenation and the sunset cup coral is highly sensitive to changes in temperature (sensitivities taken from www.marlin.ac.uk). Monitoring species with high tolerance and high recoverability to physical disturbance may indicate other natural environmental variations but it may also be possible to collate data on environmental change so that potentially confounding effects can be identified.

4.8. An indicator species should be measurable over a large proportion of the area in which the indicator is likely to be used[9]. Annex 6 illustrates that with the exception of some of the rare and scarce species selected for their conservation value, all of the indicator species have been recorded in each of the areas under examination (i.e. voluntary closed areas, the $60nm^2$ closure, the proposed SAC and the whole of Lyme Bay).

4.9. Benthic species distributions are highly dependent on substratum. Here we are specifically examining reef associated species but since reef in Lyme Bay can encompass areas of hard rock, soft rock cobbles, pebbles, boulders, overhangs and caves (McNulty, 2008), the diversity in microhabitat and their spatial distribution will influence species distributions. For example the sunset cup coral *Leptopsammia pruvotii* is found in only a very few discrete locations in the East of Lyme Bay, only on vertical/overhanging bedrock (pers. comm. Colin Munro, 2008).

4.10. Indicator species should also be easily and accurately measured, with a low error rate[9]. The species selected here have been chosen to be ones which can be effectively examined (identified and measured) using high definition video techniques[10], although the suggested measured variable may differ between species (see section 4.1.1).

4.1.1 Application of indicator species in the Lyme Bay study

4.11. The overall aim of this project is to monitor the recovery of the reef habitats in Lyme Bay following the designation of a $60nm^2$ closure to mobile fishing gears. In addition to monitoring the marine reef community as a whole, the monitoring of representative indicator species are required to examine recoverability. The species identified in this report are representative of different levels of recoverability and of the various functional and structural groups found within the Lyme Bay Reef community, which can all be monitored using the high definition video transects. In addition to examining the community as a whole these species will be specifically monitored over the next three years to test for significant changes between the closed areas, past voluntary closed areas and areas which are still fished using mobile gear. However, the variable to be measured (e.g. abundance, size, biomass) will differ between species and groups, depending on what is most appropriate.

[10] In situ scuba diver observations for finer scale assessments of specific species will also be carried out by Marine Bio-images (Annex 4 highlights which of the species identified in the current report will also be examined in the finer scale study).

4.12. In their review of the published literature on the response and recovery within benthic communities to the cessation of fishing pressure Kaiser *et al.* (2006) found that mean abundance data between control and treatment sites was the most commonly used factor in the determination of the level and speed of recovery. Abundance is an important parameter to measure, in particular for small, fast growing species, which are highly sensitive to physical disturbance and may have been removed by mobile gear activity. An increase in the abundance of such species would be indicative of a recovery. For larger species and those which are slower to recover, abundance may also be a useful indicator of recovery, however used in isolation it is not a representative measure of health. For example some species may only be damaged by the disturbance and may still be present in similar numbers but structural damage may mean that cover or biomass is reduced. This is particularly important when measuring taxa that form colonies in which it is not easy to differentiate individuals. Small structures may survive damage by a mobile fishing gear but larger, older specimens may be more vulnerable and removed (the latter would therefore be indicative of an undisturbed community, (Kaiser *et al.*, 2006)). Similarly, slow growing species which have been removed may reappear but may not reach their maximum size for many years. For all these species some measure of size (e.g. biomass or area) would be a more appropriate measure for monitoring recovery. Previous studies in Lyme Bay have shown size to be an appropriate measure for larger-bodied, slow-growing colonial species for example Hiddink *et al.* (2008) found that the mean size of Pink sea fans (*E. verrucosa)*and Dead man's fingers *(A. digitatum*) was highest in closed not fished areas than in fished regions.

4.13. Dead man's fingers, as a colonial species, spreads by creeping stolons which generally cannot be seen. Lobes spring up from these stolons, some of which are large others are very small and therefore quantifying the species is difficult, reflected in wide variation in results between observers (Munro, pers. comm., 2008). Again measures of percentage cover or an estimation of size are easier to standardise.

4.14. The sponge *Cliona celata* grows in two very different forms - massive and boring. The massive forms are very easy to observe and has previous been recorded in significant numbers across Lyme Bay (see Annex 6), but there are also reports that even the boring form of *Cliona* is visible (yellow tips of the oscules). The high definition video techniques employed in this project should be sensitive enough to identify both types, but it is important that abundance (of each form) is measured for this species, as the different growth forms may confound biomass/ size related measures.

4.15. Finally some species may continue to play a role in providing structural habitat even when damaged or dead. The Ross Coral (*P. foliacea*) colonies have a growth rate of approximately 2 cm per year and live for up to ten years. Colonies can reach up to 40 cm in diameter (more typically up to 20 cm across) and 10 cm in height, and these two parameters are suggested as the most appropriate measure for this species. Physical disturbance and other pressures may lead to the death of the colony (when dead, the deep orange colour fades to a pale buff) but may leave some structural remnants which may still (also he case for the Pink Sea Fan). For these species measures should be made separately of dead and live material.

4.1.2 Considerations of wider application of species and selection method

4.16. Table 4 illustrates the recorded occurrences of the selected indicator species in other South West area Marine Protected Areas. With the exception of the rare and scarce species, the other selected indicator species are likely to be suitable for use in monitoring reef habitats in other Marine Protected Areas in the region where video and diver surveys are employed and where they are present in those sites. However, each MPA will have its own specific environmental conditions and the habitat features for which sites were designated are not always reef, therefore these selected indicator species will not always be the most representative. Also recovery of communities after impacts varies based on the original community and the frequency and intensity of disturbance (Auster, 1998), both of which are very much site specific.

Table 4 Recorded occurrences of the selected indicator species in other MPAs in the South West

	Special Area of Conservation with marine components in the South West				
Species	Chesil & The Fleet	Fal & Helford	Isles of Scilly Complex	Lundy	Plymouth Sound & Estuaries
Actinothoe sphyrodeta		1	63	32	26
Aiptasia mutabilis		8	5		2
Alcyonium digitatum		1	103	113	23
Axinella dissimilis			24	17	1
Asterias rubens	1	36	55	35	31
Cellepora pumicosa		19	17	4	12
Chaetopterus variopedatus		13	17	1	5
Cliona celata		2	47	30	8
Echinus esculentus			119	94	5
Eunicella verrucosa			19	32	1
Halecium halecinum	1	4	11	9	8
Haliclona oculata			5	4	5
Homarus gammarus		2	1	1	1
Hoplangia durotrix			2		1
Hydrallmania falcate	1		5	7	9
Isozoanthus sulcatus		1	5		
Labrus bergylta	2	12	55	19	10
Leptopsammia pruvoti			6		
Necora puber	3	21	25	5	16
Pecten maximus	3	6	2	11	3
Pentapora foliacea			43	63	1
Phallusia mammillata	6				
Pollachius pollachius		1	26	4	2
Raspailia ramose			6	1	6
Tethya aurantium	1	4	5	9	
Thorogobius ephippiatus		2	2	1	5
Thymosia guernei				2	

4.17. The wider application of the work presented in this report is in outlining a transferable method for selecting representative indicator species for a specific site. Such a method is particularly valuable in the absence of large amounts of data and of cause and effect studies highlighting which species are key to the functioning and integrity of the system.

4.18. There are now strong arguments for incorporating measures of ecosystem functioning into monitoring (MRAG & UNEP-WCMC, 2008). Methods for measuring ecosystem processes in soft sediment dominated systems are already well established, for example measuring bioturbation[11] (Solan *et al.*, 2004) and illustrate the importance of key species (which in turn may be appropriate indicators of changes in ecosystem functioning). For hard substratum few equivalents exist, although relevant ecosystem functions to measure may include provision of habitat refugia, propagule supply/ export, energy and elemental cycling (MRAG & UNEP-WCMC, 2008). The data collected by the current project over the next few years may highlight species which are indicative of changes in ecosystem functioning.

4.19. Finally, recovery implies a return to an undisturbed state. Knowledge of what represents an undisturbed ecosystem is incomplete (i.e. what are the structural, compositional and functional properties of such systems?) and particularly the fact that such ecosystems are arguably nonexistent today. In the context of the present study recovery is likely to be measured against areas which have not been fished using mobile gears for the longest period. Recovery can be evidenced in terms of succession and interactions of species (predator-prey, etc.). There is not enough information available to identify such relationships in advance for key indicator selection in this study, but our ability to monitor all the species will allow such relationships to become evident, if they exist.

[11] Bioturbation (the biogenic mixing of sediment) - a primary determinant of sediment oxygen concentrations which, in turn, influences biomass of organisms, rate of organic matter decomposition, and regeneration of nutrients vital for primary productivity. (Source: Solan et al., 2004).

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6 References

Airoldi L. (2000). Responses of algae with different life histories to temporal and spatial variability of disturbance in subtidal reefs. *Marine Ecology Progress Series*, 195, 81-92.

Auster P.J. (1998). A Conceptual Model of the Impacts of Fishing Gear on the Integrity of Fish Habitats. *Conservation Biology*, 12, 1198-1203.

Bevilacqua S., Terlizzi A., Fraschetti S., Russo G.F. & Boero F. (2006). Mitigating human disturbance: can protection influence trajectories of recovery in benthic assemblages? *Journal of animal ecology*, 908-920, 908-920.

Borja A., Franco J. & Perez V. (2000). A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. *Marine Pollution Bulletin*, 40, 1100 -1114.

Bremner J., Rogers S.I. & Frid C.L.J. (2003). Assessing functional diversity in marine benthic ecosystems: a comparison of approaches. *Marine Ecology Progress Series*, 254, 11-25.

Bremner J., Rogers S.I. & Frid C.L.J. (2006). Matching biological traits to environmental conditions in marine benthic ecosystems. *Journal of Marine Systems*, 60, 302-316.

Carignan V. & Villard M. (2002). Selecting Indicator Species to Monitor Ecological Integrity: A Review. *Environmental Monitoring and Assessment*, 78, 45-61.

Dayton P.K., Thrush S.M., Tundi Agardy M. & Hofman R.J. (1995). Environmental effects of marine fishing. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 5, 205-232.

Devon Wildlife Trust (1993). Lyme Bay. A report on the nature conservation importance of the inshore reefs of Lyme Bay and the effects of mobile fishing gear *Report. Devon Wildlife Trust*, pp.

di Castri F., Vernhes J.R. & Younés T. (1992). Inventoring and monitoring biodiversity: a proposal for an international network. *Biology International*, 27, 1-27.

Ellis J.I., Norkko A. & Thrush S.F. (2000). Broad-scale disturbance of intertidal and shallow sublittoral soft-sediment habitats; effects on the benthic macrofauna. *Journal of Aquatic Ecosystem Stress and Recovery*, 7, 57-74.

Hiddink J.G., M.J. K., H. H. & A. R. (2008). Quantification of epibenthic fauna in areas subjected to different regimes of scallop dredging activity in Lyme Bay, Devon. *NERC funded conducted by School of Ocean Sciences, College of Natural Sciences, Bangor University. ,* pp.

Hiscock K. (2007). Lyme Bay - a conservation science viewpoint of human activities there and effects on conservation. In Devon Wildlife Trust (ed.),^(eds.).*Lyme Bay Reefs. A 16 year search for sustainability.*, pp. 10-11.

Hiscock K., Langmead O. & Warwick R. (2004). Identification of seabed indicator species from time-series and other studies to support implementation of the EU Habitats and Water Framework Directives. *Report to the Joint Nature Conservation Committee from the Marine Biological Association. Marine Biological Association, Plymouth,* 109 pp pp.

Hiscock K., Langmead O., Warwick R. & Smith A. (2005). Indicator species to support implementation of the EU Habitats and Water Framework Directives. Second edition. *Report to the Joint Nature Conservation Committee and the Environment Agency from the Marine Biological Association. Marine Biological Association,, Plymouth,* 77 pp. pp.

Hiscock K., Marshall C., Sewell J. & Hawkins S.J. (2006). The structure and functioning of marine ecosystems: an environmental protection and management perspective. Report to English Nature from the Marine Life Information Network (MarLIN). Plymouth: Marine Biological Association. English Nature Research Reports , ENRR No. 699., pp.

Hughes T.P., Bellwood D.R., Folke C., Steneck R.S. & Wilson J. (2005). New paradigms for supporting the resilience of marine ecosystems. *Trends in Ecology & Evolution*, 20, 380-386.

Jennings S., Dinmore T.A., Duplisea D.E., Warr K.J. & Lancaster J.E. (2001). Trawling disturbance can modify benthic production processes. *Journal of animal ecology*, 70, 459-475.

Kaiser M.J., Clarke K.R., Hinz H., Austen M.C.V., Somerfield P.J. & Karakassis I. (2006). Global analysis of the response and recovery of benthic biota to fishing. *Marine Ecology Progress Series*, 3, 1-14.

Kaiser M.J. & de Groot S.J. (2000a). *The Effects of Fishing on Non-Target Species and Habitats: Biological, Conservation and Socio-Economic Issues*, Oxford Blackwell Science.

Kaiser M.J. & De Groot S.J., (eds.) (2000b). *The effects of fishing on non-target species and habitats. Biological, conservation and socio-economic issues*, Oxford: Blackwell Science Limited.

Langmead O., Mieszkowska N., Ellis R. & Hiscock K. (2008). Rock and biogenic reef habitats: Review of indicators and identification of gaps. *Report to the Joint Nature Conservation Committee from the Marine Biological Association. Plymouth, Marine Biological Association. ,* 201 pp.

Moline M.A., Claustre H., Frazer T.K., Schofield O. & Vernet M. (2004). Alteration of the food web along the Antarctic Peninsula in response to a regional warming trend. *Global Change Biology*, 10, 1973-1980.

MRAG & UNEP-WCMC (2008). Defining concepts of ecosystem structure and function for UK marine monitoring *Joint Nature Conservation Committee, Peterborough,* JNCC report No. 397, 65 pp.

Noss R.F., O'Connell M.A. & Murphy D.D. (1997). *The Science of Conservation Planning: Habitat Conservation under the Endangered Species Act'*, Washington: World Wildlife Fund and Island Press.

Roberts C.M., Hawkins J.P., Fletcher J., Hands S., Raab K. & Ward S. (in prep). Guidance for designing a network of Marine Protected Areas in England: Incorporating connectivity and adequacy *Report from Environment Department, University of York to Natural England,* 50 pp.

