



Benthic Impacts Tool

Your guide to using the MSC Benthic Impacts Tool to support assessments against the MSC Fisheries Standard v3.0

MSC Benthic Impacts Tool User Manual v1.0



PRIFYSGOL
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UNIVERSITY

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Responsibility for this manual

The Marine Stewardship Council is responsible for this user manual. This is a living document and will be reviewed on an ongoing basis. Readers should verify that they are using the latest copy of this (and other documents). Updated documents, together with a master list of all available MSC documents can be found on the MSC website.

Versions issued

Version	Effective date	Description of amendment	Affected section/page
1.0	October 2022	First User Manual	n/a

Glossary

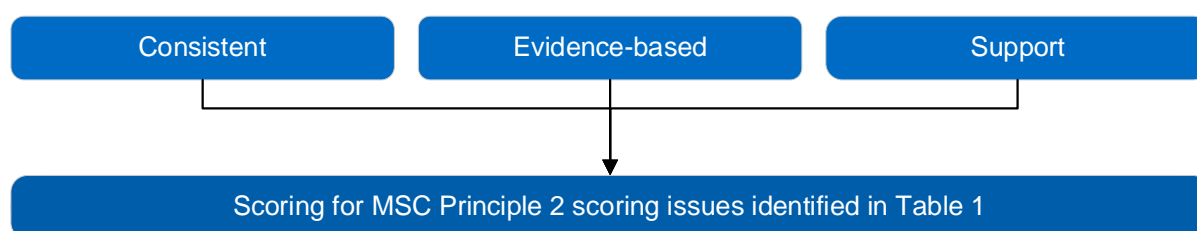
Term	Acronym	Definition
Automatic Identification System	AIS	An automatic tracking system that uses transponders on ships to record their location.
Depletion	d	The depletion rate, d , relates to the fraction of organisms killed by a single trawl pass (Hiddink <i>et al.</i> , 2017).
International Council for the Exploration of the Sea	ICES	An intergovernmental marine science organization, meeting societal needs for impartial evidence on the state and sustainable use of our seas and oceans.
Longevity		The maximum lifespan of a species in years.
Marine Stewardship Council	MSC	An independent non-profit organisation which sets a standard for sustainable fishing. Read more at www.msc.org
Performance Indicator	PI	The lowest level of sub-criterion of an MSC Criterion in the decision tree; the level at which the performance of the fishery is scored by the team.
Population model		A mathematical model which is applied to the study of population dynamics.
Recovery rates	r	The recovery rate, r , relates to the ability of an organism to recover after disturbance.
Recovery time		The time taken for a habitat to recover to full (100%) or 80% (MSC standard) carrying capacity after the cessation of fishing (Hiddink <i>et al.</i> , 2019).
Relative Benthic Status	RBS	The RBS of a grid cell indicates what proportion of the benthos has been removed. An RBS of 1 means there has been no depletion, a value of 0 means a grid cell is totally depleted.
Swept Area Ratio	SAR, year^{-1}	The number of times an area is swept by fishing gear. If a grid cell has a yearly SAR of 1 this means on average the whole cell is swept once per year. A SAR of 0.5 means that on average half of the cell is swept once per year.
Vessel monitoring system	VMS	A satellite-based monitoring system which provides data about the location, course and speed of vessels.
Vulnerable Marine Ecosystems	VMEs	These are habitats that have been designated as such by a competent authority, based on the VME criteria as defined in the International Guidelines for the Management of Deep-sea Fisheries in the High Seas

1 Introduction

Bottom trawl fisheries impact sedimentary habitats to various degrees. The Marine Stewardship Council (MSC) Fisheries Standard requires that in order to be certified, fisheries must not cause serious and irreversible harm to habitat structure, biological diversity, abundance and function.

The Benthic Impacts Tool is an assessment and decision support tool and aims to aid the user (for example, a fishery consultant, fishery client, conformity assessment body or management authority) to quantify the impact of the bottom towed fishing activity on sedimentary habitats.

Main aims of the MSC Benthic Impacts Tool



This User Manual aims to support the user through the tool, offering a consistent evidence-based approach for the scoring of mobile bottom gears within Principle 2 scoring issues (as set out in Table 1).

Table 1. Scoring issues within the MSC Fisheries Standard for which the MSC Benthic Impacts Tool can be used to inform scoring

Version of MSC Fisheries Standard	Performance Indicator (PI)	Scoring Issue (SI)
Fisheries Standard v2.01	2.4.1	a
Fisheries Standard v3.0	2.3.1	a

1.1 Tool overview

Data on the spatial distribution of fishing activity and benthic habitats are used to predict the relative benthic status (RBS) of habitats, and a predicted recovery trajectory over time if fishing were to cease. See the tool schematic below, which details the questions the tool is addressing and required data input by the user (Figure 1).

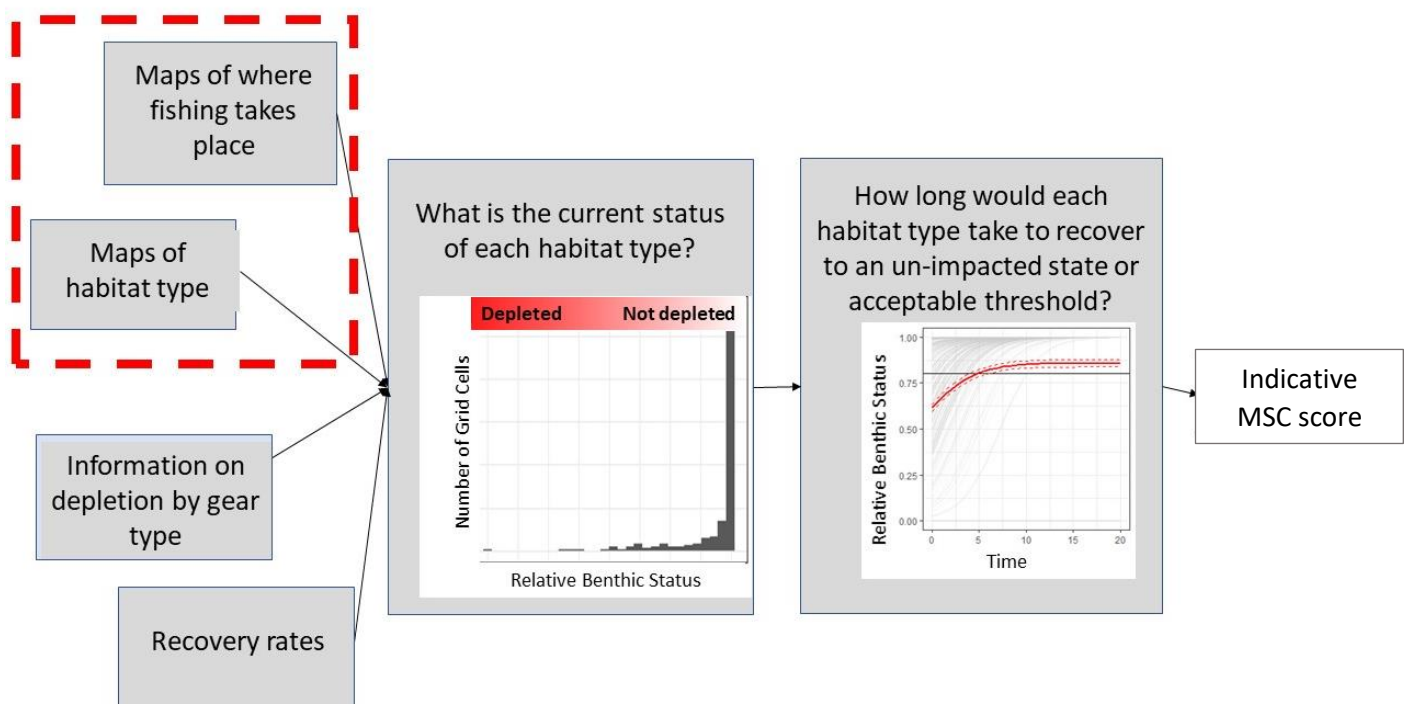
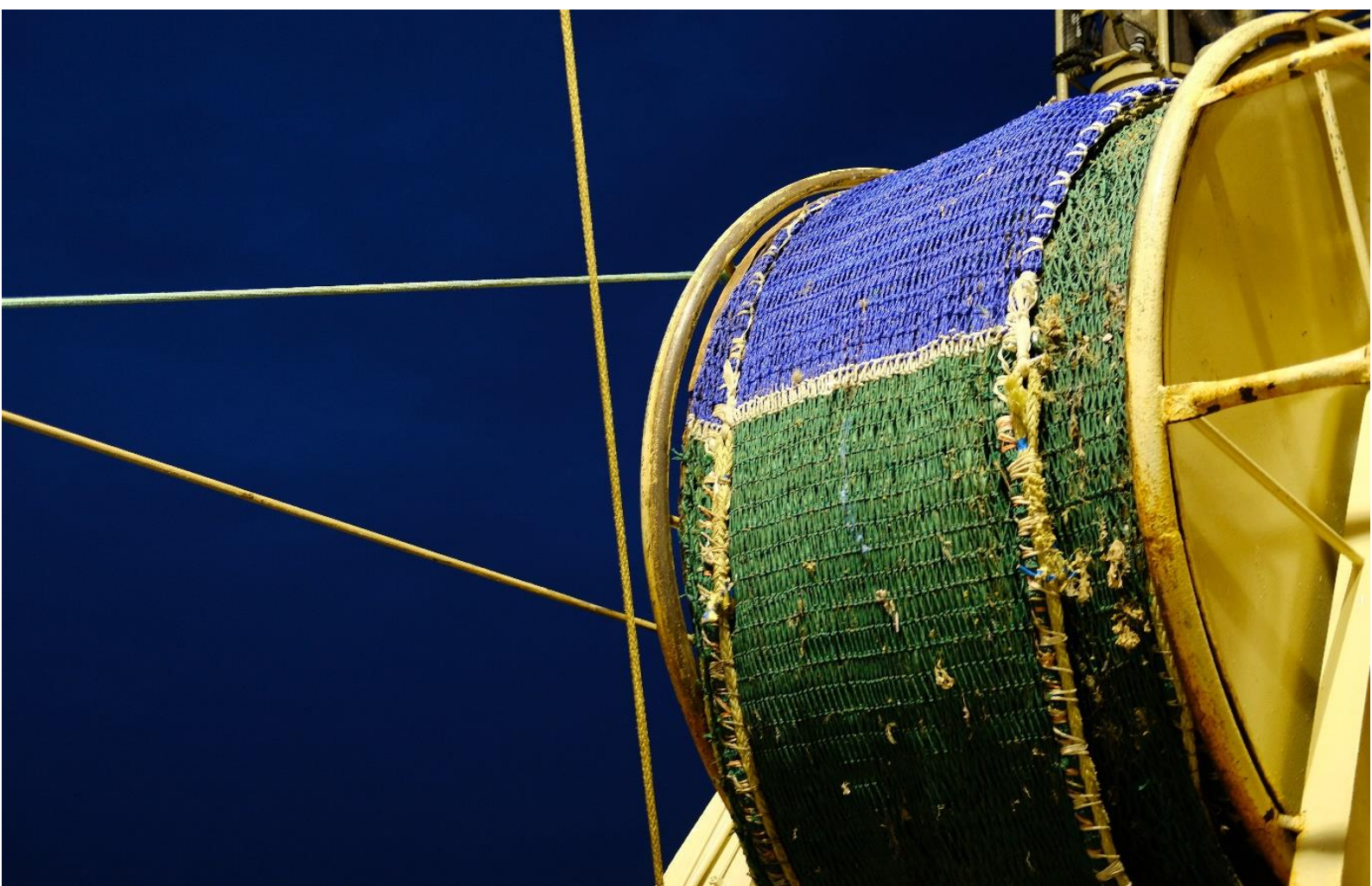


Figure 1. Schematic of the MSC Benthic Impacts Tool. Essential input is highlighted within the red dashed box.

2 The science - assessment framework

The Benthic Impacts Tool is based on a wealth of scientific information, which has been published in peer-reviewed journals (Hiddink *et al.*, 2017; Pitcher *et al.*, 2017; Hiddink *et al.*, 2019; Rijnsdorp *et al.*, 2018). The method incorporated in the tool has a relatively low demand for data layers, and combines insights based on ecological theory with the most robust available parameter estimates.

In this section, we highlight the main areas of research that were combined to build the tool's framework. For further information on the science, please contact the [helpdesk](#) (Section 15) or search for the publications highlighted in the references.



2.1 Population model

RBS is derived by solving the logistic population growth equation for the equilibrium state (Pitcher *et al.*, 2017). The effect of trawling depends on both the trawl mortality (depletion d) and the recovery rates (r) of the benthic community. In the below example (Figure 1) trawling occurs once a year, and after trawling recovery of the RBS occurs.

This tool uses a model that estimates RBS and its recovery. This model provides an opportunity for quantifying the impacts of bottom-towed gear on sedimentary environments. The approach has a low demand for data, and only requires maps of fishing effort and habitat type and their sensitivity. The RBS model parameters quantify the interaction between the gear and seabed biota (i.e. depletion rates, Section 2.2) and the recovery dynamics of this biota (i.e. recovery rates, Section 2.3-2.4). The depletion rates have been quantified by meta-analysis for typical gear types (i.e. otter trawls, beam trawls and dredges) and broadscale sediment types (i.e. mud, sand and gravel), while recovery rates have been estimated in relation to the longevity of benthic biota. Therefore, the RBS of impacted habitats depends on the impact rate (depletion by gear), the recovery rate (of species within habitat) and the exposure to trawling (Pitcher *et al.*, 2017). The outcome of the Benthic Impacts Tool provides an estimate of benthic status relative to an unimpacted habitat baseline (see Section 2.7 for the [assumptions and limitations](#) posed by the RBS model).

In the Benthic Impacts Tool, a grid is generated for the assessment, and values of fishing effort are assigned per grid cell within the area under assessment. An RBS score is calculated per habitat type per grid cell and the distribution of RBS and the mean value per habitat is generated for the assessment. Finally, the recovery trajectories for each habitat if fishing were to cease were estimated, leading to an indicative MSC score.

The following sections (2.2 – 2.4) will break down the above RBS model into the required components.

Relative Benthic Status

$$\text{RBS} = B/K = 1 - F d/r$$

That is,

$$\text{RBS} = 1 - \frac{\text{Fishing Effort} \times \text{Depletion Rate}}{\text{Recovery Rate}}$$

Pitcher *et al.* (2017)

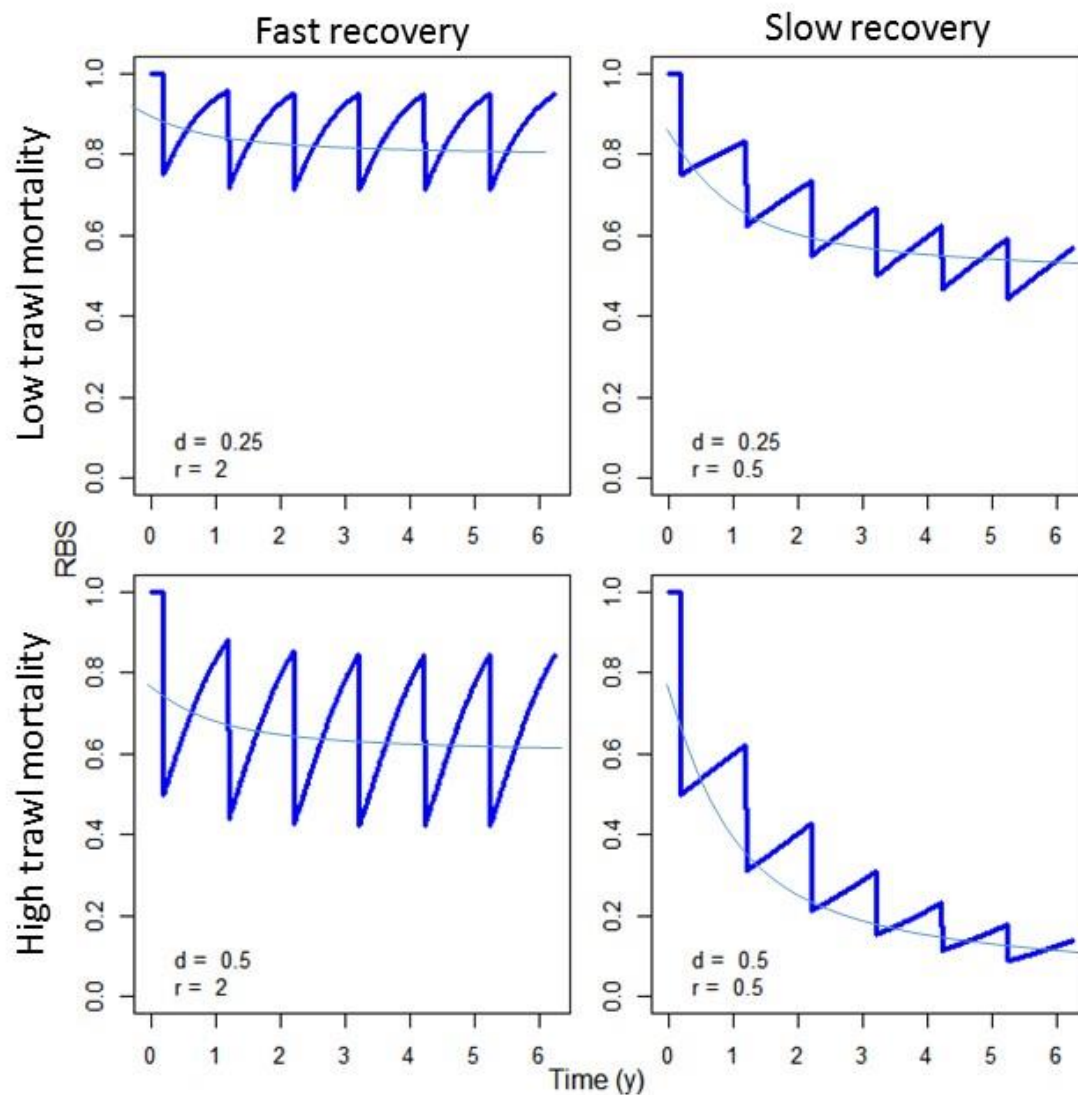


Figure 2. A range of hypothetical plots to depict what happens to RBS over time based on high/low trawl mortality and fast/slow recovery.