Sewell J. & Hiscock K. (2005). Effects of fishing within UK European Marine Sites: guidance for nature conservation agencies. Report to the Countryside Council for Wales, English Nature and Scottish Natural Heritage from the Marine Biological Association of the UK *Plymouth,* CCW Contract FC 73-03-214A, 195 pp.

Solan M., Cardinale B.J., Downing A.L., Engelhardt K.A.M., Ruesink J.L. & Srivastava D.S. (2004). Extinction and Ecosystem Function in the Marine Benthos. *Science*, 306, 1177-1180.

Tyler-Walters H. & Jackson A. (1999). Assessing seabed species and ecosystems sensitivities. Rationale and user guide. *Report to the Department of the Environment Transport and the Regions from the Marine Life Information Network. Marine Biological Association, Plymouth,* MarLIN Report No.4, 46 pp.

ANNEXES

Survey Name	From Date	To Date	Organised By	Survey Run For
1970-80 SMBA/MBA Great Britain littoral survey	23/10/1970	19/05/1980	Nature Conservancy Council	Scottish Marine Biological Association
1976 -1977 MNCR sector UK08 West English Channel Underwater Observation Scheme	01/11/1976	20/11/1977	Marine Conservation Society	
1977-1980 Dorset underwater observation scheme	16/04/1977	31/12/1980	Marine Conservation Society	
1977-1982 Devon underwater observation scheme	01/01/1977	31/12/1982	Marine Conservation Society	
1978 Devon and Cornwall shore survey	01/01/1978	31/12/1978	H T Powell	
1982-97 DWT Seasearch Great West Bay sublittoral survey	01/08/1982	01/01/1997	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1983 Dyrynda Fleet lagoon sublittoral survey	23/08/1983	29/08/1983	University College of Wales, Swansea (Dr Peter Dyrynda)	Joint Nature Conservation Committee
1984-86 Dyrynda Fleet lagoon (entrance) survey	04/11/1984	13/04/1986	University College of Wales, Swansea (Dr Peter Dyrynda)	Joint Nature Conservation Committee
1985 OPRU HRE Exe Estuary survey	18/08/1985	23/08/1985	Field Studies Council Research Centre	Joint Nature Conservation Committee
1985-87 Procter Torbay caves survey	01/01/1985	12/05/1987	Chris Proctor	Chris Proctor
1986 MCS River Dart survey	07/08/1986	10/08/1986	Unknown	Joint Nature Conservation Committee
1986 Southwest England Alcyonium glomeratum records (JNCC candidate rare/scare species files)	01/01/1986	31/12/1986	Bill Sanderson	
1987 OPRU HRE Dart Estuary survey	10/05/1987	10/07/1987	Field Studies Council Research Centre	Joint Nature Conservation Committee
1987 OPRU HRE Portland and Weymouth Harbours survey	21/04/1987	23/04/1987	Field Studies Council Research Centre	Joint Nature Conservation Committee
1988 OPRU HRE Teign Estuary survey	30/07/1988	02/08/1988	Field Studies Council Research Centre	Joint Nature Conservation Committee
1990 NRA Axe Estuary littoral survey	13/09/1990	13/09/1990	National Rivers Authority (Yorkshire Region)	Environment Agency
1990 NRA Exe Estuary littoral survey	12/09/1990	14/09/1990	National Rivers Authority (Yorkshire Region)	Environment Agency
1990 NRA Otter Estuary littoral survey	18/10/1990	18/10/1990	National Rivers Authority (Yorkshire Region)	Environment Agency
1991 Eype, West Dorset Pectenogammarus planicrurus observation	01/01/1991	31/12/1991	Michael Bell	
1991-95 DWT Orcombe littoral survey	09/11/1991	01/01/1995	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)

Survey Name	From Date	To Date	Organised By	Survey Run For
1992 North Sea and English Channel CEFAS 2m beam trawl surveys (Cor.14/92)	12/12/1992	19/12/1992	Centre for Environment Fisheries & Aquaculture Science	Ministry of Agriculture Fisheries and Food
1992 NRA Teign Estuary survey	09/08/1990	09/08/1990	National Rivers Authority (Yorkshire Region)	Environment Agency
1992-93 DWT Exe littoral survey	16/03/1992	30/12/1993	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1992-94 DWT Babbacombe littoral survey	28/07/1992	31/12/1994	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1992-94 DWT Budleigh littoral survey	21/01/1992	31/12/1994	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1992-95 DWT Axmouth littoral survey	03/09/1992	01/01/1995	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1992-95 DWT Dawlish littoral survey	16/06/1992	01/01/1995	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1992-95 DWT Sidmouth littoral survey	02/09/1992	01/01/1995	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1992-95 DWT Teign Estuary littoral survey	15/07/1992	01/01/1995	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1992-95 DWT Torbay littoral survey	17/08/1992	01/01/1995	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1992-96 DWT Ladram littoral survey	07/03/1992	01/02/1996	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1993-95 DWT Lyme Regis littoral survey	01/01/1993	01/01/1995	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1993-95 DWT Stoke Fleming littoral survey	12/11/1993	01/01/1995	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1994 Ambios Lyme Bay sublittoral sediment survey	15/05/1994	23/05/1994	Ambios Environmental Consultants	Kerr-McGee Oil (UK)
1994 DWT Beer Head to Chesil Cove (Lyme Bay) survey	25/07/1994	26/07/1994	Kerr-McGee Oil (UK)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1994 DWT Exmouth to Burton Bradstock (Lyme Bay) survey	08/08/1994	10/08/1994	Kerr-McGee Oil (UK)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1994 DWT Scabbacombe littoral survey	01/02/1994	31/12/1994	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1994 DWT Start Bay littoral survey	24/02/1994	31/12/1994	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)

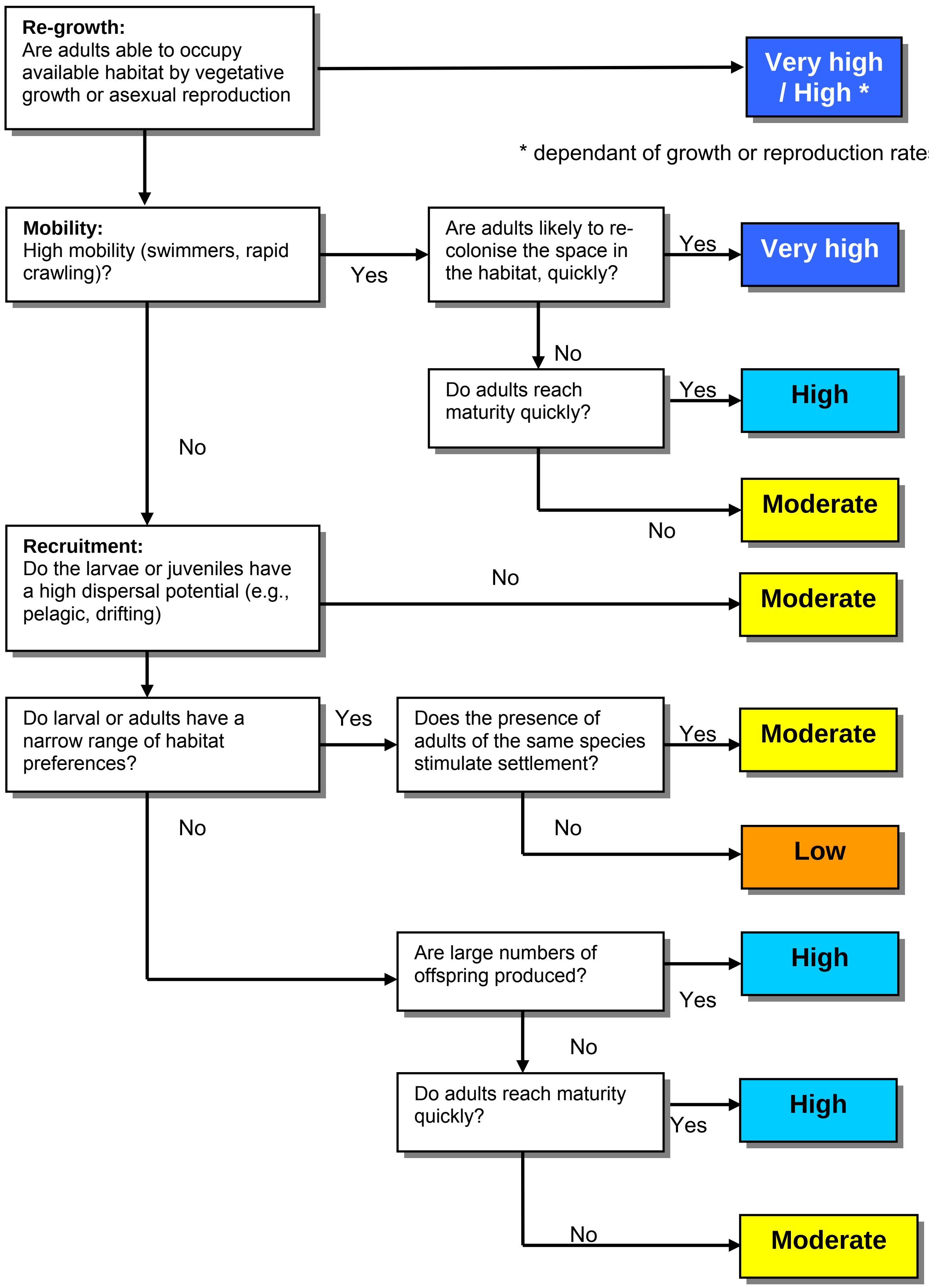
Annex 1 cont.

Survey Name	From Date	To Date	Organised By	Survey Run For
1994-95 DWT Dart estuary littoral survey	25/02/1994	01/01/1995	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1994-95 DWT Exmouth to Chesil (Lyme Bay) survey	23/05/1994	01/01/1995	Kerr-McGee Oil (UK)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1994-96 DWT Chesil littoral survey	01/01/1994	01/01/1996	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
1995 Devon and Dorset BMNH Chalk shore survey	01/01/1995	31/12/1995	Natural History Museum	
1995 EN Portland Harbour and Fleet entrance littoral survey	26/09/1995	26/09/1995	Unknown	English Nature
1995-2002 Dorset Seasearch	01/05/1995	16/09/2002	Dorset Wildlife Trust	Seasearch
1998 - current Britain & Ireland volunteer collected Sealife Survey records	01/01/1998	31/12/2006	Marine Biological Association of the United Kingdom	
1998 DWT Lyme Bay sublittoral rock survey	01/06/1998	31/12/1998	Devon Biodiversity Record Centre (Devon Wildlife Trust)	Devon Biodiversity Record Centre (Devon Wildlife Trust)
2001Lyme Bay Reef Monitoring Project	2001	2001	Devon Biodiversity Record Centre (Devon Wildlife Trust)	
2002 Chesil and the Fleet cSAC Fleet Lagoon and Tidal Rapids Survey	15/07/2002	22/07/2002	Aquatic Survey & Monitoring Ltd.	English Nature
2002 Seasearch Surveys in Devon	01/01/2002	31/12/2002	Ilfracombe Sub Aqua Club	Seasearch
2002 Western English Channel, Celtic Sea and Bristol Channel CEFAS Beam Trawl Survey (Cory 13/02)	01/01/2002	31/12/2002	Centre for Environment Fisheries & Aquaculture Science	
2002Lyme Bay Reef Monitoring Project	2002	2002	Devon Biodiversity Record Centre (Devon Wildlife Trust)	
2003 Seasearch Survey of Dorset	01/06/2003	31/12/2003	Dorset Wildlife Trust	Seasearch
2003 Seasearch Surveys in Devon	01/01/2003	31/12/2003	Seasearch	Seasearch
2003 Western English Channel, Bristol Channel and Irish Sea CEFAS 4m beam trawl survey	01/01/2003	31/12/2003	Centre for Environment Fisheries & Aquaculture Science	
2003Lyme Bay Reef Monitoring Project	2003	2003	Devon Biodiversity Record Centre (Devon Wildlife Trust)	
2004 MCS Seasearch survey of Lyme Bay	14/08/2004	17/10/2004	Lin Baldock	Devon Biodiversity Records Centre
2004 MCS Seasearch Survey of Portland	22/05/2004	23/05/2004	Marine Conservation Society	Seasearch
2004 Seasearch Survey of Dorset	01/01/2004	31/12/2004	Dorset Wildlife Trust	Seasearch
2004 Seasearch surveys in Devon	01/01/2004	31/12/2004	Seasearch	Seasearch

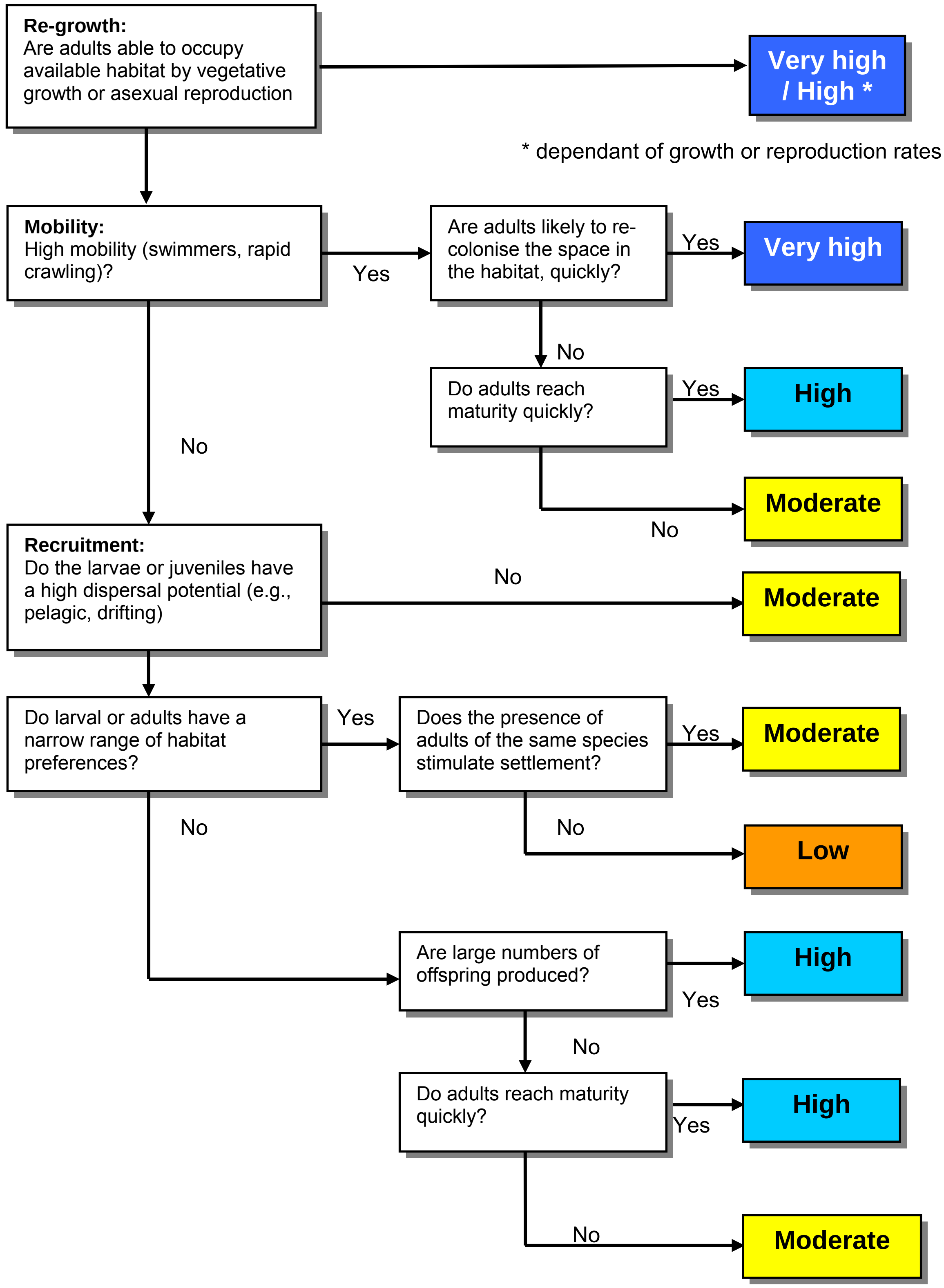
Survey Name	From Date	To Date	Organised By	Survey Run For
2004Lyme Bay Reef Monitoring Project	2004	2004	Devon Biodiversity Record Centre (Devon Wildlife Trust)	
2005 MCS Seasearch survey of Dartmouth	18/06/2005	19/06/2005	Gavin Black	Devon Wildlife Trust
2005 MCS Seasearch survey of Lyme Bay	22/06/2005	04/09/2005	Lin Baldock	Devon Wildlife Trust
2005 Seasearch Survey of Dorset	02/04/2005		Dorset Wildlife Trust	Seasearch
2005 Seasearch surveys in Devon	01/01/2005	31/12/2005	Seasearch	
2006 Seasearch East Devon	03/04/2005	30/09/2006	Devon Seasearch	Seasearch
2006 Seasearch Lyme Bay sea fan sites survey	05/07/2006	18/08/2006	Seasearch	Devon Wildlife Trust
2006 Seasearch Survey of Dorset	01/01/2006		Dorset Wildlife Trust	
2006 Seasearch Survey of Start Bay and Dartmouth	22/04/2006	07/09/2006	Seasearch	Devon Wildlife Trust
2006Lyme Bay Reef Monitoring Project	2005	2005	Devon Biodiversity Record Centre (Devon Wildlife Trust)	
240PET LymeBayEnvironmentalStudy 1995	1995	1995	Dorset Environmental Records Centre	
241PET LymeBayEnvironmentalStudyApp2 1995	1995	1995	Dorset Environmental Records Centre	
243PET LinBaldockMarineConsultant	2003	2003	Lin Baldock	Dorset Environmental Records Centre
251PET DurlstenMarineProject	2005	2005	Durlston Marine Project	

Annex 2: Flow charts for identifying recoverability
(Source: Tyler-Walters & Jackson, 1999)

Recoverability assessment of species of 'high' sensitivity



Recoverability assessment of species of 'intermediate' sensitivity



Annex 3: “Recoverability” traits scores for the 47 filtered species traits

Frag = Fragility, Reg = Regeneration, Mat = Maturity, Fec = Fecundity, DisL= Dispersal potential of larvae, DisA = Dispersal potential of adult) and scores for survivability (Surviv), reproduction potential (Repro), Repopulation potential (Repop) and the combined recoverability score (RECOV). ’X’ indicates species selected as representative and suitable for the monitoring programme

Recoverability Traits

	Species name	Frag	Reg	Mat	Fec	DisL	DisA	Surviv	Repro	Repop	RECOV
	Key Species locked in										
x	*Pecten maximus*	2	1	3	3	4	2	Medium	Medium	High	High
x	*Phallusia mammillata*	2	1	1	2	2	1	Medium	High	Low	Medium
x	*Cellepora pumicosa*	1	1	1	2	1	1	Low	High	Low	Low
x	*Pentapora foliacea*	1	1	2	2	2	1	Low	Medium	Low	Low
x	*Aiptasia mutabilis*	1	1	1	1	3	1	Low	Medium	Medium	Low
x	*Alcyonium digitatum*	1	2	3	2	4	1	Medium	Low	Medium	Low
x	*Eunicella verrucosa*	1	1	3	2	2	1	Low	Low	Low	Low
	Sessile Species										
x	*Chaetopterus variopedatus*	1	2	1	3	4	1	Medium	High	Medium	High
	Dictyota dichotoma	2	1	1	2	3	1	Medium	High	Medium	High
x	*Tethya aurantium*	2	2	2	2	3	1	High	Medium	Medium	High
	Calliblepharis ciliata	2	1	2	3	3	1	Medium	High	Medium	High
x	*Halecium halecinum*	1	2	1	2	3	1	Medium	High	Medium	High
	Bispira volutacornis	1	2	1	2	1	1	Medium	High	Low	Medium
x	*Actinothoe sphyrodeta*	2	1	1	1	3	1	Medium	Medium	Medium	Medium
x	*Hydrallmania falcata*	1	2	1	2	2	1	Medium	High	Low	Medium
	Ascidiella aspersa	1	1	1	2	3	1	Low	High	Medium	Medium
	Botryllus schlosseri	2	1	1	1	3	1	Medium	Medium	Medium	Medium
	Alcyonidium diaphanum	2	1	2	2	1	1	Medium	Medium	Low	Low
	Flustra foliacea	1	1	2	2	2	1	Low	Medium	Low	Low
	Nemertesia antennina	1	2	1	1	1	1	Medium	Medium	Low	Low
x	*Cliona celata*	2	2	3	2	2	1	High	Low	Low	Low
	*Antedon bifida**	1	1	2	2	3	1	Low	Medium	Medium	Low
	Free Living Species										
x	*Asterias rubens*	2	2	2	3	4	3	High	High	High	High
	Echinus esculentus	1	1	2	3	4	3	Low	High	High	High
	Ophiothrix fragilis	1	2	1	3	4	2	Medium	High	High	High
	Aequipecten opercularis	2	1	2	3	4	2	Medium	High	High	High
x	*Homarus gammarus*	2	2	4	3	3	4	High	Low	High	High
	Maja squinado	1	2	2	2	3	4	Medium	Medium	High	High
x	*Pollachius pollachius*	2	1	3	3	4	4	Medium	Medium	High	High
	Trisopterus luscus	2	1	2	2	3	4	Medium	Medium	High	High
	Trisopterus minutus	2	1	2	2	3	4	Medium	Medium	High	High
x	*Cancer pagurus*	2	1	4	3	4	3	Medium	Low	High	Medium
x	*Necora puber*	1	1	2	2	4	3	Low	Medium	High	Medium
	Callionymus lyra	2	1	2	1	3	4	Medium	Low	High	Medium
	Ctenolabrus rupestris	2	1	3	2	4	4	Medium	Low	High	Medium
x	*Labrus bergylta*	2	1	4	1	4	4	Medium	Low	High	Medium

	Labrus mixtus	2	1	3	1	4	4	Medium	Low	High	Medium
	Parablennius gattorugine	2	1	2	1	3	3	Medium	Low	High	Medium
	Pleuronectes platessa	2	1	3	2	4	4	Medium	Low	High	Medium
x	*Thorogobius ephippiatus*	2	1	3	2	3	3	Medium	Low	High	Medium

Sponges without traits

x	*Axinella dissimilis*	1	2	-	-	-	-	Medium	-	-	-
	Dysidea fragilis	2	2	-	-	-	-	High	-	-	-
	Esperiopsis fucorum	1	2	-	-	-	-	Medium	-	-	-
x	*Haliclona oculata*	2	2	-	-	-	-	High	-	-	-
	Hemimycale columella	2	2	-	-	-	-	High	-	-	-
	Pachymatisma johnstonia	2	2	-	-	-	-	High	-	-	-
x	*Raspailia ramosa*	2	2	-	-	-	-	High	-	-	-

Key	1	2	3	4
Fragility to disturbance	Fragile	Intermediate	Robust	
Regenerative ability	No	Yes		
Age at maturity (years)	< 1	1-2	3-5	6-10
Fecundity	<2,000	2,000 - 200,000	>200,000	
Dispersal : larvae (km)	< 0.1	0.1-1	1-10	> 10
Dispersal : adult (km)	None	< 0.1	0.1-10	> 10

* *Antedon bifida* classified as sessile for the purpose of the study

Annex 4: "Lifestyle" traits scores for the 47 filtered species

'x' indicates species selected as representative and suitable for the monitoring programme.
'z' indicates species which will also be examined at a finer scale (for limited areas) by Marine Bio-Images.

Lifestyle Traits

		Species name	Phylum	Feed	Size	Socia	Lifesp	Growth	Habit
		Key Species							
x		*Pecten maximus*	Mollusca	3	3	1	5	3	Free living
x	Z	*Phallusia mammillata*	Tunicata	3	3	1	2	3	Attached
x	Z	*Cellepora pumicosa*	Bryozoa	2	2	3	2	2	Attached
x	Z	*Pentapora foliacea*	Bryozoa	2	4	3	4	2	Attached
x	Z	*Aiptasia mutabilis*	Cnidaria	2	3	2	2	3	Attached
x	Z	*Alcyonium digitatum*	Cnidaria	2	3	3	5	1	Attached
x	Z	*Eunicella verrucosa*	Cnidaria	2	4	3	5	1	Erect
		Sessile Species							
x	Z	*Chaetopterus variopedatus*	Annelida	2	4	1	2	4	Tubiculous
		Dictyota dichotoma	Chromophycota	1	4	1	1	4	Attached
x	Z	*Tethya aurantium*	Porifera	3	2	3	3	2	Attached
		Calliblepharis ciliata	Rhodophycota	1	4	1	3	3	Attached
x		*Halecium halecinum*	Cnidaria	2	4	3	2	4	Erect
	Z	*Bispira volutacornis*	Annelida	2	2	3	3	2	Tubiculous
x		*Actinothoe sphyrodeta*	Cnidaria	2	1	2	2	1	Attached
x	Z	*Hydrallmania falcata*	Cnidaria	2	3	3	3	4	Erect
		Ascidiella aspersa	Tunicata	3	3	1	2	3	Attached
		Botryllus schlosseri	Tunicata	3	3	3	1	4	Encrusting
	Z	*Alcyonidium diaphanum*	Bryozoa	2	4	3	4	3	Attached
		Flustra foliacea	Bryozoa	2	3	3	4	2	Attached
	Z	*Nemertesia antennina*	Cnidaria	2	3	3	1	4	Attached
x	Z	*Cliona celata*	Porifera	3	5	3	5	3	Attached
		*Antedon bifida**	Echinodermata	2	3	2	3	3	Free living
		Free Living Species							
x		*Asterias rubens*	Echinodermata	4	4	1	4	4	Free living
		Echinus esculentus	Echinodermata	4	3	1	4	2	Free living
		Ophiothrix fragilis	Echinodermata	2	3	2	4	3	Free living
		Aequipecten opercularis	Mollusca	3	2	1	4	3	Free living
x		*Homarus gammarus*	Crustacea	5	4	1	5	3	Free living
		Maja squinado	Crustacea	5	3	1	4	4	Free living
x		*Pollachius pollachius*	Chordata	5	5	1	5	3	Free living
		Trisopterus luscus	Chordata	5	4	2	3	4	Free living
		Trisopterus minutus	Chordata	5	4	2	3	4	Free living
		Cancer pagurus	Crustacea	5	4	1	5	1	Free living
x		*Necora puber*	Crustacea	5	2	1	4	2	Free living
		Callionymus lyra	Chordata	5	4	1	4	4	Free living
		Ctenolabrus rupestris	Chordata	5	3	1	4	3	Free living
x		*Labrus bergylta*	Chordata	5	4	1	5	4	Free living
		Labrus mixtus	Chordata	5	4	1	5	4	Free living

		Parablennius gattorugine	Chordata	4	4	1	4	3	Free living
		Pleuronectes platessa	Chordata	5	5	1	5	2	Free living
x		*Thorogobius ephippiatus*	Chordata	4	3	1	4	2	Free living

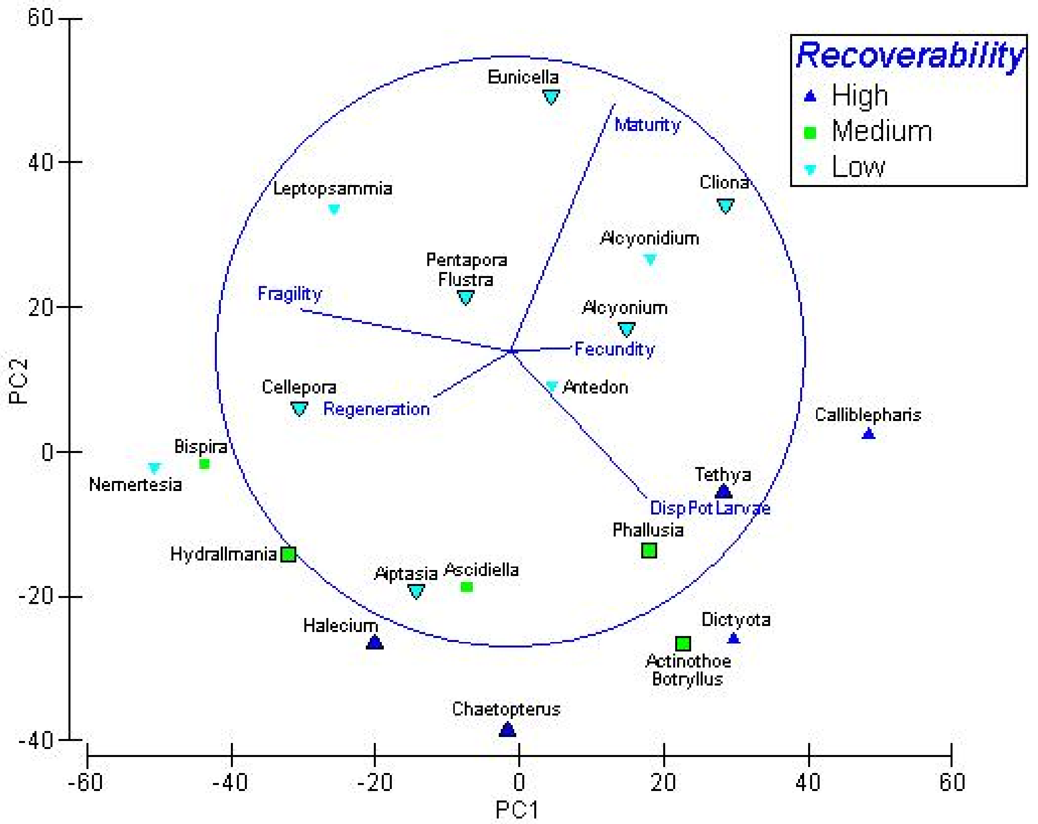
Sponges without traits

x	z	*Axinella dissimilis*	Porifera	3	3	3	-	-	Attached
		Dysidea fragilis	Porifera	3	4	3	-	-	Attached
		Esperiopsis fucorum	Porifera	3	3	3	-	-	Attached
x		*Haliclona oculata*	Porifera	3	4	3	-	-	Attached
	z	*Hemimycale columella*	Porifera	3	4	3	-	-	Encrusting
		Pachymatisma johnstonia	Porifera	3	3	3	-	-	Attached
x		*Raspailia ramosa*	Porifera	3	3	3	-	-	Attached