2.2 Depletion

The depletion rate, d , relates to the fraction of organisms killed by a trawl pass (Hiddink *et al.*, 2017). Depletion is gear specific, as different gear types have different effects on the seabed (Figure 3).

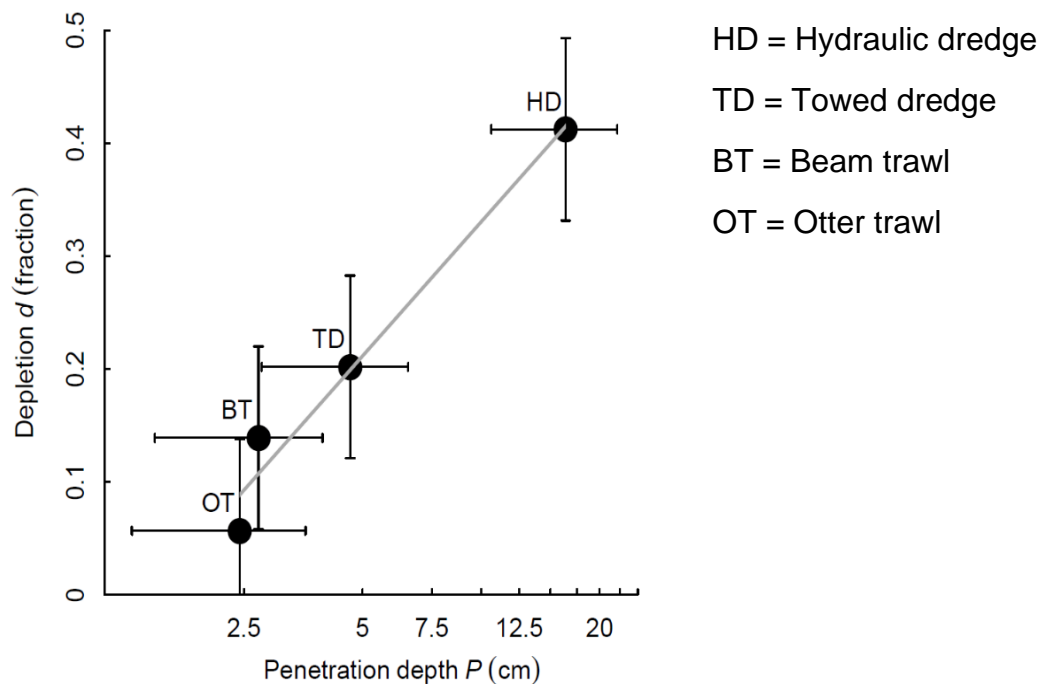


Figure 3. The relationship between the penetration depth (P) and depletion (d) of macrofaunal community biomass and numbers caused by a single trawl pass for different trawl gears (means \pm SD) (Hiddink *et al.*, 2017).

The tool provides default gear depletion rates (for otter trawl, beam trawl, dredges, and seines) that can be used for an assessment. These depletion values are based on multiple meta-analyses which provide a global standard for typical gear types (hydraulic dredge, towed dredge, beam trawl and otter trawl) and simple sediments (mud, sand and gravel) (Hiddink *et al.*, 2019, Sciberras *et al.*, 2018 and Pitcher *et al.*, 2022). The meta-analyses synthesise data from all available and relevant trawling studies and provides a systematic review of the current field of evidence to parameterise the RBS model (Hughes *et al.*, 2014). Gears that penetrate deeper into the sediment have a significantly larger impact on the benthic community than those that penetrate less (Sciberras *et al.*, 2018).

Because the penetration into the sediment depends on the sediment type, depletion is sediment specific, thus in the Benthic Impacts Tool we offer users the opportunity to define the main sedimentary type of their habitat e.g. mud, sand or gravel (Sciberras *et al.*, 2018), which updates the default gear depletion rate to a sediment specific depletion rate. As highlighted by Figure 2, the penetration depth of the gear type positively correlates with the depletion rate of the gear type, therefore the penetration depth acts as a proxy for the depletion rate. Users may input their own gear-specific depletion rate, or gear-specific penetration depth, if they have sufficient evidence to support the use of this value. The relationship between gear penetration depth and depletion rate is defined by Pitcher *et al.* (2022) and used to convert a user-provided penetration depth to a depletion rate.

2.3 Recovery rate

The effect of bottom trawling on biota increases with longevity because the recovery rate decreases (Hiddink *et al.*, 2019). The longevity of a species is the maximum potential life span (Hiddink *et al.*, 2019). The impact of bottom trawling is 2-3 times greater on long-lived species (>10 years) than on species living between 1 and 3 years. Recovery is closely related to the inverse of longevity for benthic fauna (Hiddink *et al.*, 2019). Longevity can therefore be considered a suitable proxy for habitat sensitivity and thus the estimated recovery rates for communities (Figure 4).

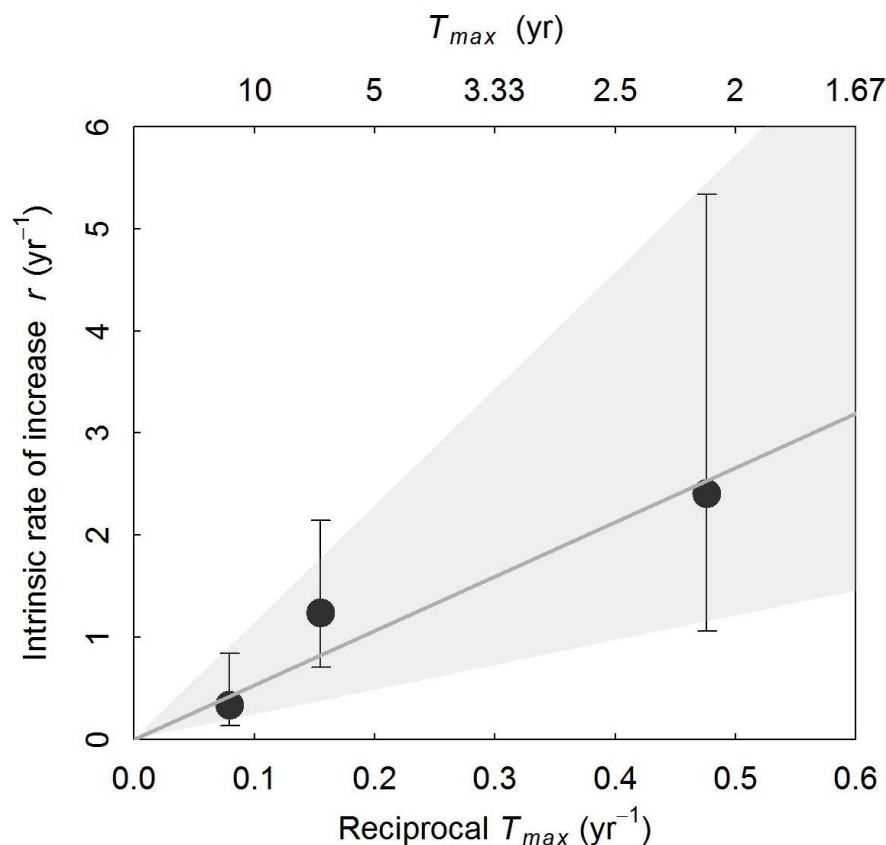


Figure 4. Relationship between r and longevity T_{max} estimated from gradient studies ($r = 5.31$ / longevity, $R^2 = 0.96$, $F_{1,1} = 73.9$, $P = 0.013$). The points and error bars are r estimates and their 95% confidence intervals, while the solid line is the fitted regression line. The shaded areas indicate the regression fits through the upper and lower confidence intervals of the data (upper: $r = 11.44$ / longevity, lower: $r = 2.43$ / longevity) (Hiddink *et al.*, 2019).

Information on the longevity distribution of unfished communities within habitats may not always be available. A meta-analysis based on comparative studies of trawling impacts at a global scale highlighted the lower confidence interval estimate of recovery (r) for whole benthic communities, with a typical longevity distribution, to be 0.42 (Hiddink *et al.*, 2017). Therefore, the value 0.42 is used as the default recovery rate within the tool for assessments that do not have specific longevity or recovery rate estimates (Hiddink *et al.*, 2017).

Also note that the value(s) obtained for r cannot be modified by the user, as these values are calculated based on the latest peer-reviewed research and considered the most appropriate for use within the Benthic Impacts Tool.

2.4 Longevity

Estimates of the longevity of species within a community help determine the sensitivity of the habitat. It is known that species which are long-lived tend to be sensitive to bottom trawling impacts, whilst species which are short lived are more resilient to bottom trawling impacts (Figure 5 and Hiddink *et al.*, 2019). The response of biota to trawling depends on their population recovery rate, r , also known as the maximum population growth rate. Longevity can be used as a proxy to determine the recovery rate of biota, as recovery and longevity significantly correlate (Figure 4 and Hiddink *et al.*, 2019).

Within the Benthic Impacts Tool there are three options for the user to determine the estimate of r within the RBS model, these are by:

- I. Using the default recovery rate of 0.42
- II. Inputting a modelled longevity distribution
- III. Inputting species longevity data (see Section 6.4 [recovery rates](#) for detail).¹

¹ Note the most accurate assessment of the impact of trawling on the seabed would be obtained by inputting specific longevity distribution parameters into the tool.

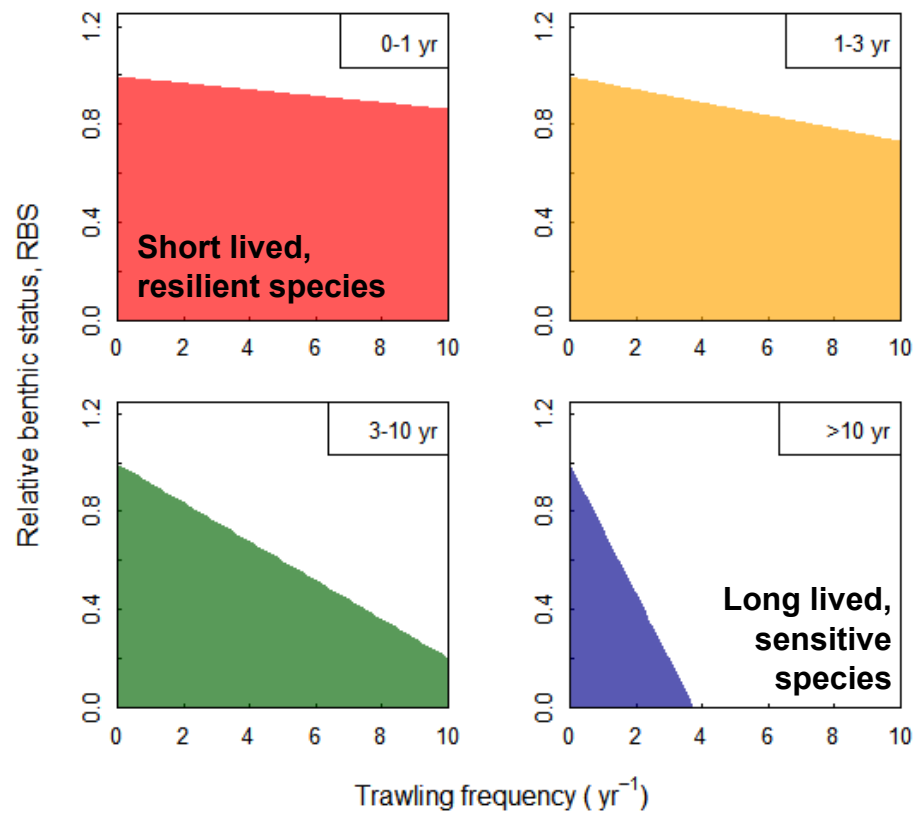


Figure 5. Each plot highlights an age category (<1, 1-3, 3-10 and >10 years) within a community. The Relative Benthic Status decreases as the trawling frequency per year increases, with different rates of change occurring per age category.

2.5 Habitat sensitivity

The distribution of longevities can then be used to estimate the sensitivity of a habitat to bottom-towed fishing gear. A benthic community with many long-lived species will have a lower mean r than a community with many short-lived species and will therefore be more sensitive to the same level of trawling intensity.

The effect of trawling is proportional to the ratio of depletion over recovery, d/r . A lower r will result in a higher impact at the same intensity of trawling. A habitat will be sensitive to trawling if a large fraction of the biomass of the community, in an untrawled community, is made up of long-lived species with a low r (Figure 6a). A habitat will be less sensitive i.e. resilient (Figure 6b) to trawling if a large fraction of the biomass of the community, in an untrawled community, is made up of short-lived species with a high r .

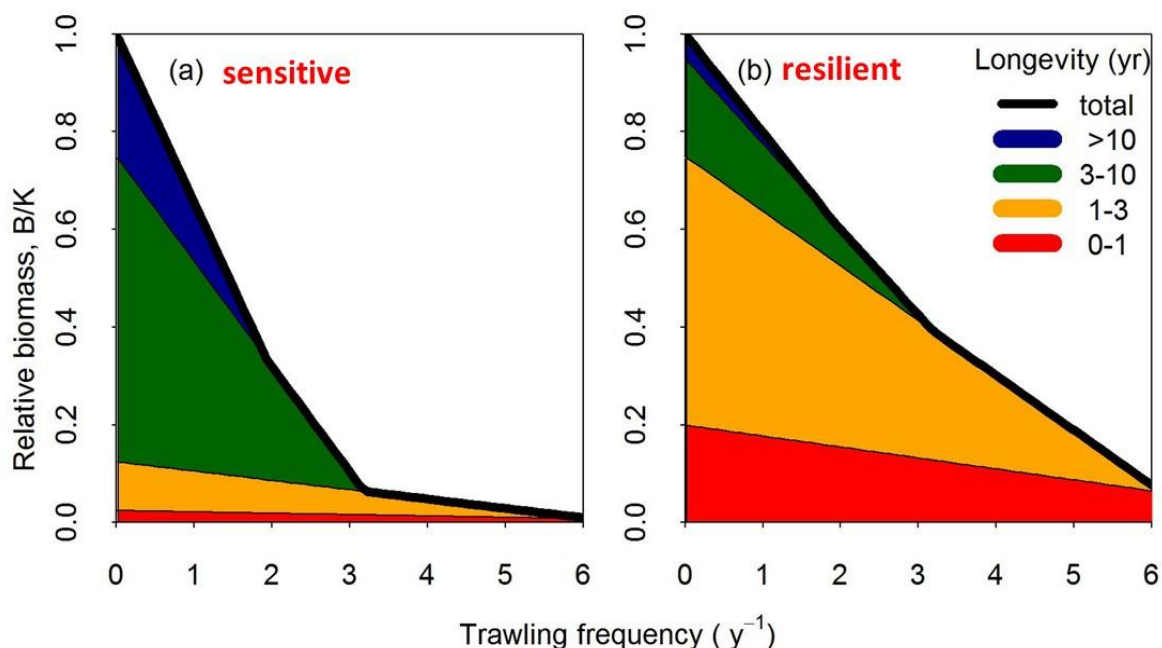


Figure 6. An example of how the longevity distribution of a benthic community under no trawling pressure affects the response of total community biomass to bottom trawling.

2.6 Indicative MSC scores

The scoring within the MSC Fisheries Standard is based on the probability that the state of each habitat in the assessed area will not recover to 80% of its unfished value within 20 years if fishing were to stop. The highest score, SG100, is awarded when the probability of the habitat failing to recover is <20%. SG80, is awarded when the probability is <30%. SG60, is awarded when the probability is <40%. If the probability of the habitat failing to recover to 80% of its unimpacted level is >40%, the Unit of Assessment will fail on PI 2.3.1 (Table 2). These scoring guideposts provide a minimum recovery trajectory, and the indicative score generated by the tool should be considered in combination with other available information and to inform the scoring of a Unit of Assessment.

The probability distribution of the RBS scores after 20 years of recovery is estimated based on the distribution of both d values and r values that went into the assessment, as described in sections 2.2 and 2.3. The distribution of d and r values was derived from the uncertainty around these parameters when they were estimated based on empirical data.

Table 2. Probability required at each scoring guidepost for the relevant performance indicators in the MSC Fisheries Standard (FS) v2.01 and v3.0 (MSC, 2022).