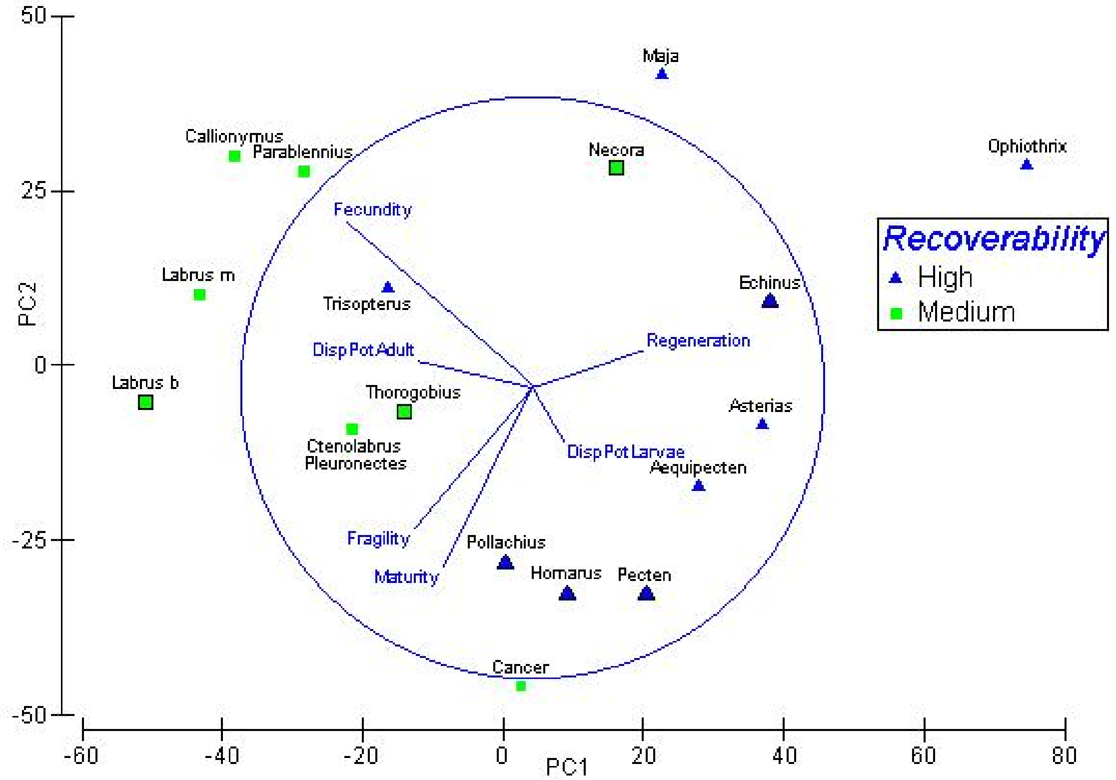
Key	1	2	3	4	5
Feeding Method	Photo-autotroph	Passive suspension	Active suspension	Deposit or Omnivore	Predator or Scavenger
Maximum size (cm)	< 2	3-10	11-20	21-50	> 50
Sociability	Solitary	Gregarious	Colonial		
Lifespan	<1 year	1-2 years	3-5 years	6-10 years	11 and over
Growth rate (cm/year)	≤1 cm	1-3 cm	3-5 cm	≥5 cm	

Annex 5: Principal component analysis plots of the recoverability traits

For sessile species recorded in Lyme Bay



For free living species recorded in Lyme Bay



Annex 6: Recorded abundance of species

Recorded abundances of the 54 species filtered species list within the voluntary closed areas, the 60nm^2 closure, the proposed SAC and the whole of Lyme Bay. 'X' indicates species selected as representative and suitable for the monitoring programme.

				Abundance				
	Species name	Common name	Phylum	Volun.	Closed area	SAC	Lyme	Status
	Key Species							
x	*Pecten maximus*	Great scallop	Mollusca	105	148	154	231	
x	*Phallusia mammillata*	A sea squirt	Tunicata	87	127	135	182	NIMF
x	*Cellepora pumicosa*	A sea mat	Bryozoa	47	80	88	109	
x	*Pentapora foliacea*	Ross coral	Bryozoa	179	234	249	289	
x	*Aiptasia mutabilis*	Trumpet anemone	Cnidaria	50	74	75	84	NIMF
x	*Alcyonium digitatum*	Dead man's fingers	Cnidaria	164	212	226	430	
x	*Eunicella verrucosa*	Pink sea fan	Cnidaria	166	191	201	238	BAP
	Sessile Species							
x	*Chaetopterus variopedatus*	Parchment worm	Annelida	42	65	68	95	
	Dictyota dichotoma	A brown alga	Chromophycota	9	63	69	242	
x	*Tethya aurantium*	Golf ball sponge	Porifera	11	32	33	63	
	Calliblepharis ciliata	Eyelash weed	Rhodophycota	41	69	74	118	
x	*Halecium halecinum*	Herring-bone hydroid	Cnidaria	30	56	64	126	
	Bispira volutacornis	A polychaete worm	Annelida	69	95	102	185	
x	*Actinothoe sphyrodeta*	Sandalled anemone	Cnidaria	49	70	76	175	
x	*Hydrallmania falcata*	A hydroid	Cnidaria	25	39	44	89	
	Ascidiella aspersa	A sea squirt	Tunicata	39	73	75	132	
	Botryllus schlosseri	Star ascidian	Tunicata	39	86	89	278	
	Alcyonidium diaphanum	Sea chervil	Bryozoa	53	84	93	156	
	Flustra foliacea	Hornwrack	Bryozoa	6	10	16	48	
	Nemertesia antennina	Sea beard	Cnidaria	98	136	146	282	
x	*Cliona celata*	A boring sponge	Porifera	89	132	143	345	
	*Antedon bifida**	Rosy feather-star	Echinodermata	2	2	2	37	
	Free Living Species							
X	*Asterias rubens*	Common starfish	Echinodermata	67	104	113	414	
	Echinus esculentus	Edible sea urchin	Echinodermata	1	2	2	13	NIMF
	Ophiothrix fragilis	Common brittlestar	Echinodermata	7	15	19	99	
	Aequipecten opercularis	Queen scallop	Mollusca	16	32	41	71	
x	*Homarus gammarus*	Common lobster	Crustacea	13	20	24	88	
	Maja squinado	Common spider crab	Crustacea	33	57	67	252	
x	*Pollachius pollachius*	Pollack	Chordata	11	20	20	121	
	Trisopterus luscus	Pouting	Chordata	46	66	74	159	
	Trisopterus minutus	Poor cod	Chordata	24	42	45	83	
	Cancer pagurus	Edible crab	Crustacea	54	97	109	395	
x	*Necora puber*	Velvet swimming crab	Crustacea	66	132	146	443	
	Callionymus lyra	Common dragonet	Chordata	7	32	36	167	
	Ctenolabrus rupestris	Goldsinny wrasse	Chordata	48	75	84	250	
x	*Labrus bergylta*	Ballan wrasse	Chordata	27	39	41	212	

	Labrus mixtus	Cuckoo wrasse	Chordata	60	76	80	139	
	Parablennius gattorugine	Tompot blenny	Chordata	49	72	81	184	
	Pleuronectes platessa	Plaice	Chordata	1	2	4	74	BAP
x	*Thorogobius ephippiatus*	Leopard-spotted goby	Chordata	42	58	65	113	

Sponges without traits

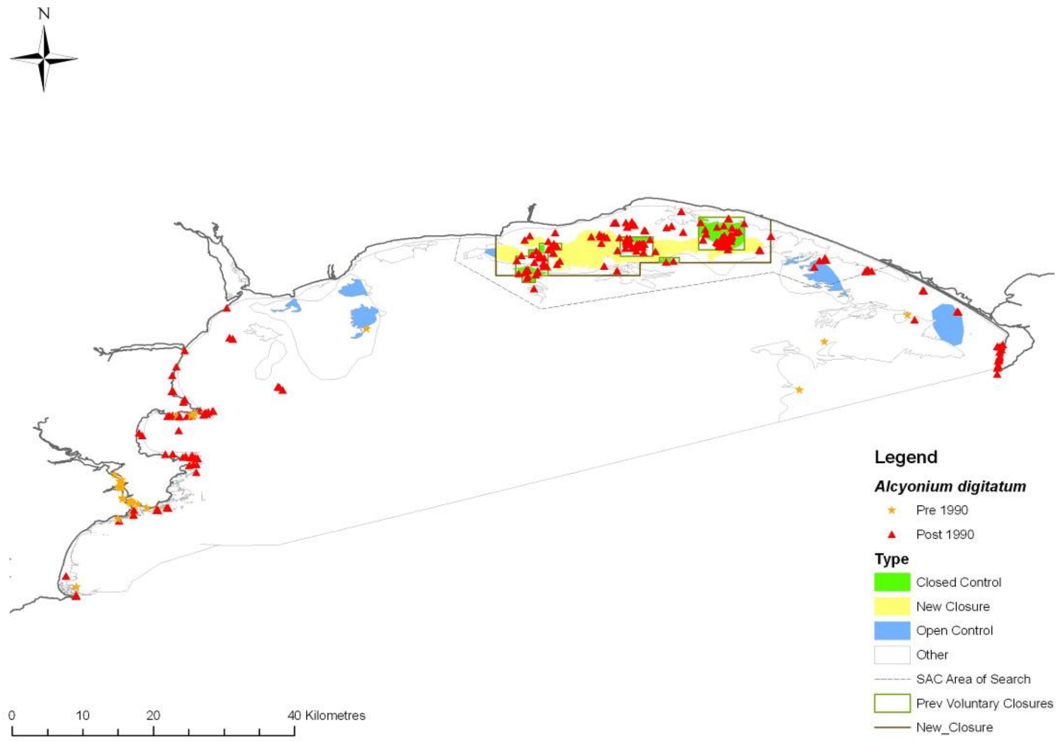
x	*Axinella dissimilis*	A braching sponge	Porifera	26	32	39	45	
	Dysidea fragilis	Goosebump sponge	Porifera	77	118	129	225	
	Esperiopsis fucorum	A sponge	Porifera	73	107	116	189	
x	*Haliclona oculata*	Mermaid's glove	Porifera	17	30	35	70	
	Hemimycale columella	Crater sponge	Porifera	71	99	107	157	
	Pachymatisma johnstonia	A massive sponge	Porifera	70	85	94	205	
x	*Raspailia ramosa*	Chocolate finger sponge	Porifera	33	48	54	84	

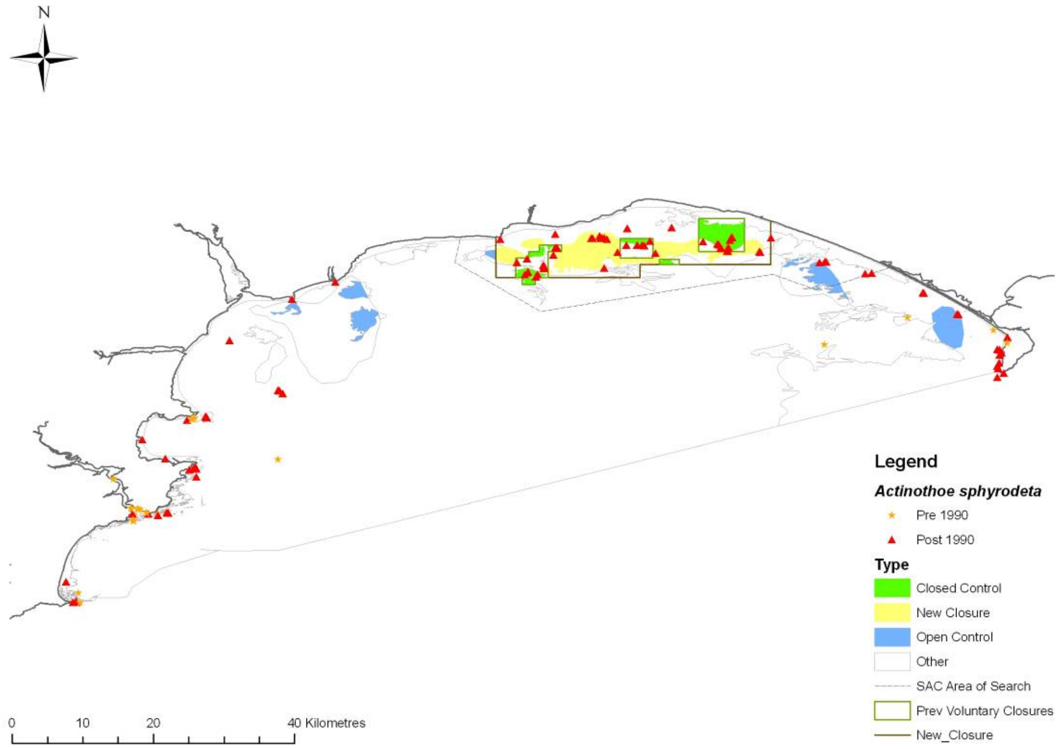
Rare/Scarce Species

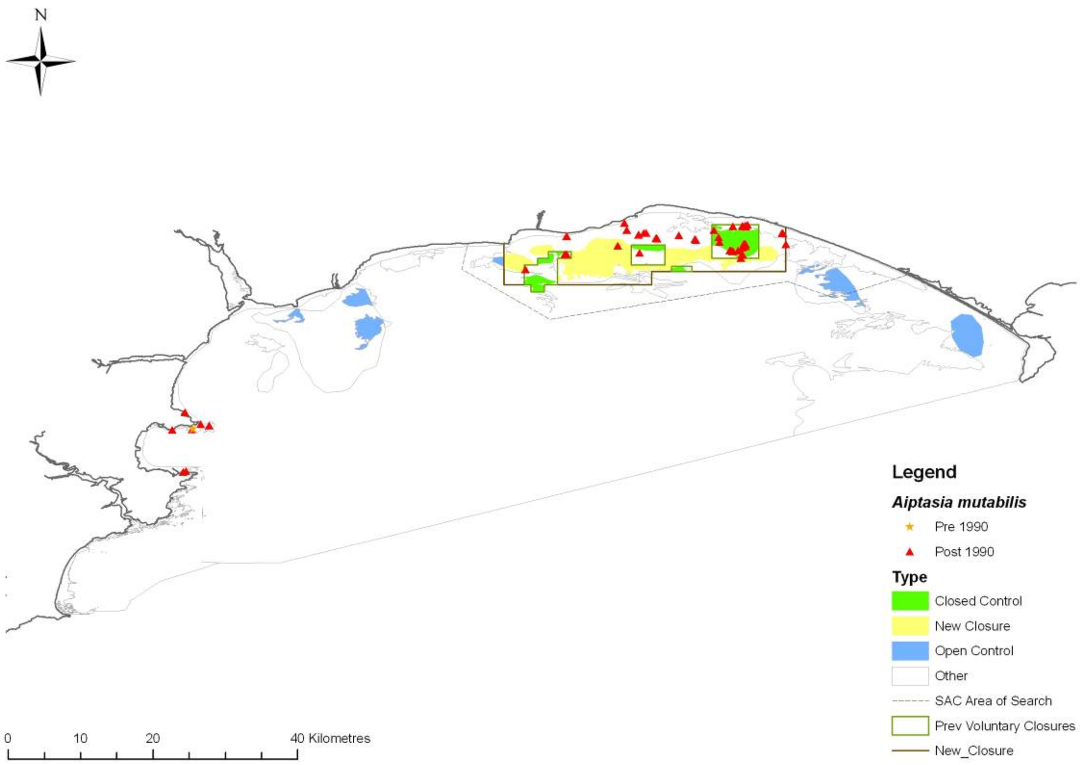
	Caryophyllia inornata	Southern cup coral	Cnidaria	6	8	9	11	Rare
	Hoplangia durotrix	Weymouth carpet coral	Cnidaria	0	1	1	1	Rare
	Isozoanthus sulcatus	Chocolate tiny anemone	Cnidaria	14	33	37	51	
	Dysidea pallescens	A massive sponge	Porifera	0	2	4	4	Rare
	Thymosia guernei	A massive sponge	Porifera	7	9	10	10	Scarce
	Adreus fascicularis	A branching sponge	Porifera	4	7	8	9	NIMF
	Leptopsammia pruvoti	Sunset cup coral	Cnidaria	5	5	6	6	BAP