Performance indicator(s)	Probability requirement at SG60	Probability requirement at SG80	Probability requirement at SG100
2.3.1 (FS v3.0) & 2.4.1 (FS v2.01)	“Unlikely” = < 40th %ile	“Highly unlikely” = < 30th %ile	Evidence of “highly unlikely” = < 20th %ile

2.7 Assumptions and limitations

The tool outlined in this manual is based on a model, and the outputs are only as good as the inputs (i.e. the data provided, the simplifications, assumptions and parameter estimates used). The logistic population growth model that is used is one of the simplest ecological models developed and is used here because of this simplicity. The simplicity makes the approach transparent and allows the robust estimation of parameters. More complex approaches require more data, making complex models less feasible for use in assessments of a wide variety of international fisheries.

The model and parameter estimates are all based on the latest science and evidence. Most of these underlying studies focused on temperate sedimentary habitats on infauna and epifauna, for bottom-towed gears. Therefore, the outputs of the tool will be most reliable for assessments with a similar focus.

The approach creates a spatial prediction of fishing impacts but does not include spatial ecological processes. This means that processes like recruitment and dispersal are not included, and that the state of one grid cell does not depend on the grid cells surrounding it. Recruitment and dispersal are not part of the processes explicitly included in the RBS model, which would mean that no recovery could ever occur once $RBS = 0$. Because this is not realistic, we assume that at least 1% of the carrying capacity remains within the habitat. This can be assumed to represent recruitment and mobility of biota from elsewhere.

The RBS is not a food web model, therefore no effects on higher trophic levels are included. Species interactions such as competition and predation are not explicitly modelled (but are represented in the parameter values estimates). Age structures, size structures and further complex structures are also not explicitly modelled but do correlate to species biomass and thus are indirectly represented by the RBS model.

The method predicts the relative community biomass, the biomass as a fraction of what it would be without bottom trawling. This has the advantage that it is easy to compare between the state of different habitats, and that the data demands of the approach are lower. It does however also mean that in final products, all grid cells will be equally weighted regardless of the amount of

biomass they can support, and areas that can support a high biomass are not given more importance.

The estimated time to recovery provided on the final tab of the Benthic Impacts Tool does not indicate whether the community may recover to the size and age composition associated with no trawling (Hiddink *et al.*, 2019). However, the estimated time to recovery does provide an idea of the recovery of abundance, which is likely to correlate with the recovery of important ecosystem processes (Hiddink *et al.*, 2019). Full recovery to the pre-trawling age structure is unlikely, especially for habitats that contain some of the longest-lived benthic biota, which may live for over 20 years if trawling is allowed to persist in that area (Hiddink *et al.*, 2019).

The parameters in the tool are not applicable to biogenic reef habitats, for example oyster or mussel beds, or reef and rocky habitats. This is because there is little scientific evidence of quantitative impacts on these habitats.

The MSC Fisheries Standard v3.0 specifies that PI 2.3.1 should evaluate whether recovery could occur in 20 years this aligns with the tool output, which indicates whether recovery is likely to occur within 20 years.

The cell position within the assessment grid is the centre of the cell and assumes that the same value of fishing effort covers the entire cell. This is where data resolution becomes very important. The lower the resolution, the less precise the RBS model outcomes become. This is most important for very small but heavily fished habitats, where a low habitat resolution map may lead to an underestimate of the fishing impact. Sensitivity analysis is being undertaken by Bangor University with the aim of providing evidence for a minimum data standard for the Benthic Impacts Tool in relation to both habitat data and fishing effort data. This minimum data standard will ensure that the Benthic Impacts Tool is used to inform robust assessments of habitat impacts based on quantitative evidence.

The RBS model assesses the equilibrium conditions, which assumes that fishing has occurred continuously and consistently over time and does not reflect the reality of peaks and troughs in fishing activity, whether on a yearly or seasonal basis. It is recommended to use several years of effort data, ideally around 5 years, but longer periods are appropriate for habitats that contain very long-lived species.

To conclude, the outcomes of the Benthic Impacts Tool reflect its inputs. Therefore, if the data inputted is of poor quality, then the RBS model outcome may also be poor. Therefore, it is important to keep note of the data types and sources, as well as the choices made as the user proceeds through the tool, as these will certainly impact the final outcomes. If the Benthic Impacts Tool is used to inform scoring in a MSC fishery assessment, it is important that all user choices and any final tool outcomes are considered in the evaluation of evidence that informs scoring decisions.



2.8 Frequently Asked Questions

The model estimates relative total community biomass, how does this relate to seafloor integrity, biodiversity, structure and function?

Community biomass is known to correlate with many ecosystem functions. When local biomass is decreasing, local biodiversity and species richness will also be declining. Ecosystem processes that benthos provide, including bioturbation, nutrient cycling, and the provision of food for higher trophic level species such as fish and seabirds, are all tightly linked to benthic biomass.

Some opportunistic species will increase in abundance in response to trawling, how does this approach capture this?

After trawling, smaller, short-lived species may increase in abundance as a result of being released from competition and predation by the larger, longer-lived species. Discards may also provide a food subsidy to some species, although this has been shown to be a very minor fraction of diet for benthos. Because species that increase in abundance after trawling are generally small in size, total community biomass will largely reflect the loss in the larger species, and increases in smaller opportunistic species will have little affect on total community biomass. These emergent effects are incorporated into the parameter estimates used in the Benthic Impacts Tool.

How did the studies that provided the input data study unfished areas? Is all of the seabed already trawled? How do we know what 'pristine condition' is?

Many of the studies that were used went through a careful process of site selection to ensure the true effect of trawling was detected. There are areas in all seas that are unfished, these are used many of the studies as 'control' locations. For example, Amoroso *et al.* (2018) showed that even in the most heavily trawled seas such as the North and Adriatic seas, around 20% of the area is not trawled. Other studies have included 'control' locations that were infrequently trawled and where a large fraction of the seabed is likely to have been untouched by trawling for many years. Nevertheless, there may have been some loss of the most sensitive fauna over the last century, and we are unable to quantify this loss using current methods and data. As a result, trawl impacts may be underestimated when there is uncertainty on how 'trawl-free' the control locations have been in the last century.

3 Technological requirements

All you need is a computer with an internet connection.

Requirements: 64 MB RAM minimum; 256 MB RAM or higher recommended as the tool deals with the processing of large spatial datasets.

Currently the tool is available on a server at Bangor University:
<https://rstudio.bangor.ac.uk/shiny/benthic/>.

The username is: benthic, and the password is: GreyClouds.



4 Tool navigation

The tool is divided into eight tabs which require data input and user interaction. Below is a summary of the role of each tab within the Benthic Impacts Tool, with underlined words indicating the main role of the tab.

Tab 1 Information about the tool

Tab 2 Fishing effort data is uploaded and checked

Tab 3 Habitat data and an assessment area boundary are uploaded as shapefiles and a data grid is generated for analysis

Tab 4 Fishing effort data is converted to swept area ratio (SAR, year⁻¹) estimates, which indicate how often a particular area of the seabed is fished per year.

Tab 5 Depletion values are determined for each gear type.

Tab 6 Recovery rates are set, either using the default recovery rate, or estimated from the longevity of species present in each habitat type.

Tab 7 The swept area ratio (SAR, year⁻¹) values are combined with the depletion rates for the fishing gear to determine the Relative Benthic Status (RBS) of the seabed in each habitat type. The RBS score indicates to what extent the benthic biota has been affected by fishing [RBS = 1 = natural community, 0 = fishing has resulted in the removal of the original benthic community].

Tab 8 The recovery trajectory for each habitat type is predicted from the current RBS and the recovery rate, with indicative MSC scores and estimated recovery time highlighted.

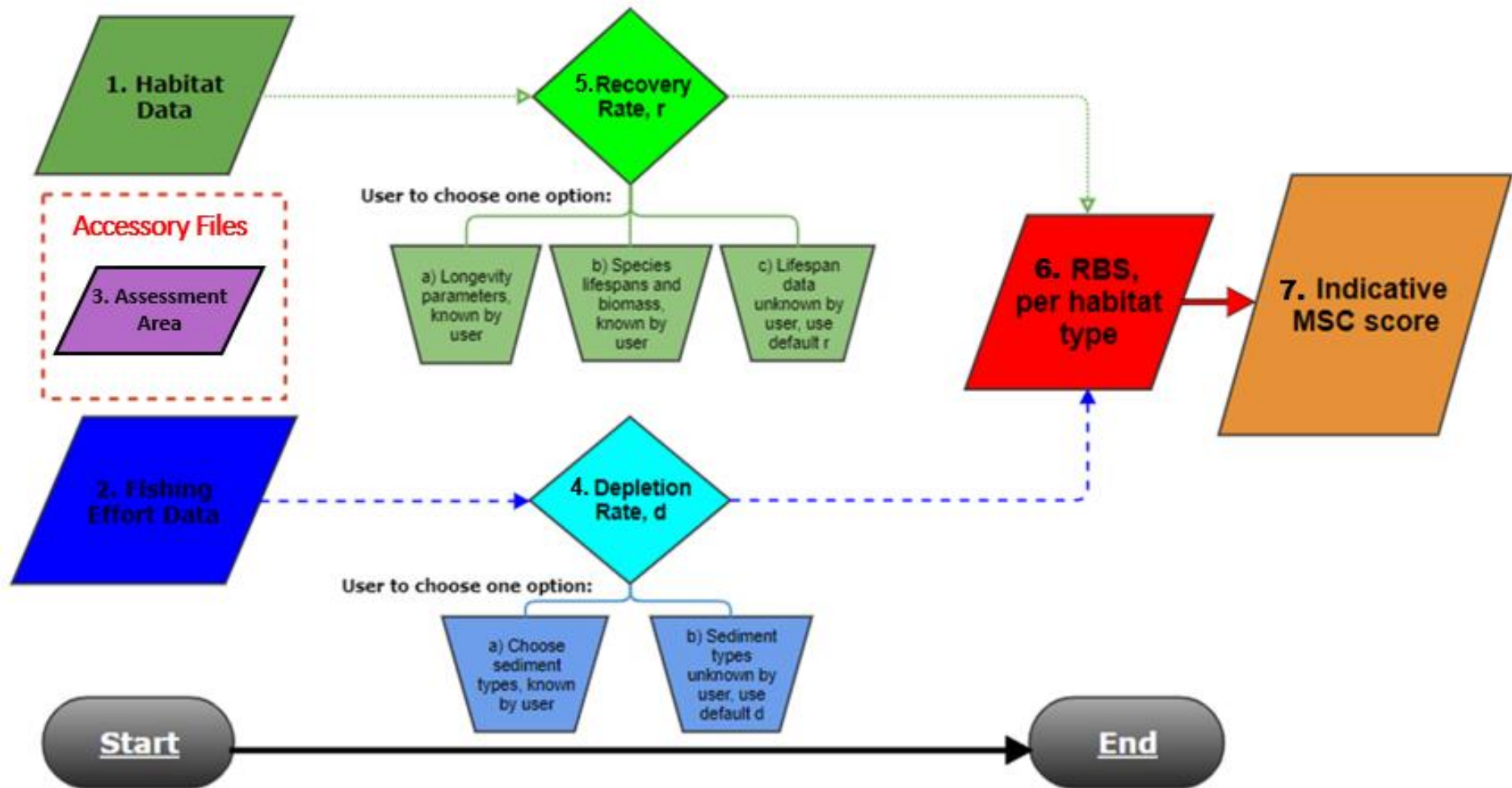


Figure 7. A flowchart highlighting the user input (1 – 3), user interactions (4 and 5) and user output (6 and 7) of the Benthic Impacts Tool.

5 Data requirements

The minimum data requirements include:

- Fishing effort data
- Habitat data
- Assessment area boundary

For improved confidence in the output the user can also include the following (if the information is available):

- Species longevity data
- Species longevity distribution parameters

See [Section 6](#) for advice on formatting your data.

6 Formatting data

6.1 Assessment area shapefile (mandatory)

A shapefile is a vector data storage format for storing the location, shape and attributes of geographic features. This includes a set of related files. The assessment area shapefile (e.g. named 'Assessment Area') should outline your assessment area as a polygon. This will allow the tool to ensure all analysis occurs within this assessment area. The assessment area shapefile is a mandatory upload which delineates the area under consideration, including the area being fished and the extent of the habitat under consideration. This shapefile can be generated within a Geographic Information Systems (GIS) software such as ArcMap or QGIS (many others are available). Using the GIS software, draw around the assessment area of interest and save this as a shapefile. The assessment area shapefile will allow the Benthic Impacts Tool to trim down all the other data inputs to ensure that only the area of interest is considered within the assessment. We are only interested in the assessment area, as large datasets or shapefiles increase the processing time of the Benthic Impacts Tool (this can vary between computers). Ensuring that all datasets are focused on this assessment area is therefore highly recommended.

The assessment area must be processed such that it only includes relevant areas (i.e., areas where fishing could reasonably take place). For example, areas of land must not be included in the assessment area shapefile. If a user creates a square polygon for an assessment area (e.g. Figure 8a), this must be processed to remove areas of land (e.g. Figure 8b).

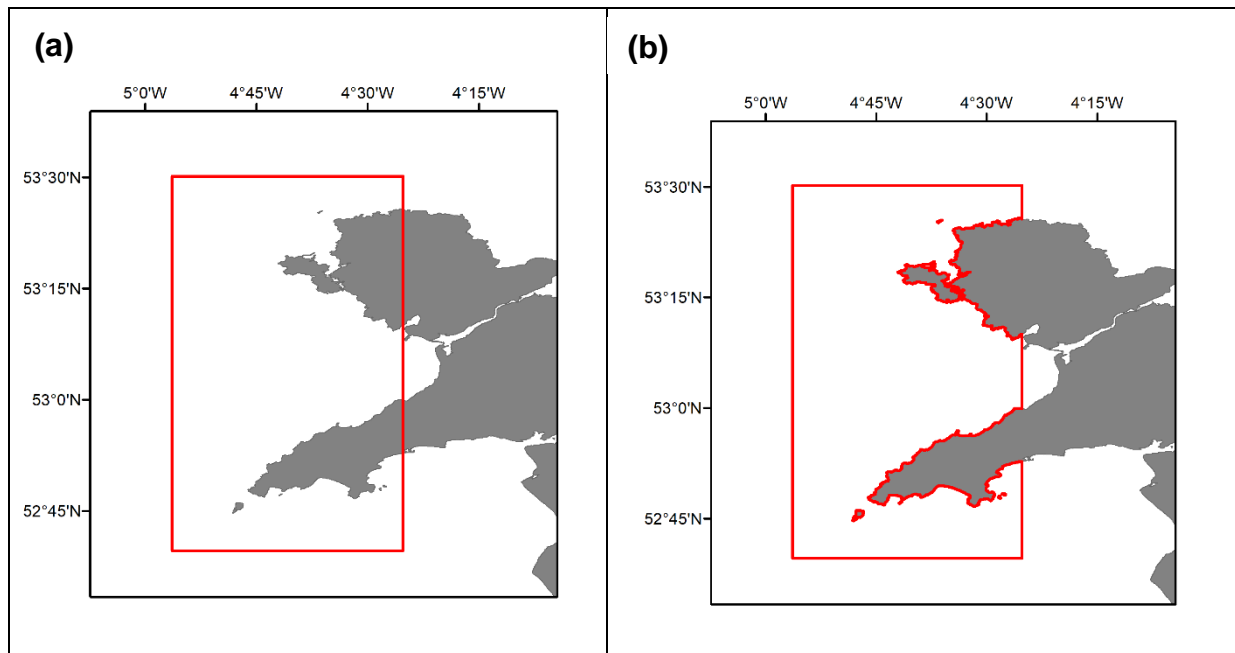


Figure 8. The assessment area shapefile provides an outline of the area where data should be processed. It must be clipped such that areas of land are not included in the assessment area. Figure 8 (a) is an assessment area that is not suitable, as it includes areas of land. Figure 8 (b) is a useable assessment area where the land has been removed.

6.2 Fishing effort data (mandatory)

6.2.1 What is fishing effort?

In the Benthic Impacts Tool, fishing effort is defined by the Swept Area Ratio (SAR, year⁻¹). The swept area (km²) of a vessel depends on the gear swept width and the tow speeds, and this is the value required to use the Tool. The Swept Area Ratio (SAR, year⁻¹) is then calculated by the Tool itself, and this is calculated as the total swept area per grid cell divided by the grid cell area.

The user specifies the size of grid cell, which must match up to the resolution at which the fishing effort data is aggregated at. For example, if the effort data is aggregated to 0.05°, then the grid cell size used must also be 0.05°.

6.2.2 Why do we need it?

We need the fishing effort data in order to calculate the impact the fishing activity is having on the benthic communities. The swept area (km²) calculation gives an easy format to assess using square grid cells which are comparable over time and space.

6.2.3 Which gear types can be processed through the Benthic Impacts Tool?

The following general gear types may be considered for assessment: hydraulic dredge (HMD), towed dredge (DRB), beam trawl (TBB), otter trawl (OT) and seine netting (SEINE). They must follow the abbreviated naming convention as highlighted in brackets after each gear type. This is important for the tool to be able to recognise the gear type chosen and associate the required depletion data to this gear type. Only one single gear type can be assessed at a time with the tool.