Annex 7: Maps for each of the selected indicator species

Based on existing data to inform the subsequent survey and monitoring programme



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Pre 1990
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Open Control
Other
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10
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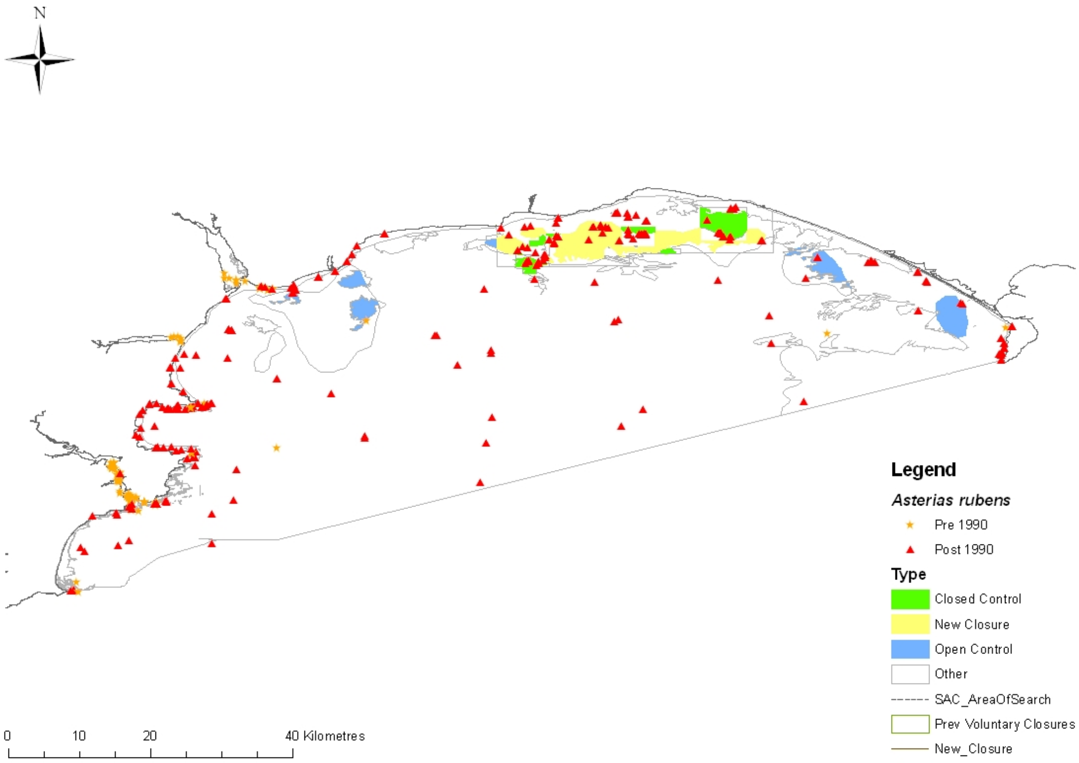
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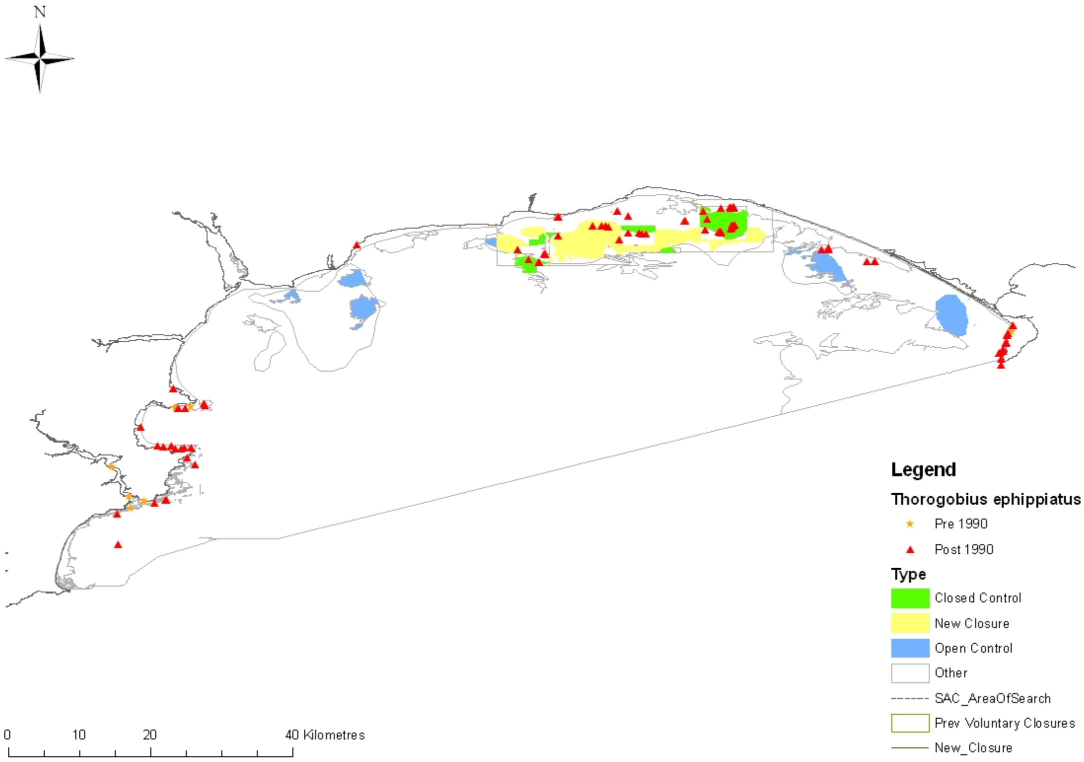
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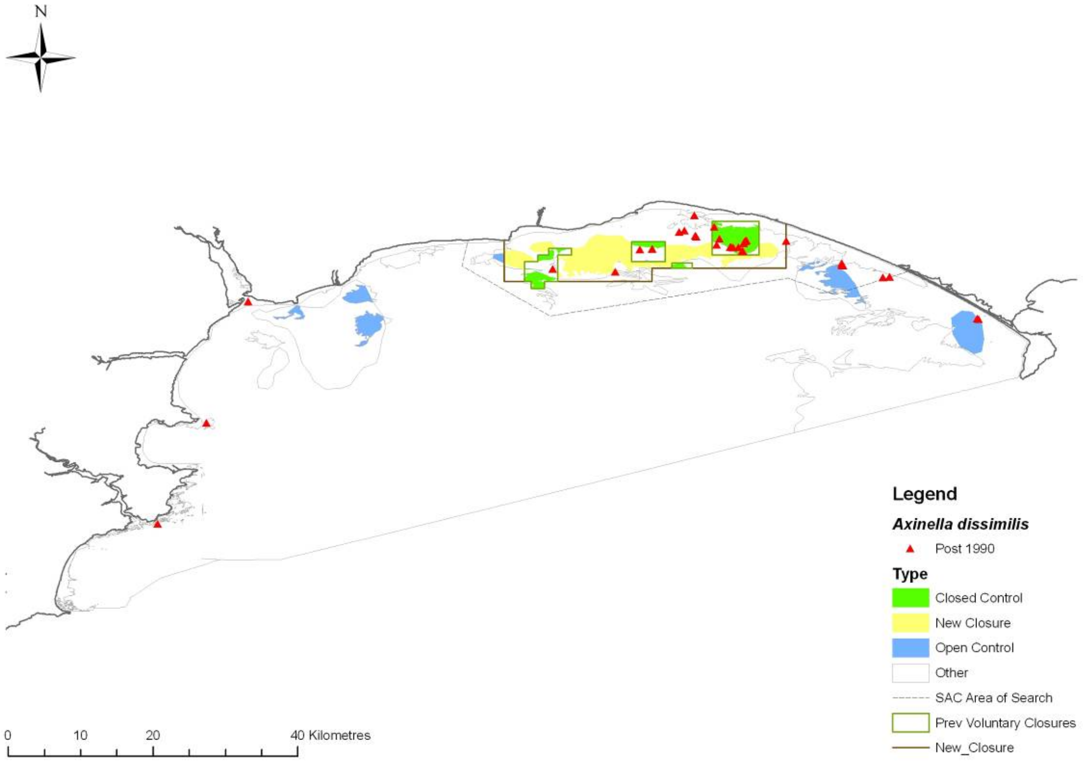
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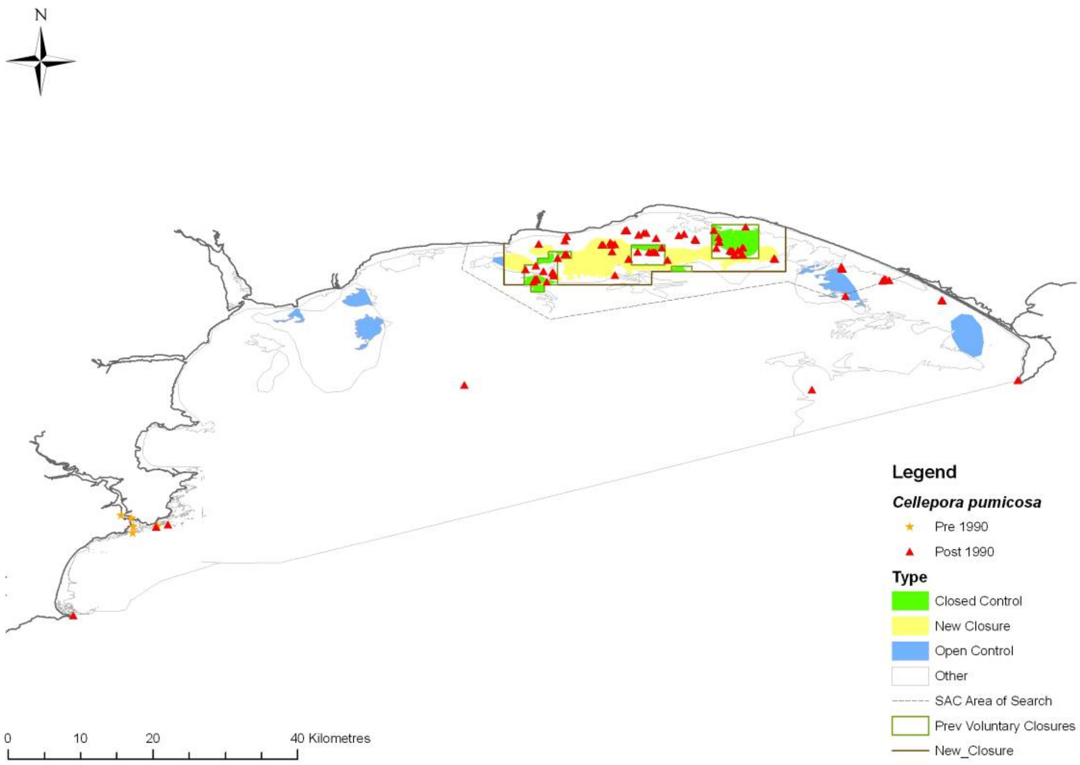
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Post 1990
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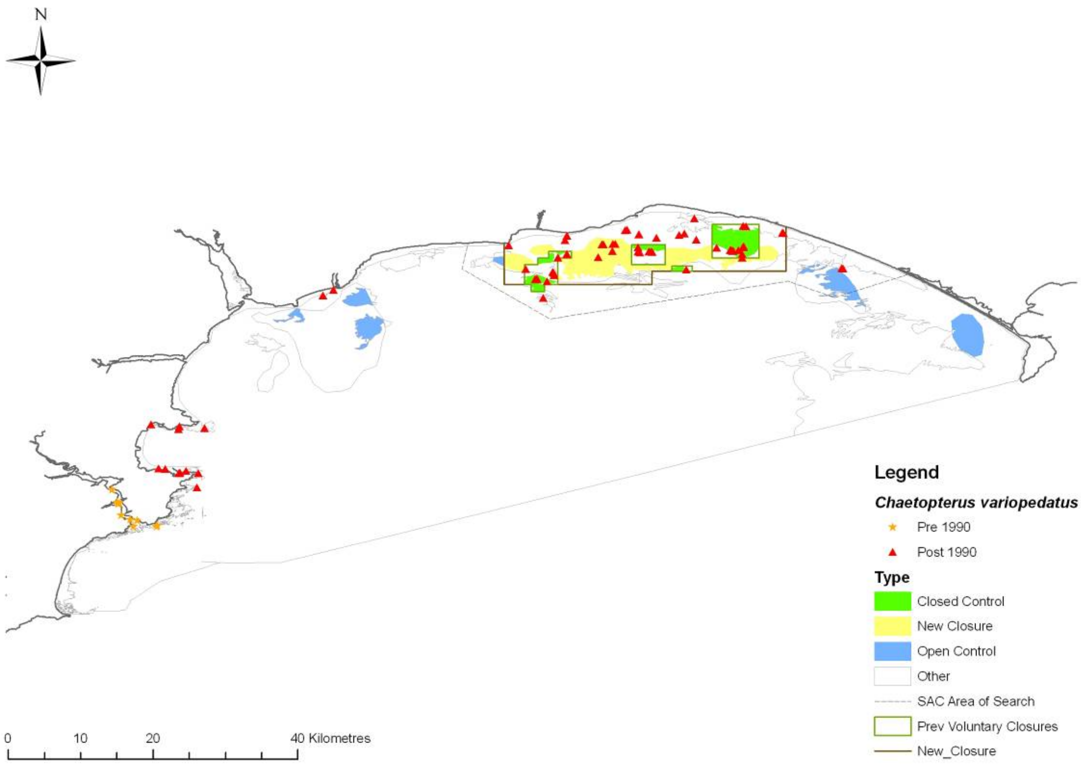
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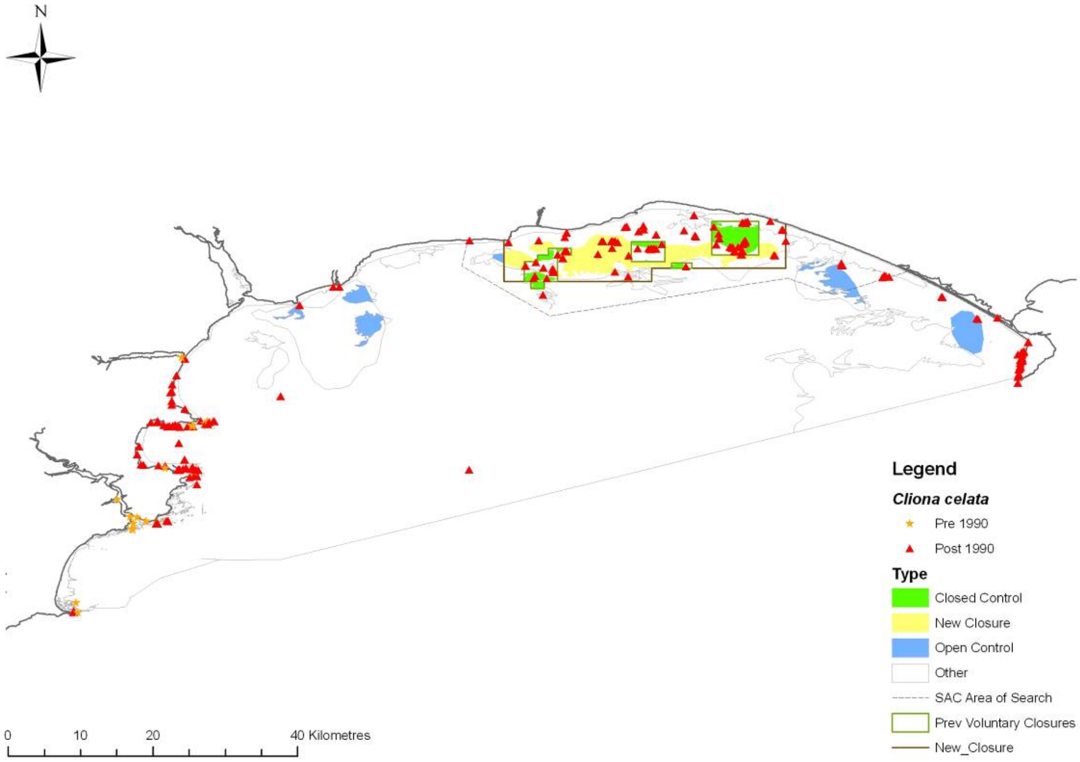
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Cliona celata
Pre 1990
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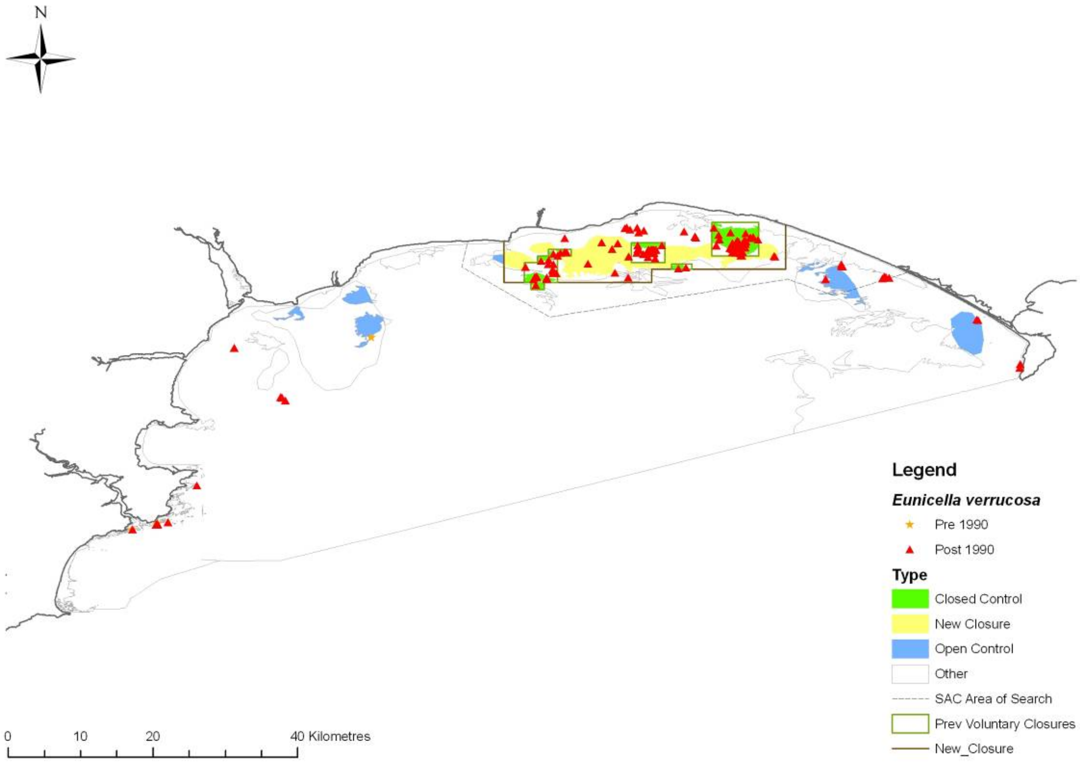