Another functionality of the tool is to allow the input of modified gear types. In order to input modified gear type values, either the depletion rate or the penetration depth for the new gear type needs to be calculated by the user (see Section 2.2 on [depletion](#) to learn how to calculate this).

If a modified gear depletion rate or penetration depth is input by the user, suitable evidence must be provided in the report to support this.

6.2.4 What data is suitable?

Vessel monitoring system (VMS) data, Automatic Information System (AIS) data, or GPS tracker data of fishing vessels can be used to generate inputs for the Benthic Impacts Tool data. Pre-processing of the fishing effort data will likely be required before inputting to the tool, as your fishing effort data must be aggregated to a grid before inputting to the tool (i.e. sum of area swept, aggregated to a regular grid defined in decimal degrees). The tool reads .csv files of fishing effort, which should only contain points that represent fishing activity (i.e. no steaming activity). Fishing effort is not required to be continuous across the entire assessment area (Figure 9). The data should use the WGS84 coordinate system to aggregate your fishing effort data to a decimal degree grid, there is flexibility in the tool to set your aggregation resolution, if you are unsure what resolution to use, we recommend an aggregation of $0.05^\circ \times 0.05^\circ$ (as followed by ICES methodologies). The final .csv file input to the tool must contain the following column headings, formatted in the same way (i.e. use of capitals and underscores) (Figure 10).

Latitude	Latitude of the aggregated data point in decimal degrees ($^\circ$)
Longitude	Longitude of the aggregated data point in decimal degrees ($^\circ$)
AreaSwept	The area swept represented by that fishing point (i.e. speed x gear width x duration) (km^2)
Gear	Fishing gear (e.g. TBB, DRB, OT, HMD, SEINE)

N.B. When working with coordinates, use decimal degrees (with no use of commas).

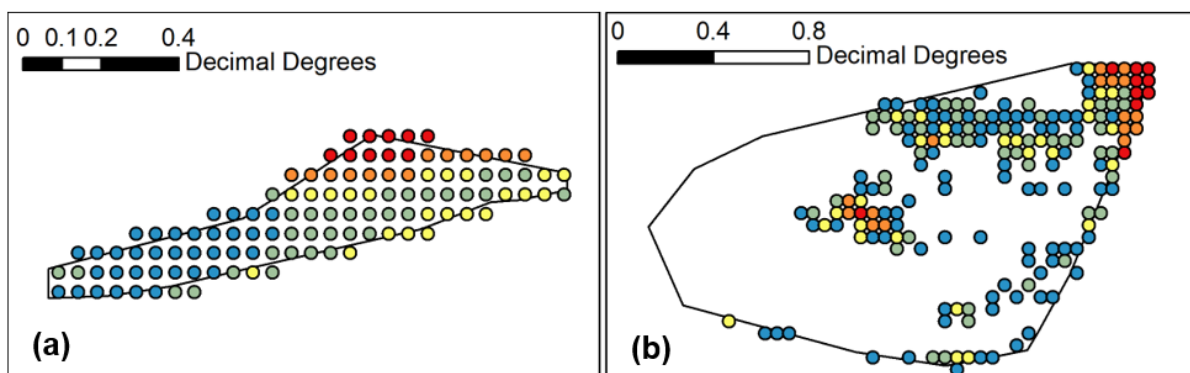


Figure 9. Fishing effort data must be aggregated to a point grid, using WGS84 decimal degree longitude and latitudes.

	A	B	C	D
1	Latitude	Longitude	AreaSwept	Gear
2	50.325	0.025	16.35349658	TBB
3	50.325	0.075	17.75144175	TBB
4	50.375	0.025	21.88457425	TBB
5	50.375	0.075	17.74218583	TBB
6	50.325	0.125	5.331364582	TBB

Figure 10. Example of the columns required in the fishing effort .csv file.

6.2.5 How to deal with different fishing gear types?

Within the tool, each gear type must be assessed separately. Multiple gears can be stored in the .csv file of fishing effort data, but when inputting the data into the tool the user will specify which gear type to assess with the tool.

6.2.6 How to obtain fishing effort data?

SAR can be calculated using vessel monitoring system data, AIS or GPS tracker data. Your local fisheries authority or fisheries manager representative may be able to supply the required fishing effort data.

6.2.7 How to process VMS data?

We recommend processing and cleaning the VMS and logbook data through the R statistical programming software, where the package “vmstools” has been developed for this purpose (<http://nielshintzen.github.io/vmstools/>). Eigaard *et al.* (2017) provides a good description of how to convert VMS records into SAR estimates.

6.3 Habitat data shapefile (mandatory)

6.3.1 What is habitat data?

A shapefile is a vector data storage format for storing the location, shape and attributes of geographic features. This includes a set of related files. The shapefile should provide an outline of habitat types within your area of assessment, this may range in resolution from basic sedimentary descriptors (e.g. sand, mud, gravel) to more complex descriptors (e.g. EUNIS codes). However, it is recommended to use the best resolution data available to support MSC requirements.

6.3.2 What data is suitable?

Within the MSC Fisheries Standard (v3.0), the benthic habitat under assessment should correspond to at least one of the below habitat characteristics:

1. Substratum: Sediment type (e.g. hard substrate)
2. Geomorphology: Seafloor topography (e.g. flat rocky terrace)
3. Biota: Characteristic flora or fauna groups (e.g. kelp dominated seagrass bed and mixed epifauna).

6.3.3 Why do we need it?

The habitat data is required as the Benthic Impacts Tool assessment is undertaken per habitat type. That is, an RBS score and an indicative MSC score is calculated for each habitat type.

6.3.4 How do we decide on the best habitat data to use?

Using a coarse scale habitat type will likely give a higher RBS score than a finely described habitat type, as the area is likely to be larger for the coarse scale habitat type and therefore diluting the impact of fishing across a broader area if fishing is patchy (Figure 11 highlights how RBS may change depending on the resolution of the habitat data used). We do recommend the use of the highest resolution habitat data available, as this will ensure that each habitat is represented, and a more detailed analysis of fishing impact is obtained. At Bangor University, we are currently undertaking a sensitivity analysis, which will highlight a minimum standard of habitat data resolution required for using the Benthic Impacts Tool and should be available towards the end of 2021.

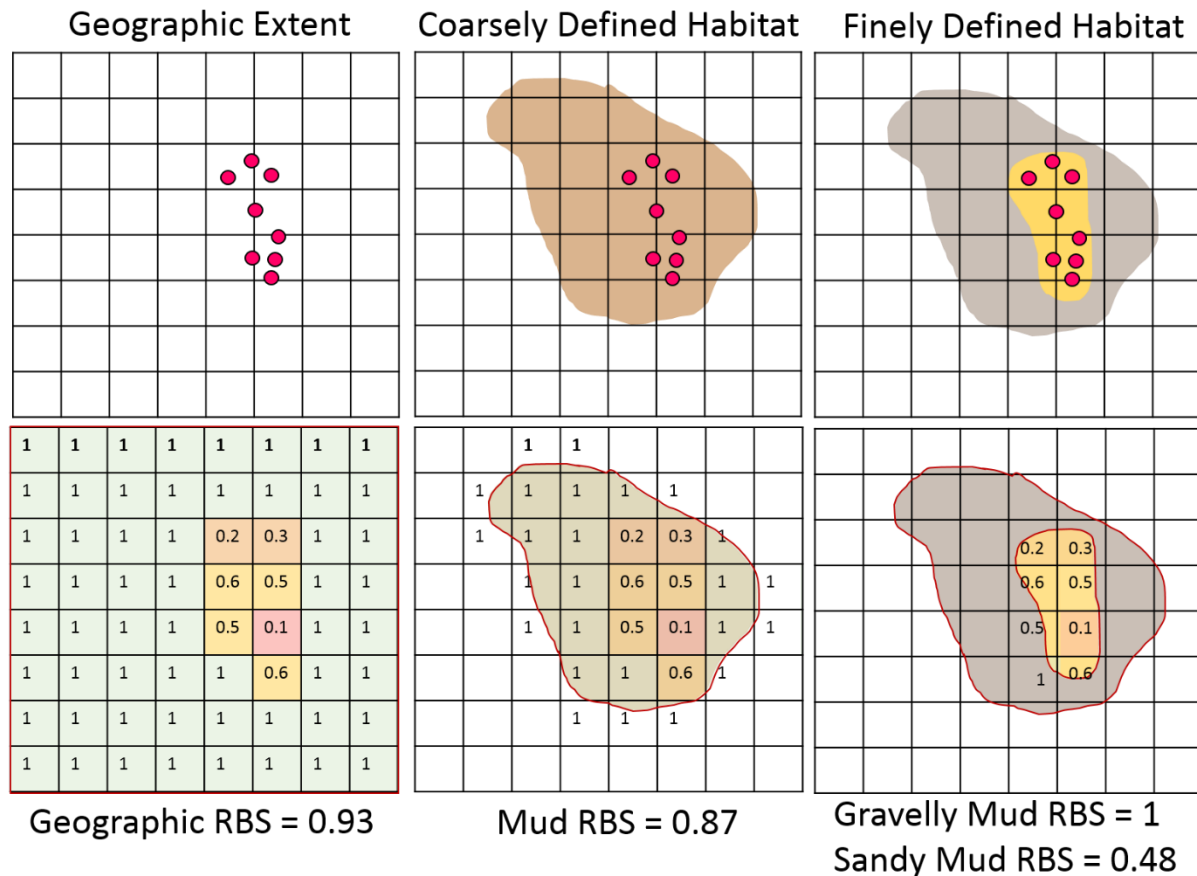


Figure 11. Schematic highlighting how mean RBS values per habitat may change depending on the resolution (from coarse to fine) of habitat data processed through the Benthic Impacts Tool.

6.3.5 What habitat types is the tool suitable to assess?

The Benthic Impacts Tool was designed for the assessment of sedimentary habitats as the parameter values for depletion and recovery for more sensitive habitats, including FAO vulnerable marine ecosystems, were not available when the tool was designed.

6.3.6 How to obtain habitat data?

Please contact your local environmental management authority, who may have shapefiles of habitat available for local seascapes. In England (UK), the BGS and JNCC may have the required data. The EU Seabed habitat map found at <https://www.emodnet-seabedhabitats.eu/> is also a good source.

6.3.7 How to process the habitat data?

Not much processing of the habitat data is required. For the tool to recognise different habitat types, please rename the habitat types column to “HabitatID” by either using ArcMap (or another GIS software) or R (or another programming software). HabitatID is the name used for habitat types within the Benthic

Impacts Tool for a habitat to be recognised. We also recommend that you cut the habitat shapefile to the appropriate size of your assessment area (this will reduce overall processing time within the tool). For more information see Section 14 and explore the example datasets provided.

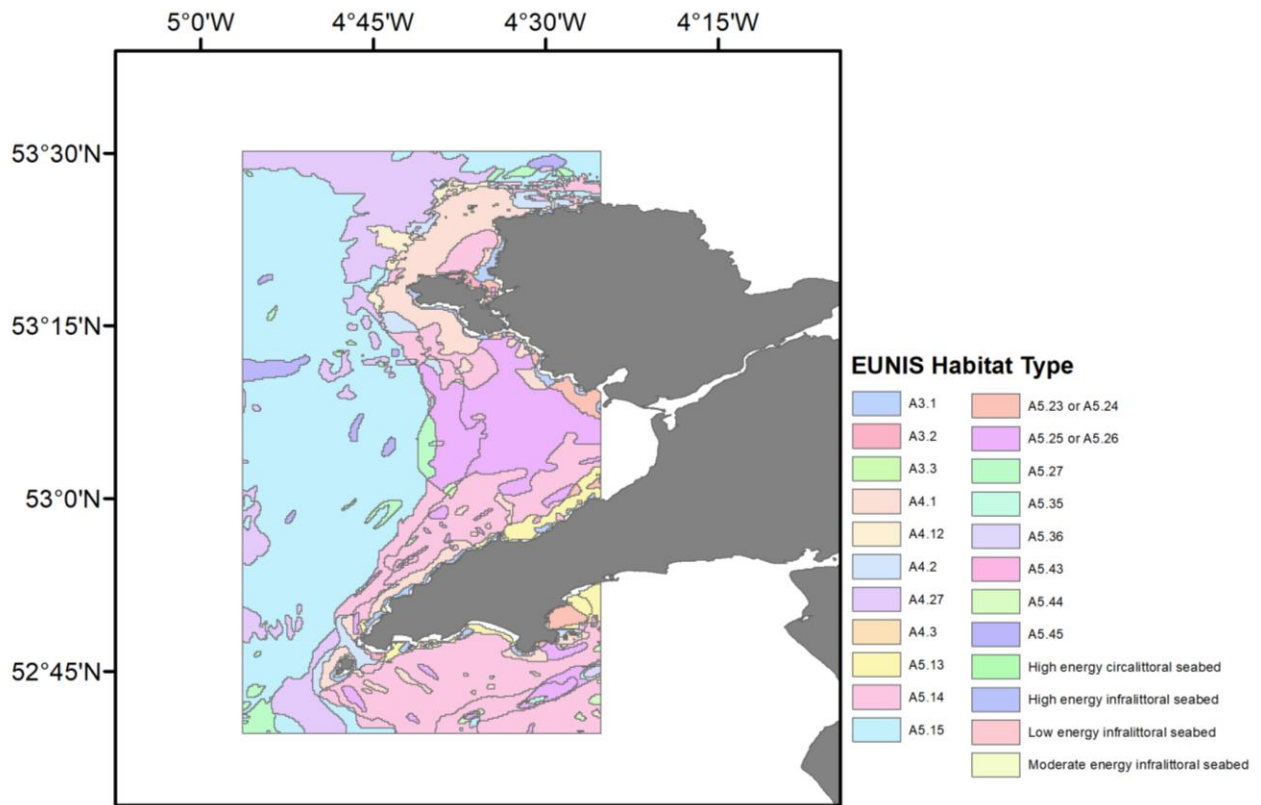


Figure 12. An example habitat data map. The habitat types are highlighted in the legend (EUNIS habitat type in this case), and input into the tool using the habitat data shapefiles.

6.4 Recovery rates (optional)

There are three options for the user to choose from to determine recovery rates within the Benthic Impacts Tool:

- I. Input longevity distribution parameters
- II. Input species data
- III. Use a default recovery setting

6.4.1 Input longevity distribution parameters

The first option requires the user to provide the longevity distribution per habitat type within the area under assessment based on a logistical regression of the cumulative biomass distribution by $\log(\text{longevity})$ for each habitat using the approach in Rijnsdorp *et al.* (2018). This logistic regression will provide estimates of the slope m and intercept b , which together describe the longevity-biomass distribution for the community. These m and b values can be entered in the tool in the table for the first longevity option within the Benthic Impacts Tool. This approach requires a sophisticated analysis of extensive benthic sample data that needs to include areas of no or low bottom trawling effort but will yield the most accurate assessment of the impact of trawling on the seabed.

6.4.2 Input species data

The second longevity option requires a species dataset to be uploaded as a .csv file. This dataset should contain the habitat name, species name, species longevity (in years) and the proportion of biomass per species. This data should be obtained from benthic samples at unfished stations that represent an undisturbed state. An example dataset is shown below (Table 3) – **your column headings must match the column headings shown here exactly (i.e. same capitalisation and spacing)**. The dataset can be written in Microsoft Excel and saved as a .csv file or by any other method for making .csv files. This dataset is then processed within the tool without further user processing required. This option requires data from unfished stations, which can be difficult to obtain. It is also recommended to disregard the target species from this list of species (even if it is part of the community) as the biomass and distribution of these species are likely heavily impacted by fishing activity.

An existing database of species longevities exists at this link: <https://datadryad.org/stash/dataset/doi:10.5061/dryad.426658h>

For species longevity not included in the above database, consider looking through further peer-reviewed and published literature.

Table 3. Example dataset including heading names and layout of longevity data upload – your column headings must match these columns names exactly. Please do not include units or spaces between the heading titles, the species longevity column needs to be in years and the proportion of biomass as a fraction between 0 and 1. Species longevity is given in years. The proportion of the biomass needs to sum to 1 for each HabitatName.

HabitatName	SpeciesName	SpeciesLongevity	ProportionOfBiomass
A5.14	species 1	4	0.05
A5.14	species 2	6	0.2
A5.14	species 3	15	0.30
A5.14	species 4	25	0.4
A5.14	species 5	40	0.05
A5.25	species 6	2	0.6
A5.26	species 7	7	0.4
A5.45	species 8	4	0.02
A5.45	species 9	1	0.98
A4.27	species 10	5	0.59
A4.27	species 11	14	0.41
A5.27	species 12	56	0.1
A5.27	species 13	20	0.9
A5.15	species 14	1	0.99
A5.15	species 15	23	0.01

6.4.3 Use a default setting

The third option is for the user that does not have access to benthic species longevity and biomass data within their assessment area. The tool has an inbuilt precautionary value for the species recovery rate which is the value of $r = 0.42$. This value has been calculated as the lower confidence interval estimate of r for an average benthic community, regardless of habitat or location, from Hiddink *et al.* (2017). This is based on a global meta-analysis and based on all available experimental and comparative data on benthic impacts of trawling and is therefore likely to be precautionary for most benthic habitats but may not be appropriate for some of the more sensitive habitats. See Section 2.3 on [recovery rates](#) for further information about how these are calculated.

6.4.4 How is uncertainty in the recovery rates accounted for in scoring?

The MSC SG scores are based on the probabilities of achieving an RBS > 0.80 after 20 years without fishing. This probability is estimated based on the distribution of r around its median value. Because r is estimated based on the longevity, the distribution of the parameter a that determines the relationship between r and longevity is used to for the estimation of RBS, where $r = a/\text{longevity}$. These parameter estimates were based on the assumption that the distribution of r around the median is log-normal and estimated from the regression analysis in Hiddink *et al.* (2017).

Table 4. The value of a (median, $a = 5.31$) used for estimating the different SG scores.

	20% (SG100)	30% (SG80)	40% (SG60)
a	3.81	4.32	4.79
Example r for longevity = 10 years	0.38	0.43	0.48

Table 5. Parameter estimates for the default of median $r = 0.42$ used for estimating the different SG scores.

	20% (SG100)	30% (SG80)	40% (SG60)
r	0.21	0.29	0.35

For further explanation about MSC scoring grades, please see [Section 2.7](#).

7 Data downloads

There are buttons within the tool that can be used to download outputted maps and tables. The outputs that can be downloaded include the following:

- Map of swept area ratio across the assessment area
 - Habitat map across the assessment area
 - Table showing depletion rates used in the assessment
 - Map showing RBS scores across the assessment area
 - Table showing mean RBS score per habitat type
 - Histogram showing distribution of RBS values across each habitat
 - Plot showing recovery trajectory for each habitat type
 - Table showing predicted recovery times and indicative score for each habitat type
-

8 Quick starter guide

- ☐ **Task 1:** Create a data folder
- ☐ **Task 2:** Start the tool (Tab 1)
- ☐ **Task 3:** Upload fishing effort csv (Tab 2)
- ☐ **Task 4:** Choose a gear type to assess (Tab 2)
- ☐ **Task 5:** Upload assessment area shapefile (Tab 3)
- ☐ **Task 6:** Upload habitat map shapefile (Tab 3)
- ☐ **Task 7:** Input a grid cell size in degrees (Tab 3)
- ☐ **Task 8:** Tell the tool how many years of fishing activity data you have (Tab 4) to calculate SAR
- ☐ **Task 9:** Tell the tool whether you will be using default gear depletion rates provided by the tool or inputting your own gear specific values (Tab 5)
- ☐ **Task 10:** Select the gear type being assessed (Tab 5)
- ☐ **Task 11:**
 - a) Input sediment type data (If unknown table modification is not required) (Tab 5)
 - b) Enter gear specific depletion value between 0 and 1 (If unknown default depletion rate will be used) (Tab 5)
 - c) Enter gear specific penetration depth (cm) (If unknown default penetration depth will be used) (Tab 5)
- ☐ **Task 12:** Choose method to calculate recovery rates: input longevity distribution parameters (proceed to Task 13a), species longevity data (proceed to Task 13b) or choose default recovery value (proceed to Task 13c) (Tab 6)
- ☐ **Task 13:** Click to generate recovery rates (Tab 6):
 - a) Enter longevity distribution parameters for each habitat
 - b) Upload a csv file containing species longevity data
 - c) Click the button to use default recovery rates
- ☐ **Task 14:** Click to calculate RBS (Tab 7)
- ☐ **Task 15:** Click to calculate recovery time and MSC scores (Tab 8)

9 Running the tool

This section of the manual guides you through running the tool, providing extra guidance and information on each task.

9.1 Tab 1: Information

The first tab of the tool gives a brief overview of the tool, including a list of key references and collaborations.

9.1.1 Task 1/15: Is the folder ready?

Before you start using the tool, it is a good idea to get a data folder ready, containing all of the data files you need for the assessment.

In this folder as a minimum you would need an assessment area shapefile, a habitat data shapefile, and your fishing effort .csv data.

Give each file an easy to remember name, for example:

- habitat_data
- assessment_area
- fishing_effort
- species_longevity_data

Refer back to Section 6 for how to [format the data](#) to ensure compatibility with the tool.

9.1.2 Task 2/15: Start the assessment

When you have read the information on this tab, and your data is ready, click on the 'click to start' button to start the tool.



9.2 Tab 2: Effort data

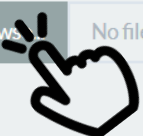
The second tab of the tool is for loading fishing effort data.

9.2.1 Task 3/15: Choose CSV file of aggregated VMS data

Click on the 'browse' button to look for your fishing effort .csv file and upload this. Once the file has been uploaded, the top 6 lines of the dataset will be displayed and the upload complete icon will appear.

TASK 3/15 - Choose CSV File of aggregated VMS data (click the button once only)

Browse No file selected



Once the data has successfully uploaded the top 6 lines of the dataset will be displayed to the right.

9.2.2 Task 4/15: Choose a gear type to assess

Use the drop down menu to select the gear type to be assessed – only one gear type can be assessed at a time in the tool. Below, is the table output:

TASK 3/15 - Choose CSV File of aggregated VMS data (click the button once only)

Browse... Final_Western_Channel_Otter_Intensity.csv


Upload complete

Thank you for your input. Please proceed to the next tab once you have chosen the gear type for assessment by clicking - 3. Habitat Data - at the top of the page.

Once the data has successfully uploaded the top 6 lines of the dataset will be displayed to the right.

TASK 4/15 - Choose a Gear type to assess

OT



Gear	Latitude	Longitude	AreaS	Depth
OT	49.48	-4.17	74.45	
OT	49.48	-4.22	101.97	
OT	49.48	-4.28	107.04	
OT	49.42	-4.38	104.64	
OT	49.48	-4.33	75.92	
OT	49.48	-4.38	63.11	

Example

Navigate to next tab...

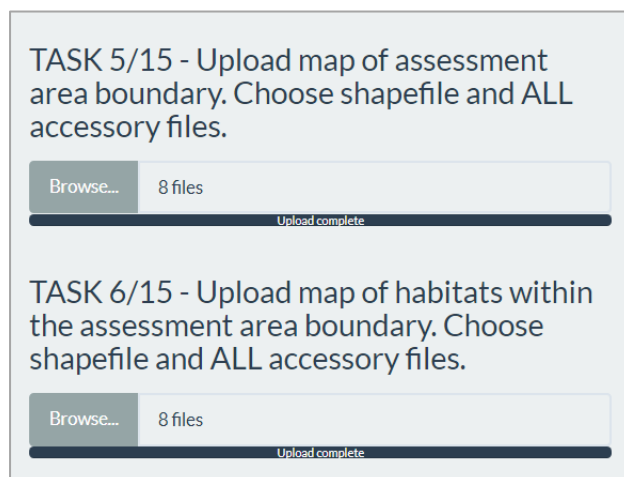
9.3 Tab 3: Habitat data

The third tab of the tool is for loading the assessment area shapefile and the habitat data shapefile.

9.3.1 Task 5/15: Upload map of assessment area boundary

9.3.2 Task 6/15: Upload map of habitats within the assessment area boundary

Click on the 'Browse' button to select the files to load. Note that all files that make up a shapefile must be selected (there can be up to 7 files, all with the same name but a different extension), so there will be more than 1 file selected for the assessment area shapefile and habitat data shapefile (see instructions below for selecting the files).



The screenshot displays two identical file upload task boxes. Each box contains a title, instructions, a file selection interface, and a progress bar.

TASK 5/15 - Upload map of assessment area boundary. Choose shapefile and ALL accessory files.

Browse... 8 files

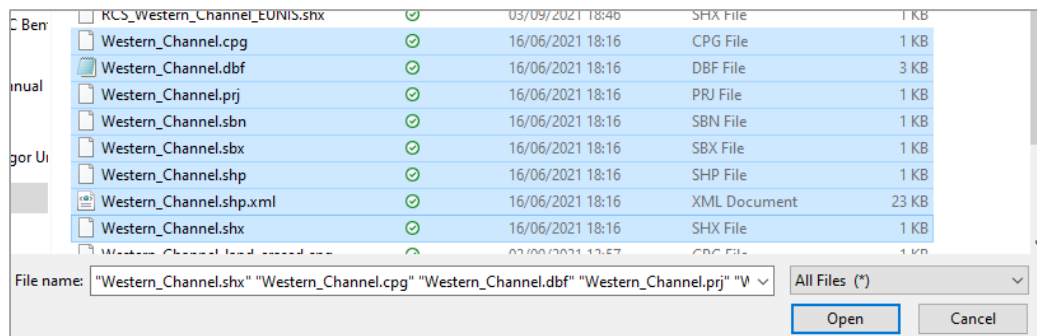
Upload complete

TASK 6/15 - Upload map of habitats within the assessment area boundary. Choose shapefile and ALL accessory files.

Browse... 8 files

Upload complete

When loading the shapefiles you need to select all accessory files. For example, as shown below for the Western Channel assessment area shapefile, all files called Western_Channel were selected, including all file extensions, then press 'Open'.



9.3.3 Task 7/15: Input a grid cell size in degrees

Here you need to set the grid cell size to be used in the tool. This *must* match the scale of aggregation of your fishing effort data. For example, if your fishing effort data is aggregated to a 0.05 degree grid, this must be set at 0.05 degrees.

Task 7/15 - Input a grid cell size in degrees - which must match the spatial aggregation of your fishing effort data

0.05

Click to load files and plot map

Click here

Click the 'Click to load files and plot map' button once, and then wait. Depending on the size of the assessment area this may take several minutes to run.

Once the data is successfully loaded, an interactive map will appear on the right to show the assessment area and the habitat types. You can pan around and zoom in and out of this map. A non-interactive version of the map can be downloaded by clicking the download button below the map.



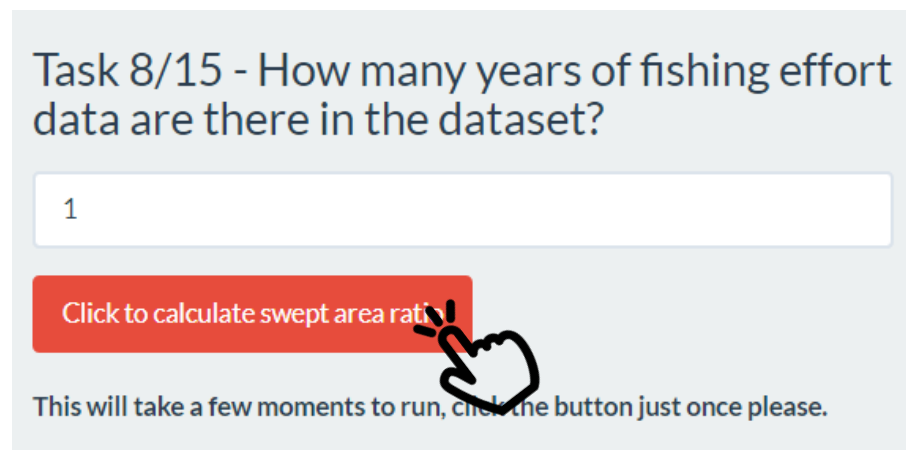
Navigate to next tab...

9.4 Tab 4: Swept Area Ratio

The fourth tab of the tool calculates the Swept Area Ratio (SAR, year⁻¹) based on the number of years of fishing activity occurring in the assessment area, the swept area, and the size of the grid cell.

9.4.1 Task 8/15: How many years of fishing effort data are there in the dataset?

Here you must state how many years of fishing effort data have been used to create the area swept values, so that a yearly swept area ratio can be calculated by the tool.



The screenshot shows a light blue rectangular box containing the text "Task 8/15 - How many years of fishing effort data are there in the dataset?". Below this text is a white input field with the number "1" inside. Underneath the input field is a red button with the text "Click to calculate swept area ratio". A black hand icon with a pointing finger is positioned over the red button. At the bottom of the box, there is a line of text: "This will take a few moments to run, click the button just once please."

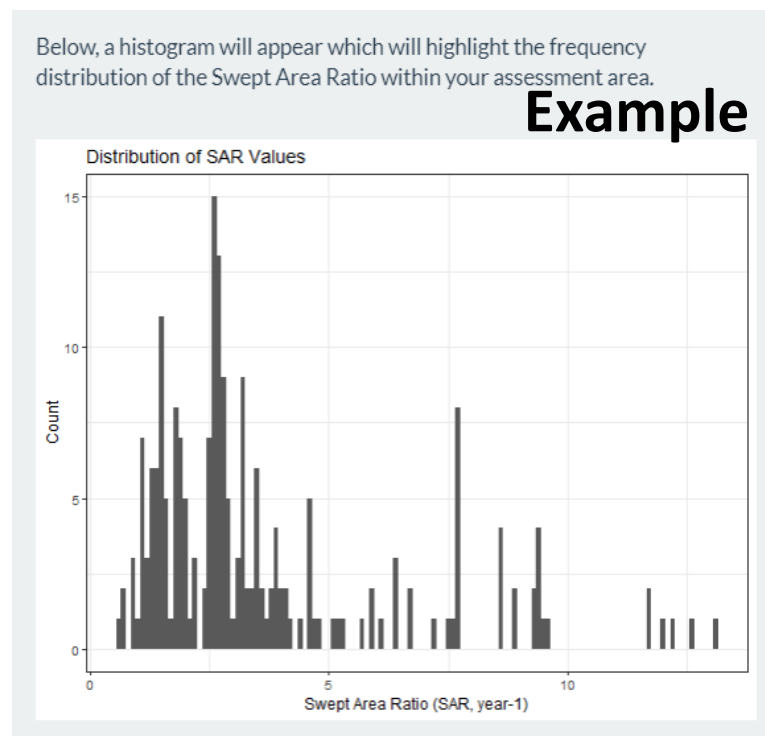
Modify the number of years as appropriate, then click the 'Click to calculate...' button.

The output will include a map of SAR for the assessment area, which again is interactive, so have a look around.

You can download this swept area ratio map by clicking the 'Download the SAR map' button.



A histogram is also output, which shows the distribution of SAR values. You can download this by using the download button beneath the map.



Navigate to next tab...

9.5 Tab 5: Depletion values

The fifth tab of the tool associates depletion values to the data already uploaded. The depletion defines the fraction of organisms killed by a single trawl pass and is dependent on gear and sediment type (see the [Section 2](#) for further details).

9.5.1 Task 9/15: Will you be using default gear depletion rates provided by the tool, or inputting your own gear specific values?

Here you must select whether you will use the standard depletion rates provided by the tool, input your own gear-specific depletion rate or input your own gear-specific penetration depth.

TASK 9/15 - Will you be using default gear depletion rates provided by the tool, or inputting your own gear specific values?

- ☒ I will be using the standard depletion rates provided by the tool
- ☐ I will be inputting my own gear-specific depletion rate
- ☐ I will be inputting my own gear-specific penetration depth

You should only use your own estimates of depletion or penetration depth if you have good evidence to underpin these, otherwise the provided values are likely to be more appropriate.

9.5.2 Task 10/15: Select the type of gear type being assessed in the drop down box

Then, you need to select the gear type under assessment. This is a critical task, as it will influence the rest of the calculations within this tool.

The gear type of assessed fishery needs to be chosen here by modifying the dropdown box, the corresponding penetration depth per sediment type will then be highlighted for your interest.

TASK 10/15 - Select the type of gear being assessed in the drop down box below:

OT

Gear Type	Default Depletion Rate
OT	0.06

Improved depletion rates are available for the following sediment types:
Mud, Sand and Gravel

Gear Type	Sediment	Depletion Rate
OT	gravel	0.11
OT	mud	0.12
OT	Sand	0.05



The gear type has already been chosen in the previous tab... so no need to interact. If you would like to see the values for other gear types, click on the drop down to choose. However, make sure that your chosen gear type is the selected gear type for processing in the Tool.

9.5.3 Task 11a/15: Select the sediment type from the drop down menu for each habitat type

Now you need to associate the habitat to a sediment type, if this information is available/known. If sediment is unknown, table modification is not required and default settings will be applied.

TASK 11a/15 - If sediment type is known, choose either mud, sand or gravel from the dropdown box next to the associated habitat type. If sediment is unknown, table modification is not required.

	Habitat.Type	Sediments
1	A5.45	No sediment type chosen
2	A5.15	sand
3	A4.27	gravel



Choose sediment type here from dropdown box (if known)

9.5.4 Task 11b/15: Enter gear specific depletion rate

If you want to use your own gear depletion value, between 0 and 1, specific to the gear being assessed modify the gear specific depletion rate.

TASK 11b/15 - If you have a gear depletion value specific to the gear being assessed, enter it here. It must be a value between 0 and 1.

Gear Specific Depletion Rate:

Enter value here (if known)

9.5.5 Task 11c/15- Enter gear specific penetration depth

Here you can state the penetration depth of the specific gear being assessed, if known. This value must be positive and in centimetres.

TASK 11c/15 - If you have a gear penetration depth (cm) specific to the gear being assessed, enter it here. It must be a positive value, in centimetres (cm).

Gear Specific Penetration Depth:

Enter value here (if known)

TASK 11a/15 - If sediment type is known, choose either mud, sand or gravel from the dropdown box next to the associated habitat type. If sediment is unknown, table modification is not required.

	Habitat.Type	Sediments
1	A5.45	gravel ▾
2	A5.15	mud ▾
3	A4.27	gravel ▾

TASK 11b/15 - If you have a gear depletion value specific to the gear being assessed, enter it here. It must be a value between 0 and 1.