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Post 1990
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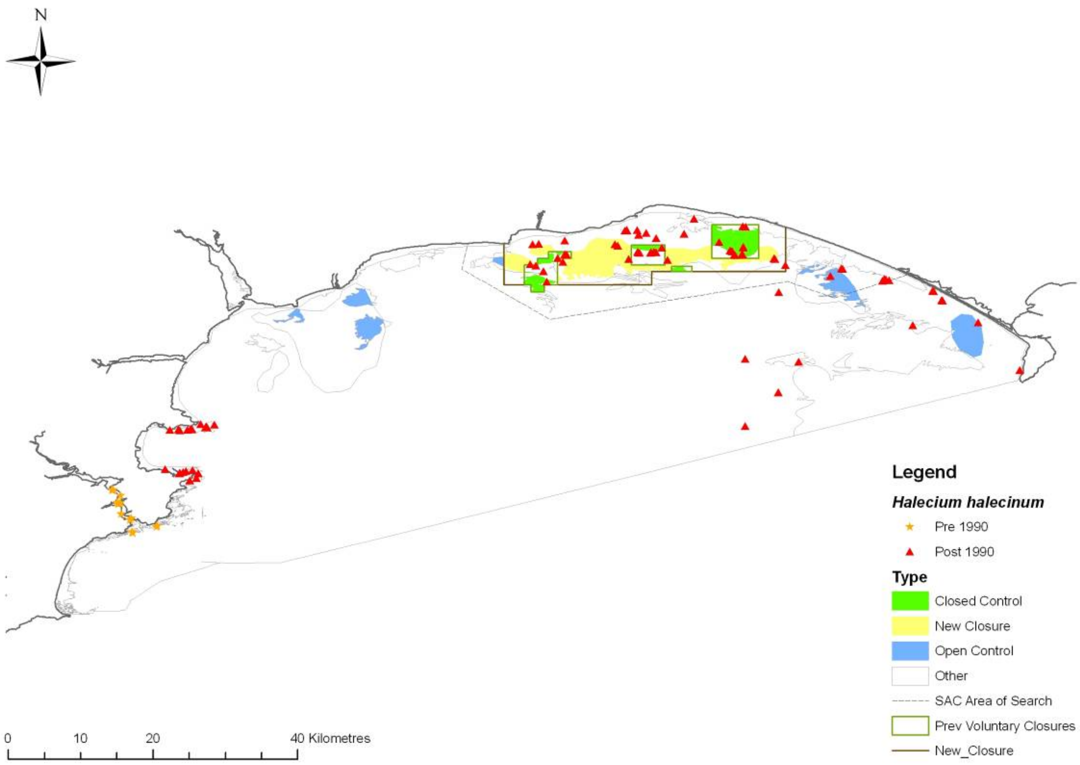
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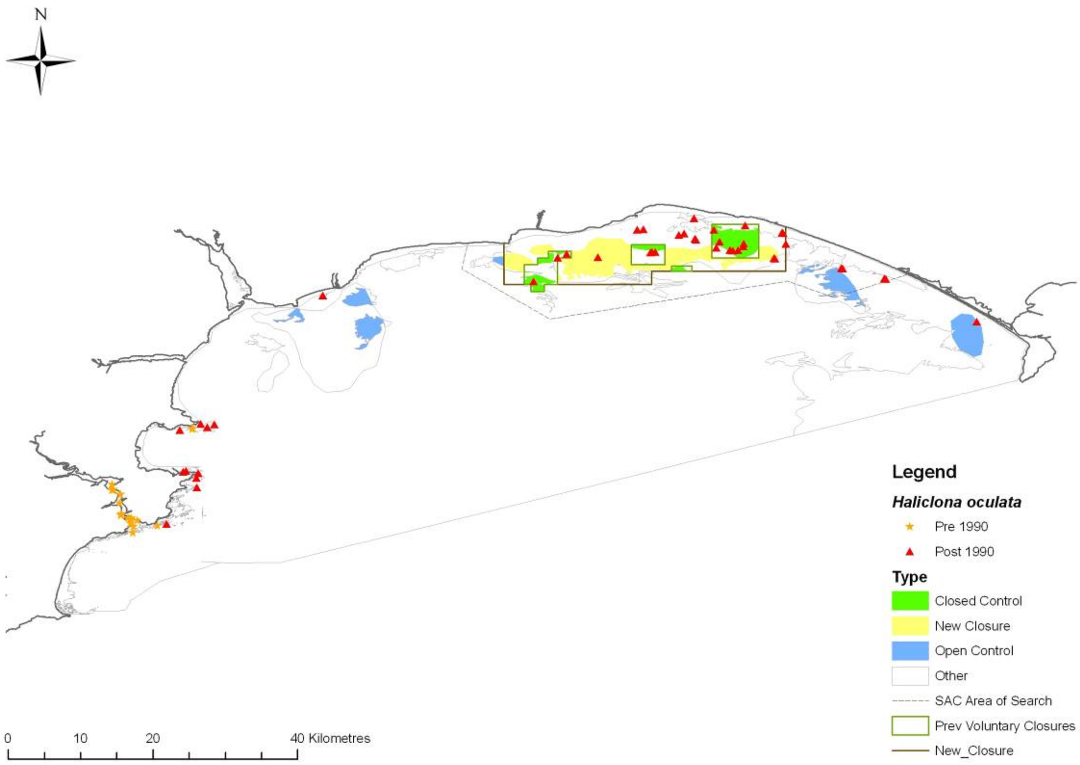
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Pre 1990
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Open Control
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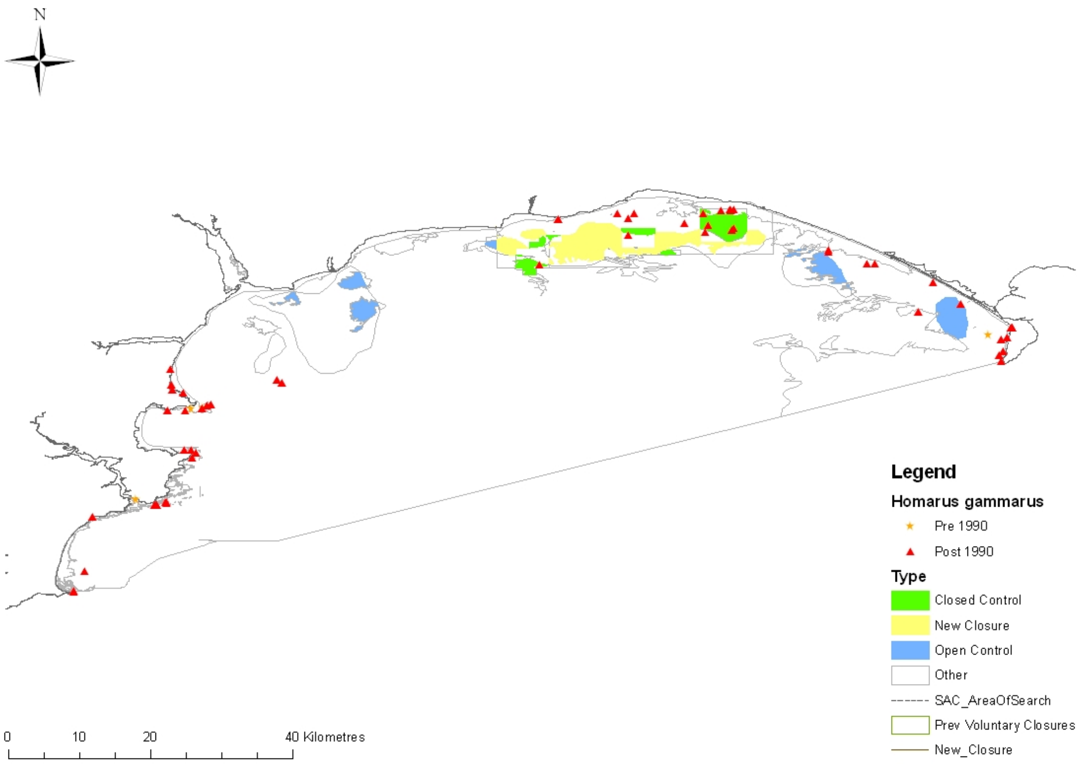
40 Kilometres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Homarus gammarus
Pre 1990
Post 1990
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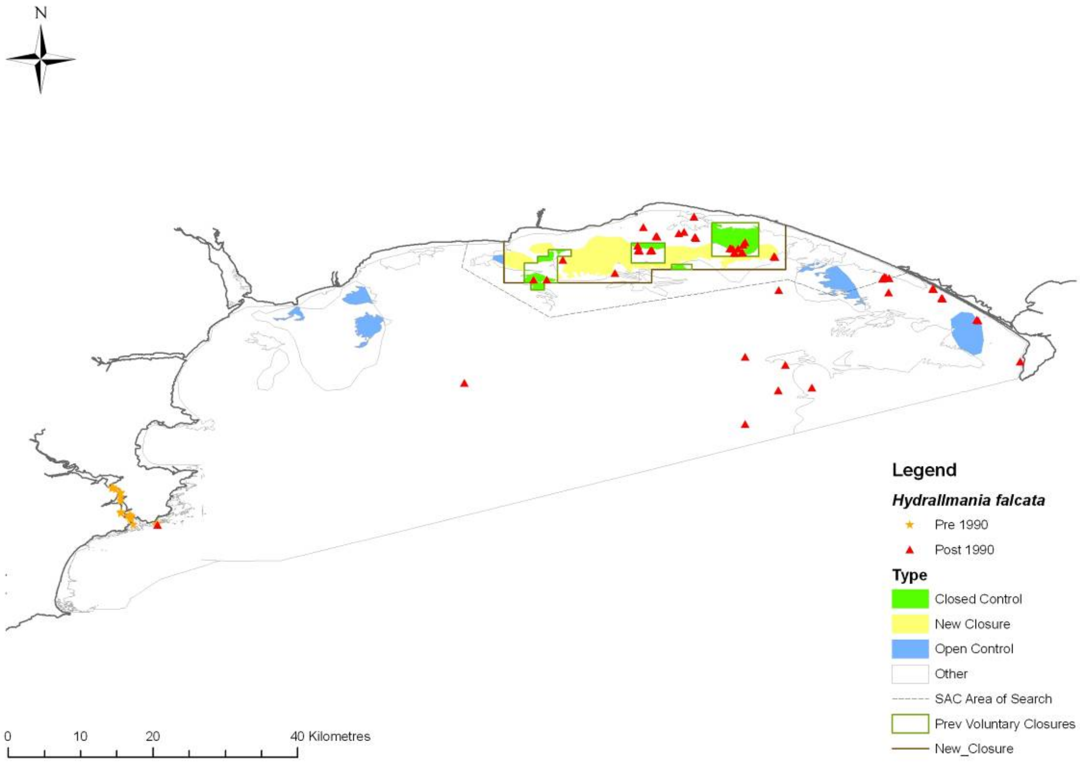
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Hydrallmania falcata
Pre 1990
Post 1990
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Open Control
Other
SAC Area of Search
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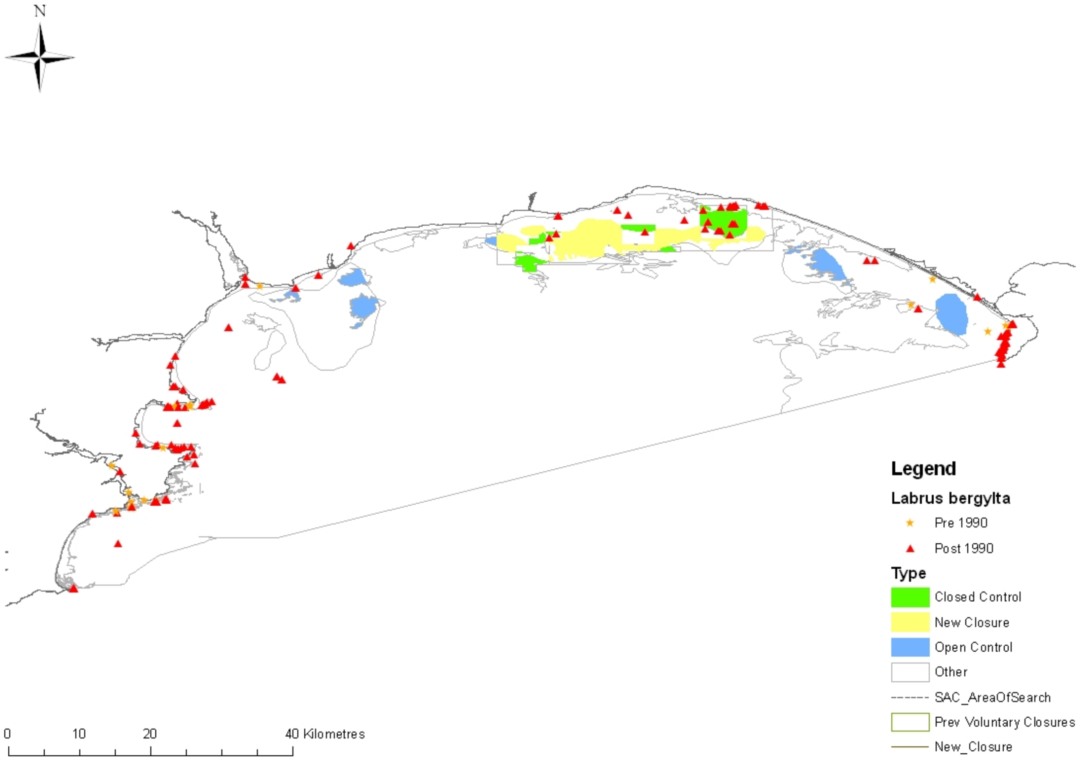
40 Kilometres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Pre 1990
Post 1990