Gear Specific Depletion Rate:

TASK 11c/15 - If you have a gear penetration depth (cm) specific to the gear being assessed, enter it here. It must be a positive value, in centimetres (cm).

Gear Specific Penetration Depth:

Click to generate depletion values




Example

When ready to move on, click on the 'Click to generate depletion values' button.

9.6 Tab 5: Depletion values (continued)

Depletion values for the fishery will be generated in a table, alongside the gear type, habitat names(s) and sediment type. The table also displays either the sediment specific depletion rate, the user inputted gear depletion rate or the depletion based on user inputted penetration, dependent on option selected in Task 9.

Gear Type	Habitat Name(s)	Generic Gear Depletion Rate	Sediment Type	Sediment Specific Depletion Rate	User Inputted Gear Depletion Rate	Depletion Based on User Inputted Penetration	Depletion Rate used in Assessment
OT	A5.45	0.06	gravel	0.11	NA	NA	0.11
OT	A4.27	0.06	gravel	0.11	NA	NA	0.11
OT	A5.15	0.06	mud	0.12	NA	NA	0.12

 Download the depletion rates used per habitat

Example

Depletion values registered. Please proceed to the next tab by clicking - 6. Recovery Rates - at the top of the page.

You can download this table of depletion rates. Click the 'Download the depletion rates used per habitat' button to download the table to your computer.

Navigate to next tab...

9.7Tab 6: Recovery rates

The sixth tab of the tool calculates recovery rates, based on the longevity of species within the unit of assessment. This tab gives the user three options:

9.7.1 Task 12/15: How will you determine the recovery rates to use?

TASK 12/15 - How will you determine the recovery rates to use?

- ☐ Input longevity distribution parameters
- ☐ Input species data
- ☐ Use a default setting

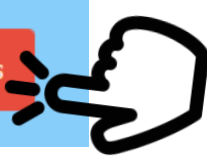
The three options are ranked by decreasing precision of the resulting outputs, and also by decreasing complexity of providing the inputs. I.e. it is best to using the longevity distribution parameters, but these also require the most data and analysis before use in the tool.

Option 1: Input longevity distribution parameters

9.7.2 Task 13a/15: Enter longevity distribution parameters for each habitat type then click to generate the recovery rates

This option requires prior knowledge of the longevity distribution, and the plotting of the logistic model outside of the tool. A table is available to input the m slope and b coefficient values per habitat type. For interest, two plots with sliders are also available which can be modified. However, only the values entered into the table will be registered by the Tool.

	habitat	m_slope	b
1	A5.45	Add value	Add value
2	A5.15	Add value	Add value
3	A4.27	Add value	Add value

Click to generate recovery rates 

Navigate to next tab if this option is chosen...

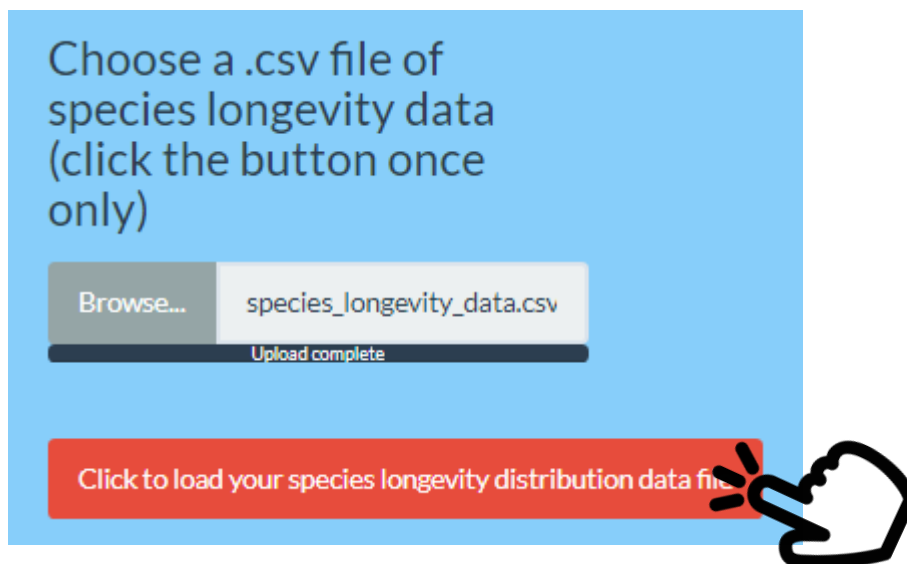
9.8 Tab 6: Recovery rates (continued)

Option 2: Input species data

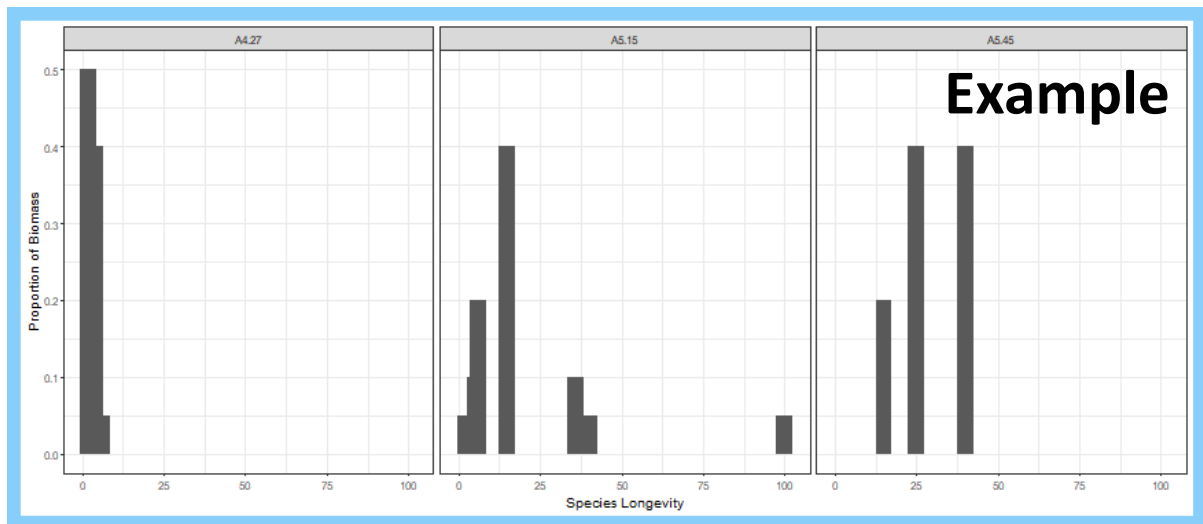
9.8.1 Task 13b/15: Upload a .csv file that contains species longevity data for each habitat type, to generate the recovery rates

This option allows the user to input further species longevity data for the habitats under assessment (if available). See [data formatting section](#) for further information on data type.

Upload the species longevity .csv file, using the 'Browse' button.



Then click the 'Click to load your species longevity distribution data file' button to load the new dataset into the tool. A plot and table of the data will be displayed. See example below.



The table below shows the recovery rate per habitat. Displayed is the overall recovery rate, and the recovery rate within confidence intervals of SG60, SG80 and SG100. Please see the User Manual for further details about the confidence intervals or how the recovery rate is calculated.

Habitat Name	Recovery Rate	SG60 Recovery Rate	SG80 Recovery Rate	SG100 Recovery Rate
A4.27	1.96	1.76	1.59	1.40
A5.15	0.65	0.58	0.53	0.46
A5.45	0.21	0.19	0.17	0.15

Example

Navigate to next tab if this option is chosen...

9.9Tab 6: Recovery rates (continued)

Option 3: Use a default setting

9.9.1 Task 13c/15: Click button to use the default recovery rates

This default setting is the value 0.42. This was chosen as the lower confidence interval estimate of r based on work by Hiddink *et al.* (2017). For further information, see [The Science section](#) or consult the published peer-reviewed journal paper.

TASK 13c/15: Click the button below to use the default recovery rates

The default value is 0.42 and this value is the lower confidence interval estimate of r from Hiddink et al (2017). (Further detail: $r = 0.42$ (median = 0.82, with 5-95% confidence intervals = 0.42 and 1.53))

Click to choose default recovery rate

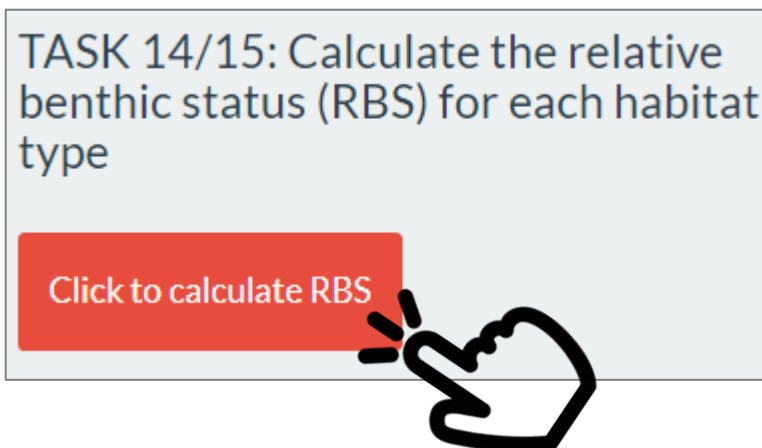


9.10 Tab 7: Benthic status

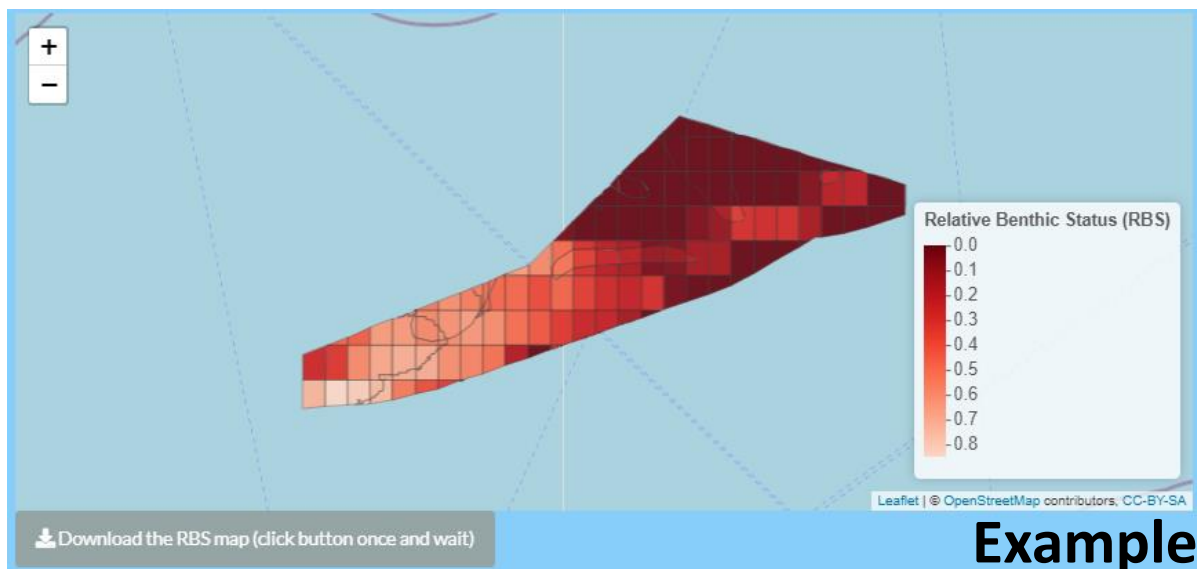
The Relative Benthic Status (RBS) will be calculated on this seventh tab.

9.10.1 Task 14/15: Calculate the RBS for each habitat type

The RBS combines the data and information provided on previous tabs and considers the ratio between depletion and recovery. Click on the 'Click to calculate RBS' button.



This will output an interactive map, a table and histograms per habitat type.

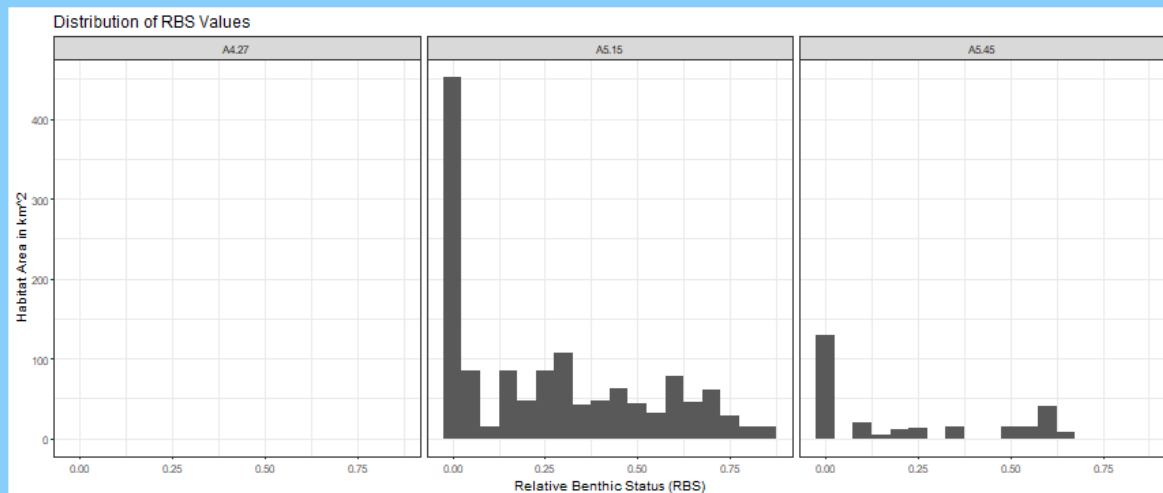


Habitat Type	Mean RBS Score	Total Area of Habitat Type (km ²)
A4.27	0.29	0.19
A5.15	0.26	1341.83
A5.45	0.22	272.77

 Download the RBS summary table

Example

The plot below illustrates the distribution of RBS scores for each grid cell of each habitat type.



 Download the RBS histogram

Example

A4.27 does not have visible bars in this example because the area of this habitat is very small as you can see in the table.

You can download the map showing the RBS, the table of RBS values per habitat type and the histogram of RBS values per habitat type using the 'Download the RBS' buttons.

Navigate to next tab...

9.11 Tab 8: Recovery time

The eighth and final tab calculates a projected recovery time and the indicative MSC score per habitat type.

9.11.1 Task 15/15: Generate the recovery time trajectories per habitat and indicative MSC scores

These outputs will be used alongside other data by MSC assessment teams to support their scoring of the fishery. Again, we consider all the data uploaded and values calculated from previous tabs to calculate an estimated recovery time trajectory for each habitat type within the community.

To commence this calculation, click on the 'Click to calculate recovery time and MSC Scores' button.

TASK 15/15: Generate the recovery time trajectories per habitat and the indicative MSC score(s).

Click to calculate recovery time and MSC Scores

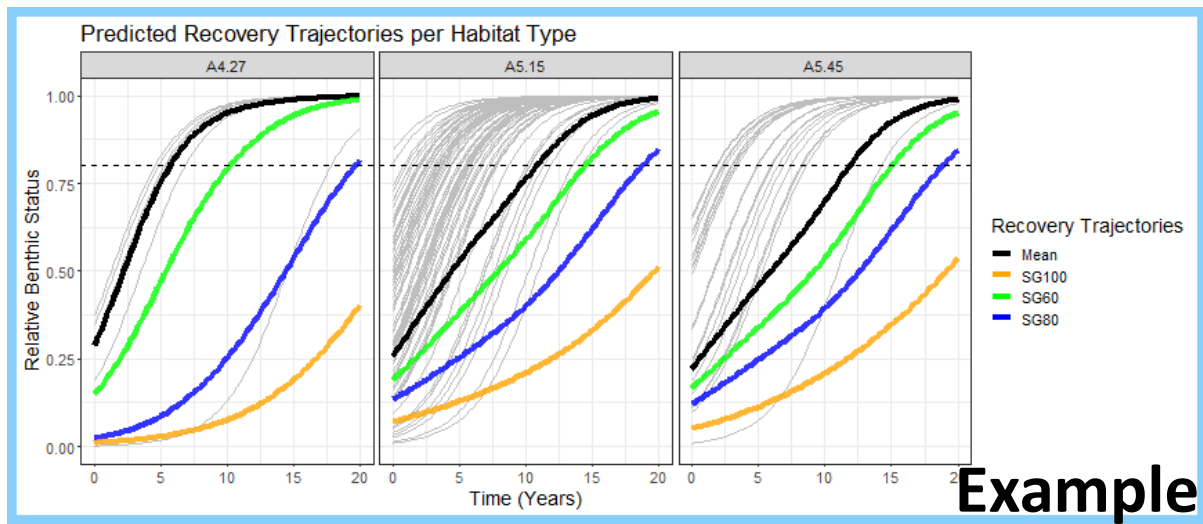


The first plot generated will highlight the recovery trajectory when considering the entire longevity distribution of species in the community.

Each plot represents one habitat type, the grey lines illustrate the recovery trajectory for an individual grid cell, and the black lines indicate the mean estimate of the recovery trajectory across all species. The other three lines indicate the recovery trajectories based on the probabilities matching SG60, SG80 and SG100.

The dashed line indicates an RBS of 0.8 (this is 80% habitat carrying capacity). See next page for further information on indicative MSC scores.

In the example below, for each of the habitats, recovery to RBS=0.8 occurs for SG60 and SG80 (but only just for habitat A4.27), but not for SG100.



A table output will detail the overall recovery time and recovery times for each SG score confidence interval with an indicative MSC score for each habitat type.

Habitat Name	Mean Time to Recovery (years)	SG60 time to recovery	SG80 time to recovery	SG100 time to recovery	Suggested MSC Score
A4.27	5.75	10.25	19.75	20+ years	SG80
A5.15	11.00	14.50	19.00	20+ years	SG80
A5.45	12.00	15.25	19.00	20+ years	SG80

[Download the suggested MSC score table](#)

Tool Finished Running. Assessment Complete.

Example

The tool has now finished running and the assessment is complete!

Download the recovery plot which shows the recovery trajectory for each habitat type and the indicative MSC score table and include them in your report.

10 Troubleshooting

Some steps in the tool can take some time to process, and you have to be patient for the server to complete actions. The 'All done' box often appears a little before the action is actually complete, but you will know that the action is complete when the output appears. Don't push any more buttons while you are waiting.

The tool is not designed to deal with backtracking through the options, so please start over when you want to change any choices.

When something goes wrong in the tool and the server cannot complete a computation, the screen colours go grey, and the tool needs to be closed and started again. Generally, the reason for such crashes relates to the input data layers. Examples of possible mistakes are:

- Columns in .csv files or GIS files do not have the names specified in this manual
 - The spatial extent of the habitat shapefile, the area of assessment shapefile and the fishing effort positions are not for the same area. You may have chosen the wrong file, or may have misspecified the coordinate system, or mixed longitudes on the eastern and western hemisphere. Plot all data layers outside the tool to check that they match in space.
-

11 References

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***Proceedings of the National Academy of Sciences*, 119, e2109449119.**

<https://www.pnas.org/doi/10.1073/pnas.2109449119>

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<https://doi.org/10.1111/faf.12283>



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See <https://trawlingpractices.wordpress.com/> for further information.

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- Andrew Hough
- Rob Blyth-Skyrme
- Phil Taylor
- Philipp Kanstinger
- Stephanie Good

13 Report checklist

Whilst running the Benthic Impacts Tool you can download all available options (i.e. maps and tables), for example if you want to use these in a report. See MSC Toolbox for details on what information and templates require completion when using this tool for MSC scoring.

13.1 Data input

You should state what data has been input to the Benthic Impacts Tool to run the assessment. This should include:

- Fishing effort data
 - State the format and source of the fishing effort data (e.g. VMS data obtained from, AIS data obtained from) and what resolution this data is aggregated to.
 - Include a map of the fishing effort data.
 - State what grid cell size has been used in the tool, and whether it is in km or degrees- note, this must match the resolution at which your fishing effort data has been aggregated to.
 - State how many years of fishing effort data are included in the dataset, and include a statement that confirms this was set correctly in the BIT when calculating the swept area ratio.
- Include a map of the assessment area boundary file used, and justify this boundary- e.g. has it been clipped to remove areas where no fishing could possibly take place (such as land/ islands).
- Include a map of the habitat data input to the tool, clearly indicating what habitat types are included (this can be created independently from input data, or can also be downloaded from the BIT).

13.2 Tool outputs

- Swept Area Ratio
 - Download the map of swept area ratio from the BIT.
 - Depletion rates
-

- State whether you used the standard depletion rates provided by the tool, your own gear specific depletion rate, or your own gear specific penetration depth.
 - If using standard gear depletion rates:
 - State whether you were able to assign the sediment types of mud/ gravel/ sand to the different habitat categories included in your data.
 - If so, provide any evidence you used to support this.
 - If not, justify why this was not possible.
 - If using your own gear depletion or penetration depth, include evidence to justify this.
 - Download the table of depletion rates from the BIT and include this in your report.
 - Recovery rates
 - State whether you used the default recovery rates provided in the tool, input longevity distribution parameters, or input species data to generate recovery rates.
 - If inputting longevity distribution parameters, state what coefficients were used for each habitat type, and provide evidence to support this.
 - If inputting species data, include a table of the species data in your report, and explain how these data were obtained, and any links to relevant published literature.
 - Relative Benthic Status
 - Download and include the map of relative benthic status from the BIT.
 - Download and include the table of RBS values per habitat type from the BIT.
 - Download and include the histogram of RBS values per habitat type from the BIT.
 - Recovery
 - Download and include the recovery plot which shows the recovery trajectory for each habitat type.
 - Download and include the suggested MSC score table.
-

14 Processing data for the BIT using GIS

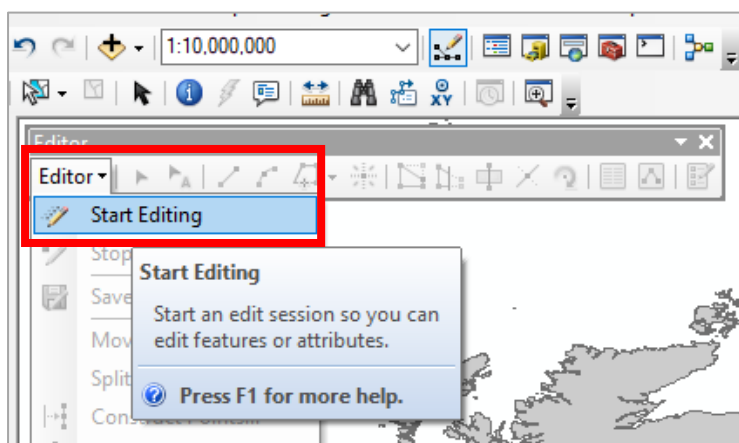
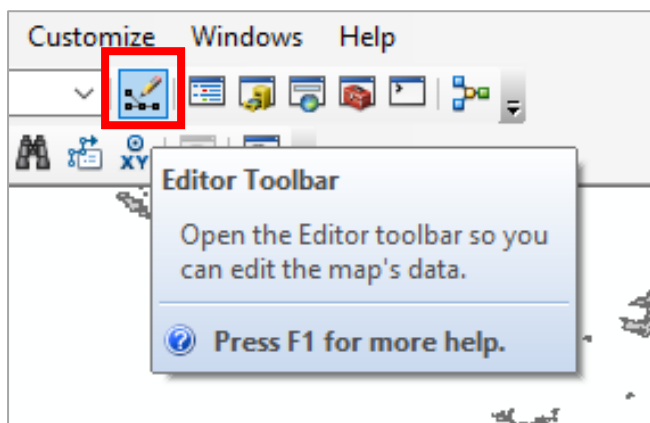
The following examples were completed using ArcMap 10.8.1, the instructions assume the user has some prior knowledge of GIS. Processing on other programmes or models will look different.

14.1 Processing the assessment area shapefile

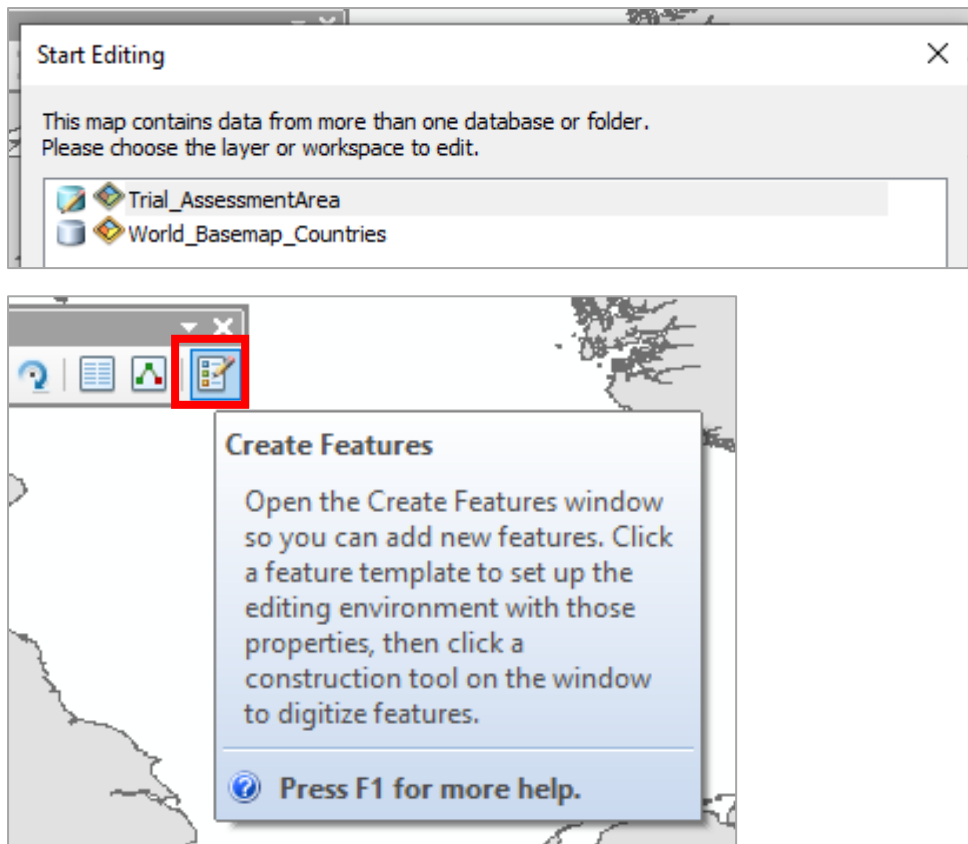
14.1.1 Drawing your own assessment area

First load your habitat and fishing intensity shapefiles to ensure the assessment area is located in the right position.

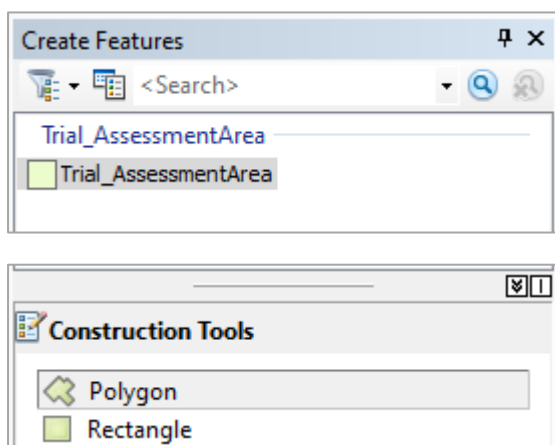
To draw your own assessment area outline on the data layer you wish to edit click on the 'Editor Toolbar' and from the drop down menu select 'Start Editing'.



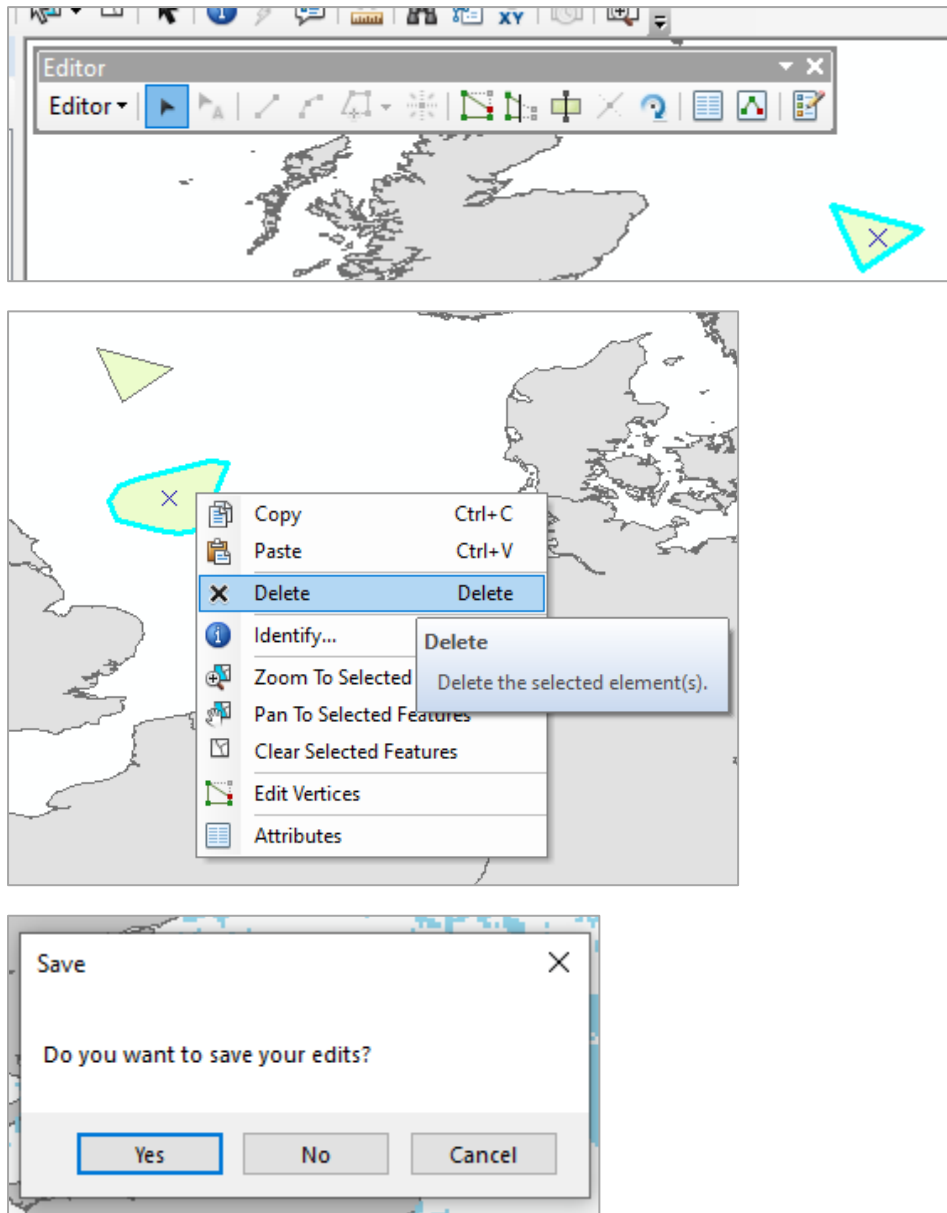
Then select the data layer you would like to draw the assessment area boundary/ polygon in and click on the 'Create Features' button on the 'Editor Toolbar'.



















Select the data layer you want to edit again and then under 'Construction Tools' select 'Polygon'.



Draw your assessment area outline and double click to finish. Remember if there are other polygons in the data layer to delete these. To delete additional polygons whilst in editor mode, right click on the unnecessary polygon and select 'Delete'. Then click to save the edits.



The edited shapefile and all accessory files containing the drawn assessment area boundary will be saved in the original folder.

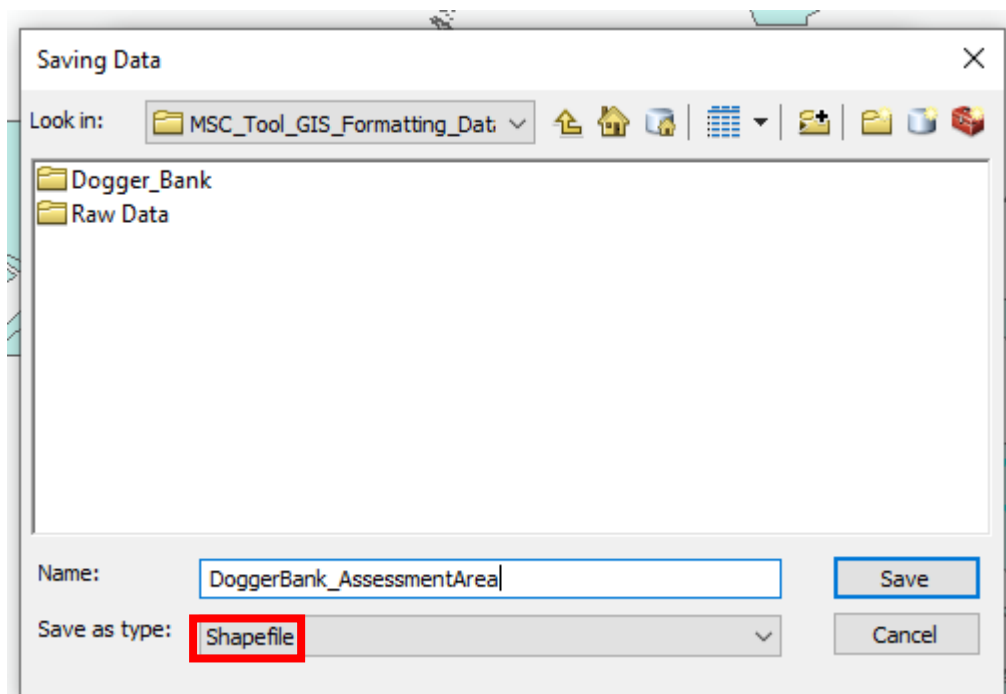
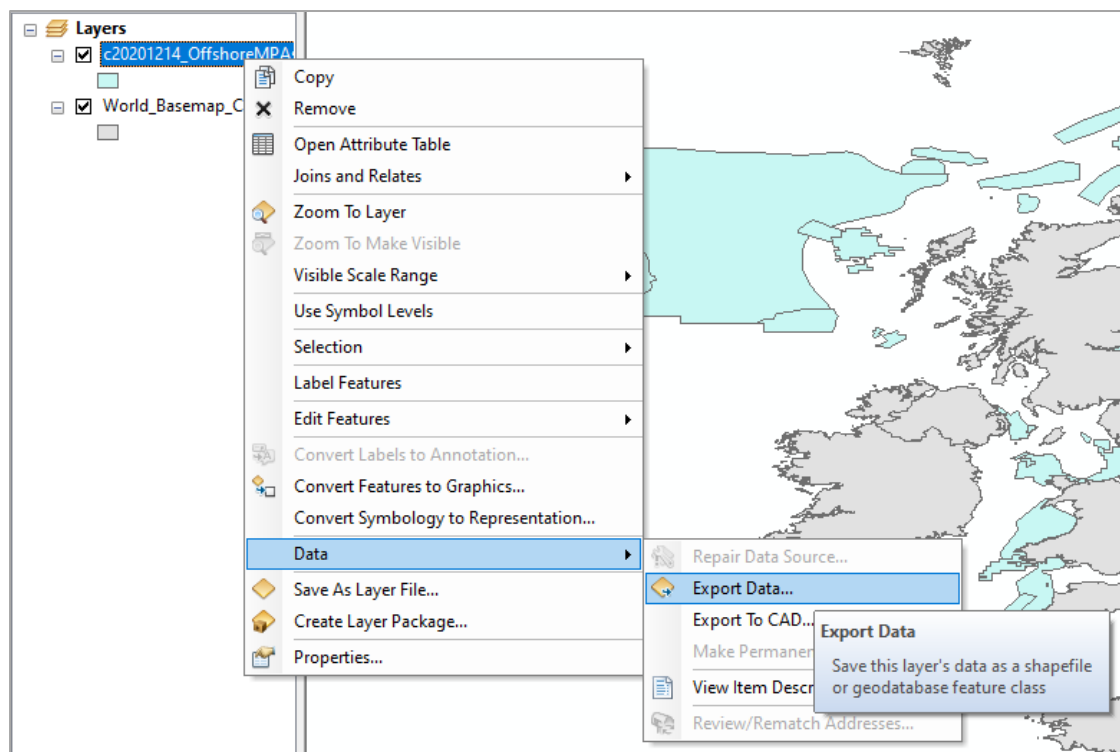
	 Trial_AssessmentArea.cpg
	 Trial_AssessmentArea.dbf
	 Trial_AssessmentArea.prj
	 Trial_AssessmentArea.sbn
	 Trial_AssessmentArea.sbx
	 Trial_AssessmentArea.shp
	 Trial_AssessmentArea.shp.xml
	 Trial_AssessmentArea.shx