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Open Control
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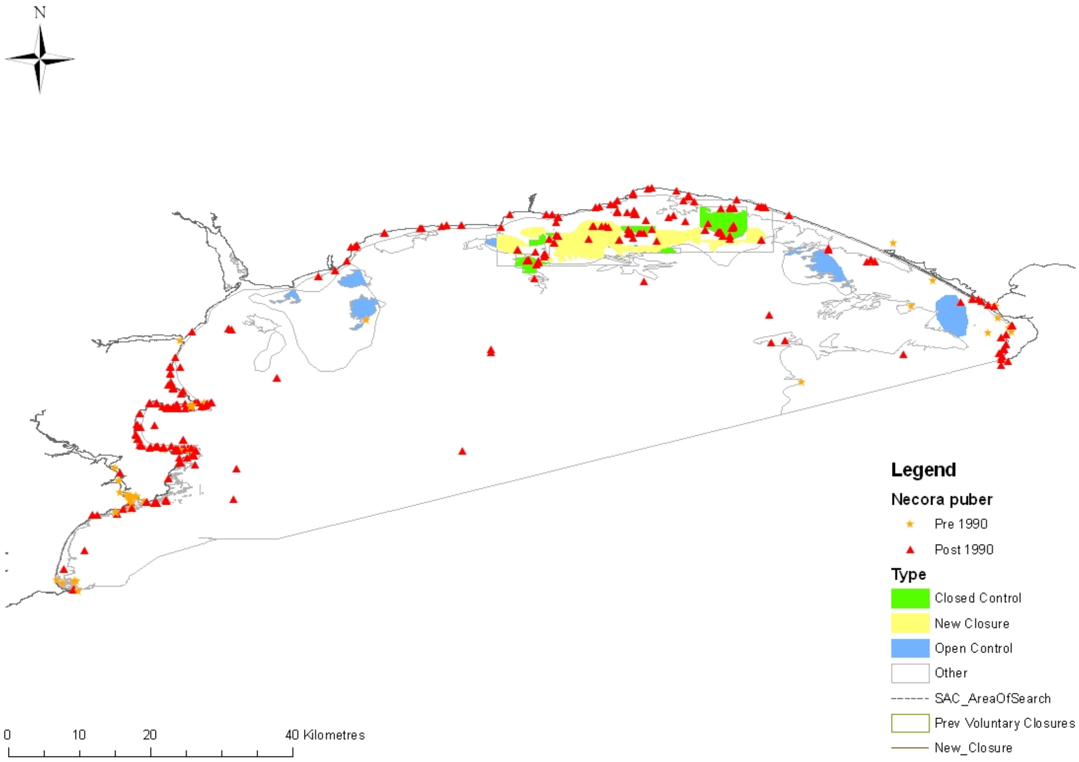
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Necora puber
Pre 1990
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Other
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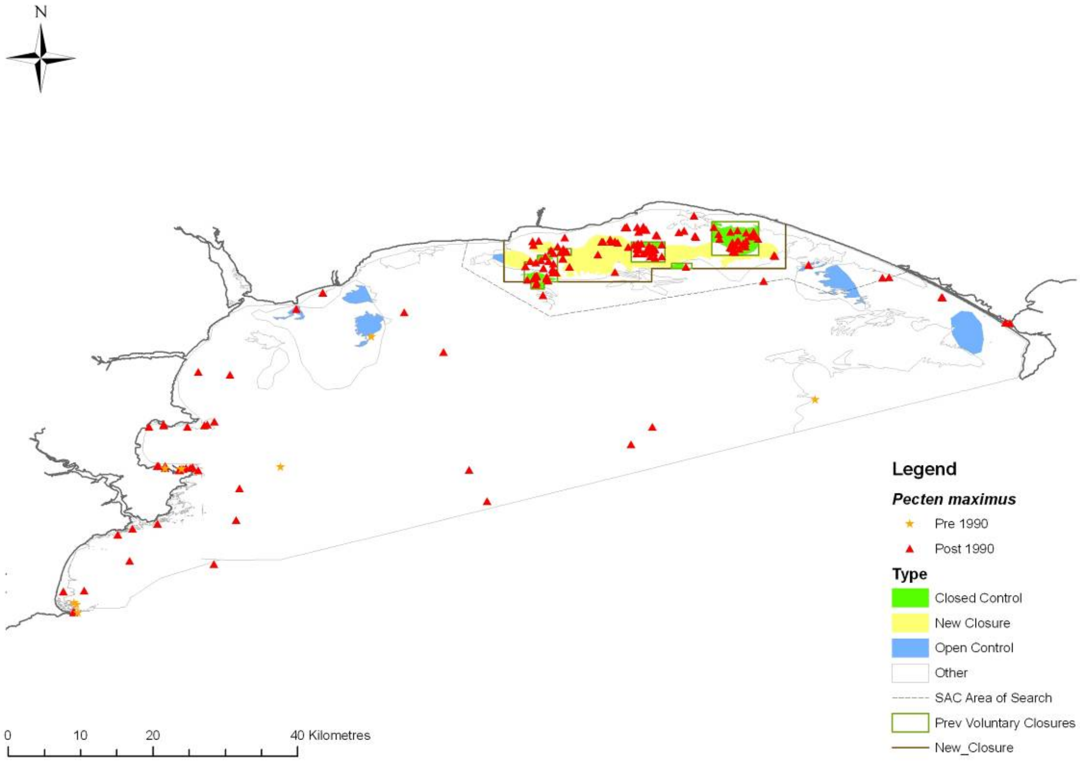
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Pecten maximus
Pre 1990
Post 1990
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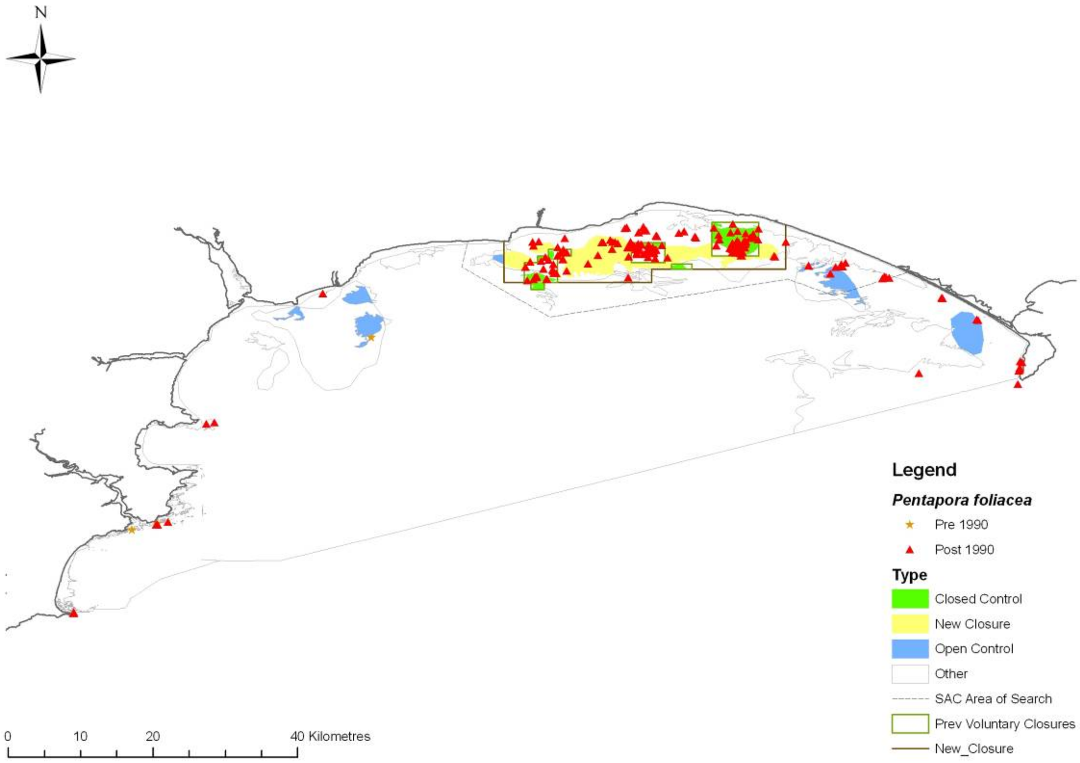
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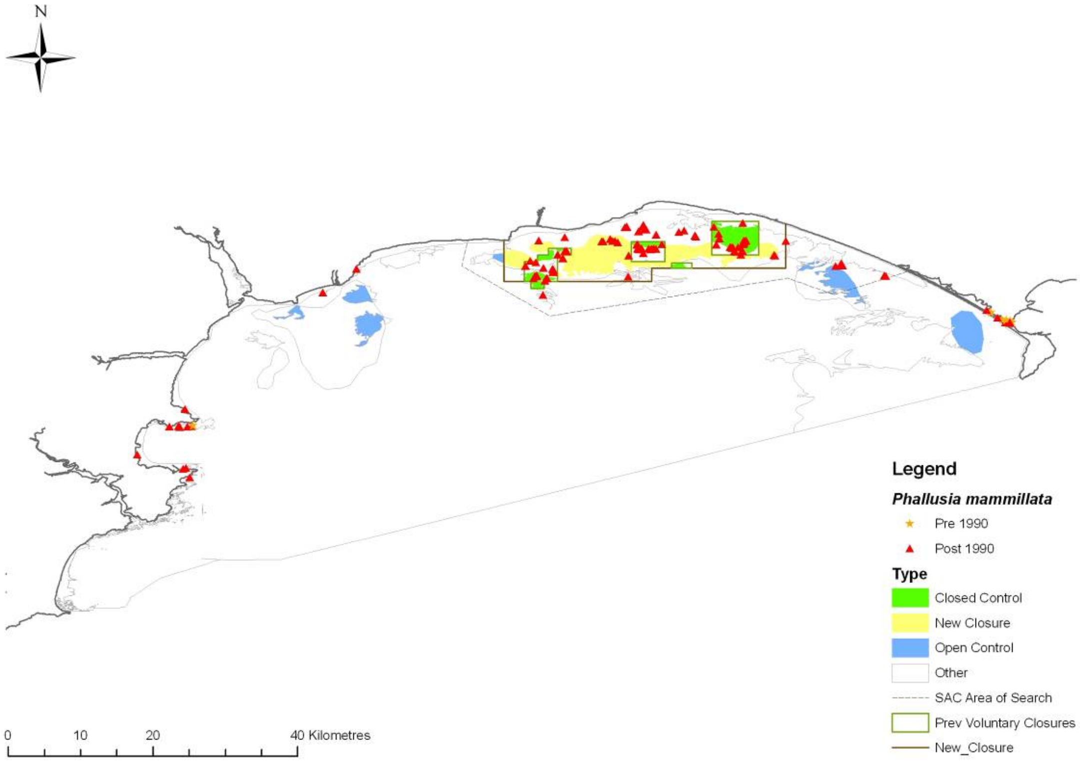
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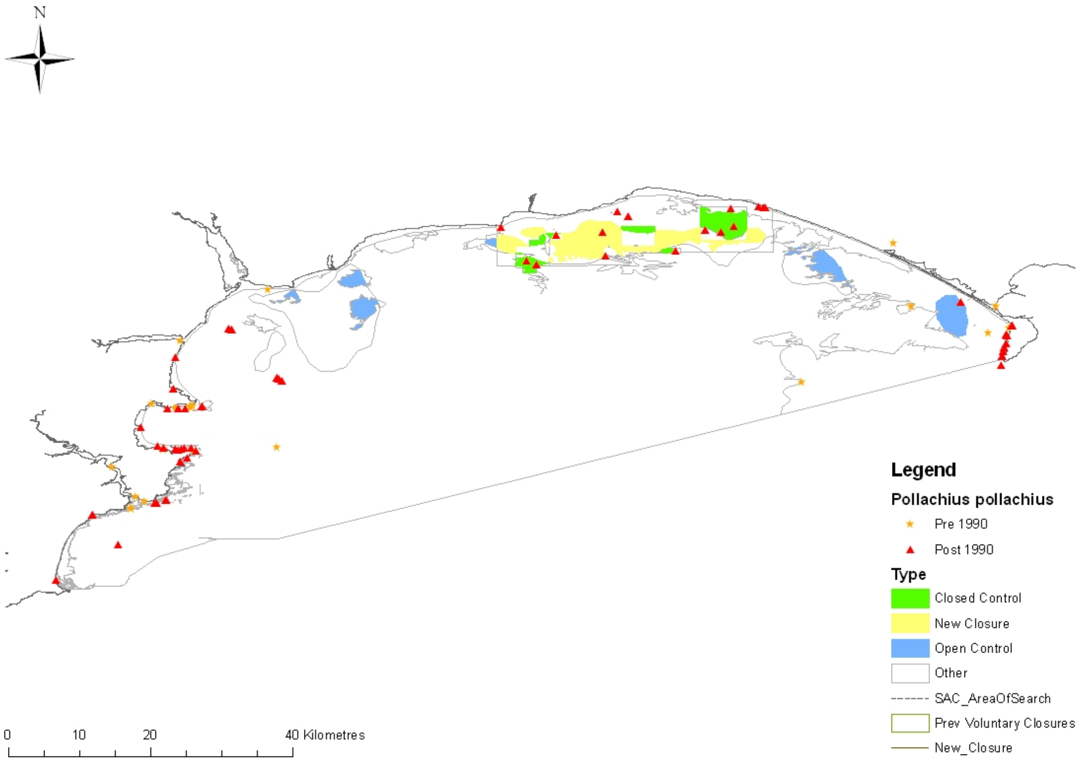
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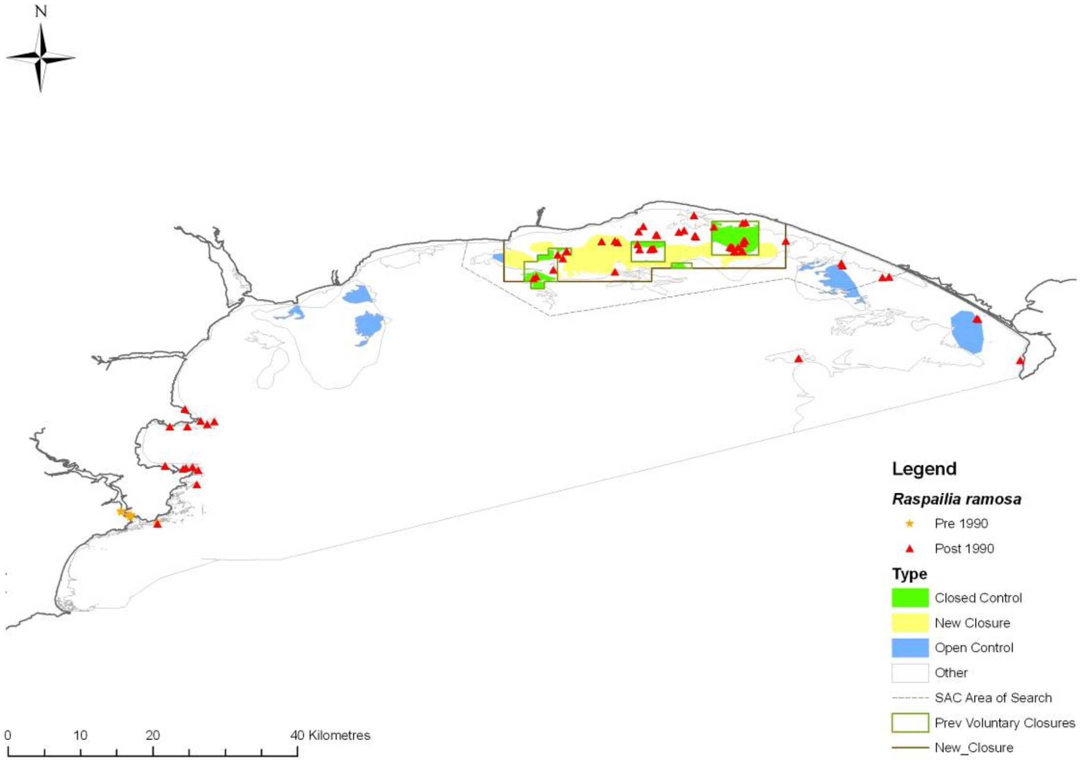
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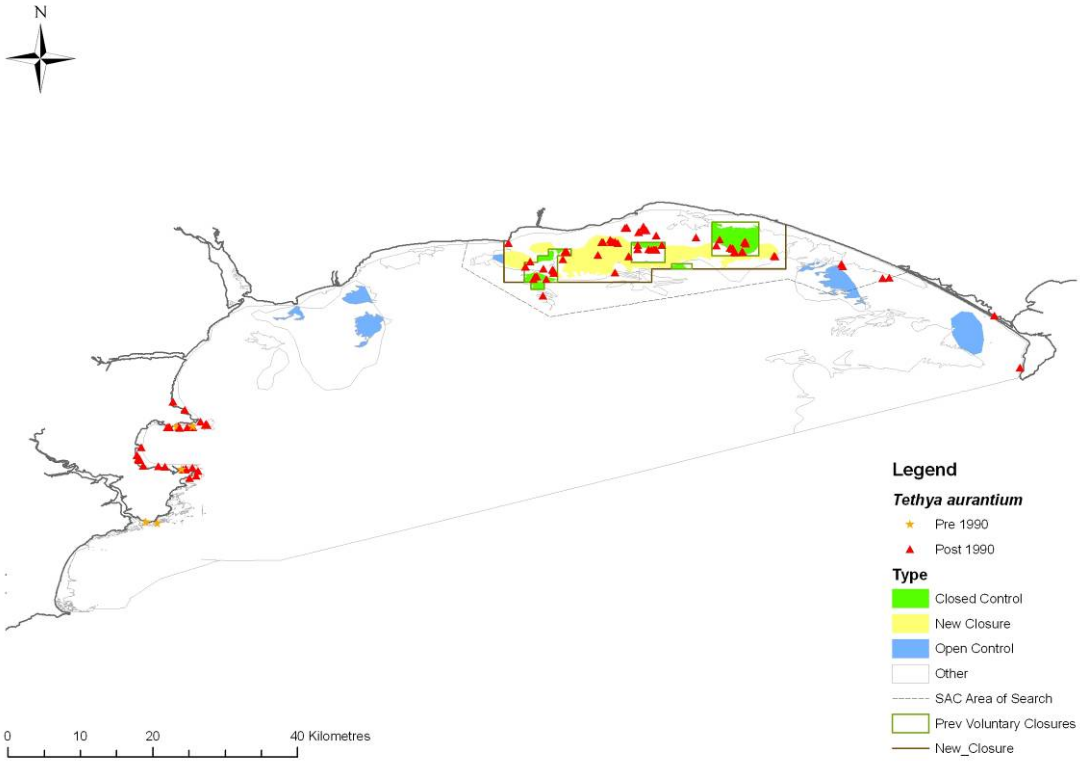
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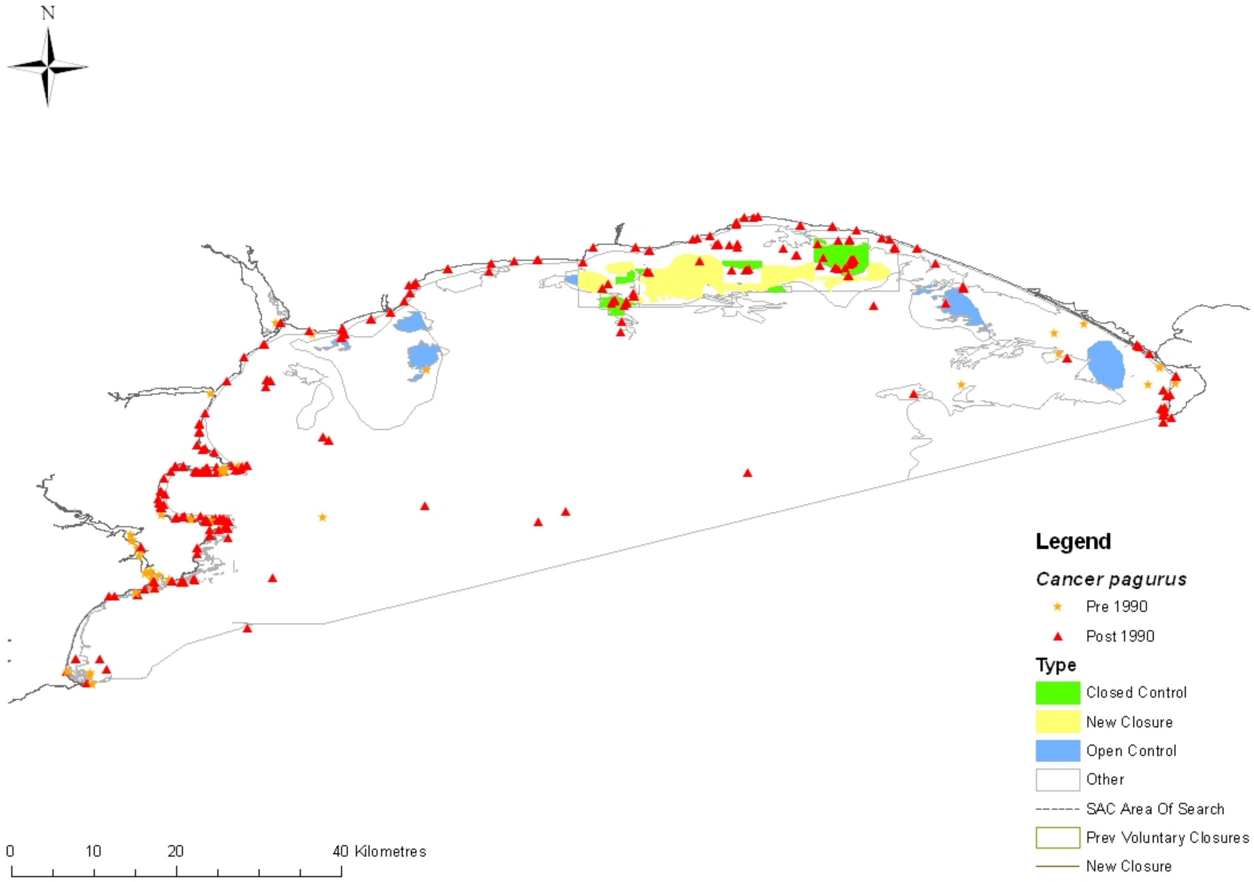
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10
20
40 Kilometres