14.1.2 Isolating an existing polygon to select your assessment area

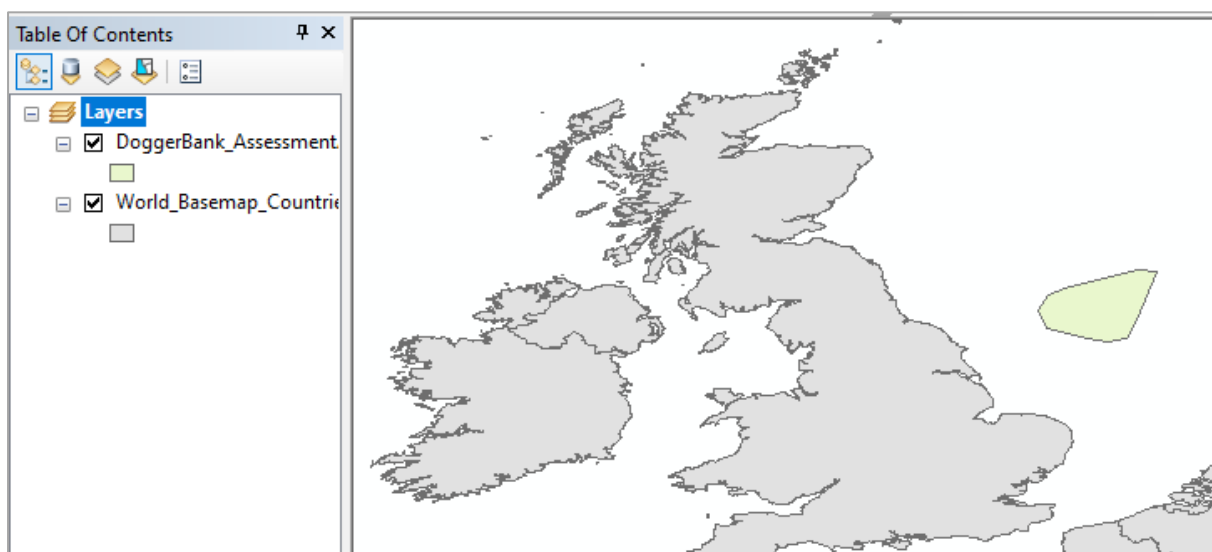
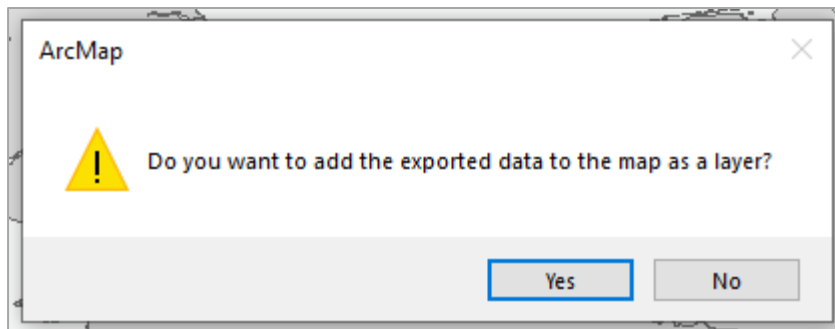
If the assessment area you wish to study is already within a shapefile amongst other polygons upload this shapefile to GIS. Open the attributes table and select the polygon you want to be the assessment area, it will be outlined in blue.



Then right click on the data layer and select 'Data' and 'Export Data'. Then save the data in a suitable folder and rename the layer to an appropriate and recognisable name. Ensure the 'Save as type:' is set to 'Shapefile'.

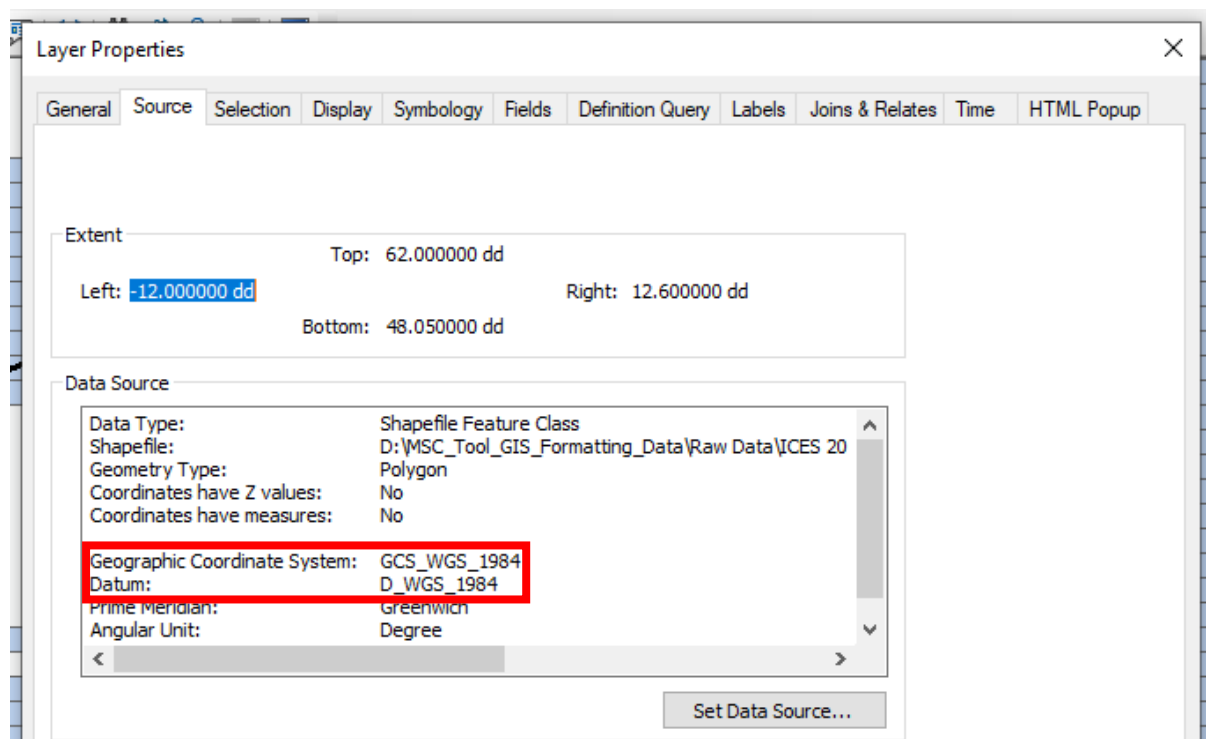
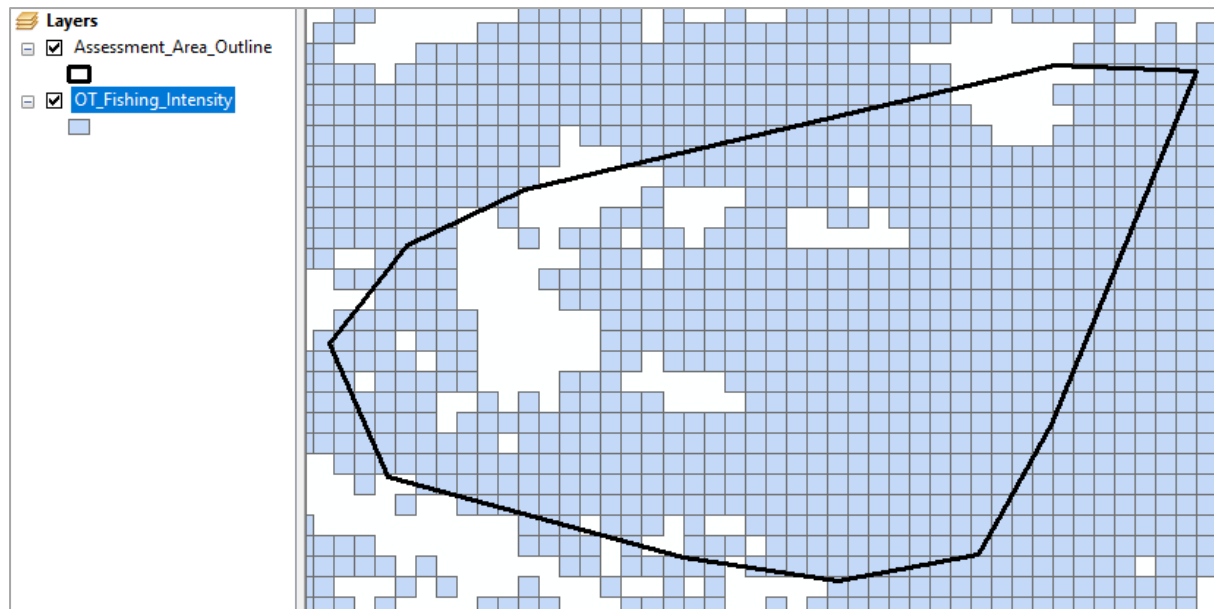


If you select to add the exported data to the map as a layer then you will see the assessment area boundary and you will find the shapefile and all relevant accessory files in the folder you selected.

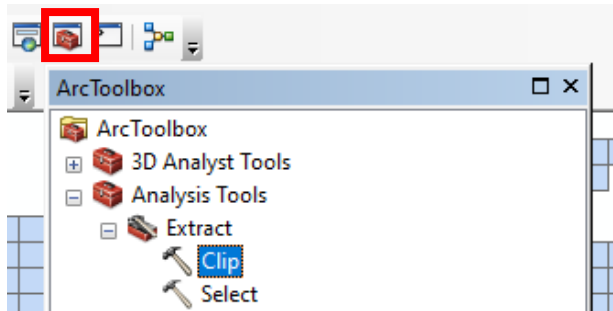


14.2 Processing fishing effort data

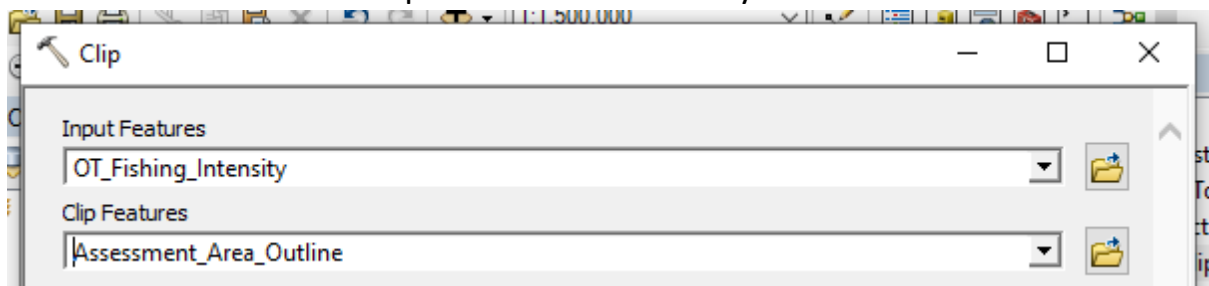
To process your fishing intensity data load this and your assessment area outline shapefiles into GIS. Right click on the fishing intensity data layer and select 'Properties' to ensure you are using the correct coordinate system.



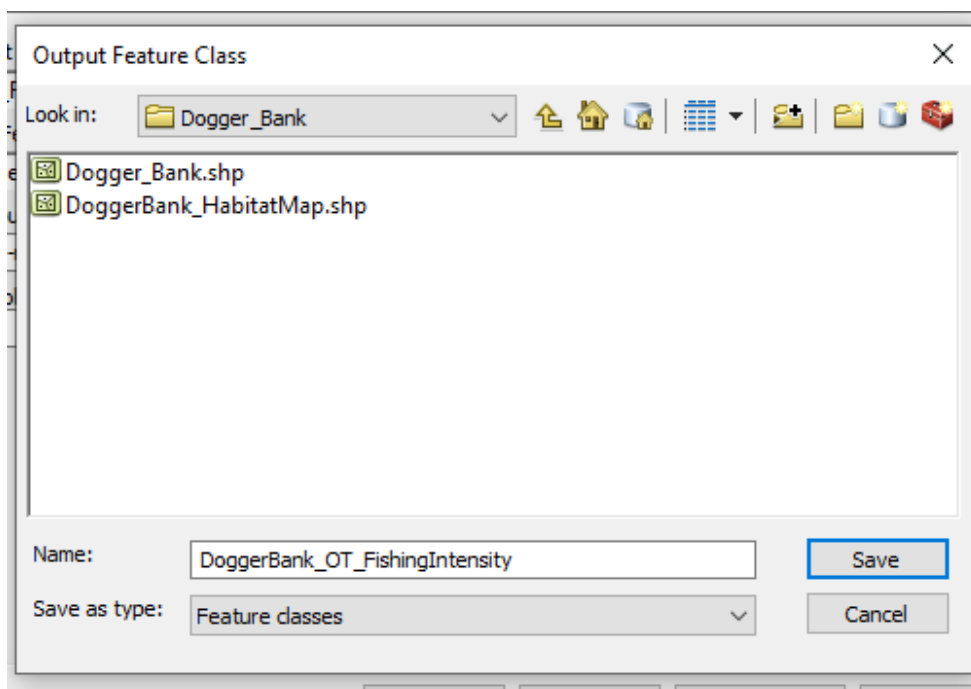
To clip the fishing intensity data to the outline of the assessment area click on the 'Arc Toolbox', select 'Analysis Tools', 'Extract' and then 'Clip'.



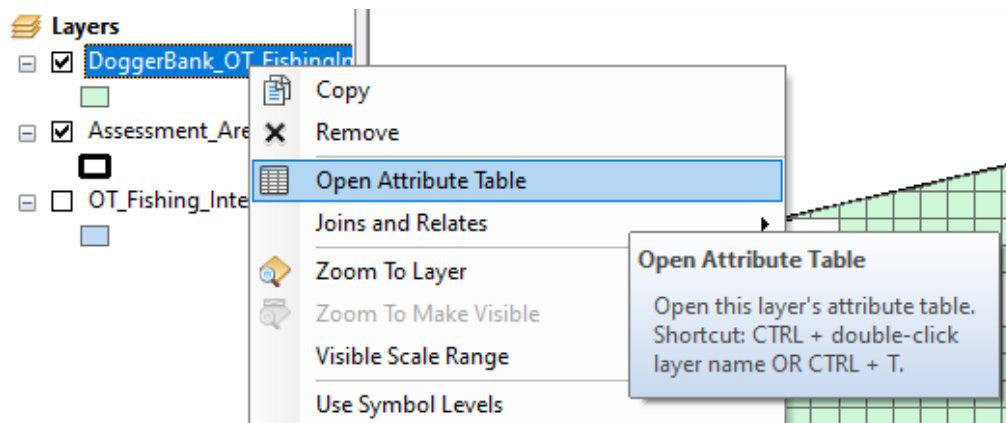
In the 'Input Features' box select your fishing intensity data from the drop down menu and for the 'Clip Features' select your assessment area data.



Below the 'Clip Features' options you can select the folder where you save the clipped fishing intensity data to. It is important this is saved as an appropriate name. Then select to add the exported data as a layer to the map.



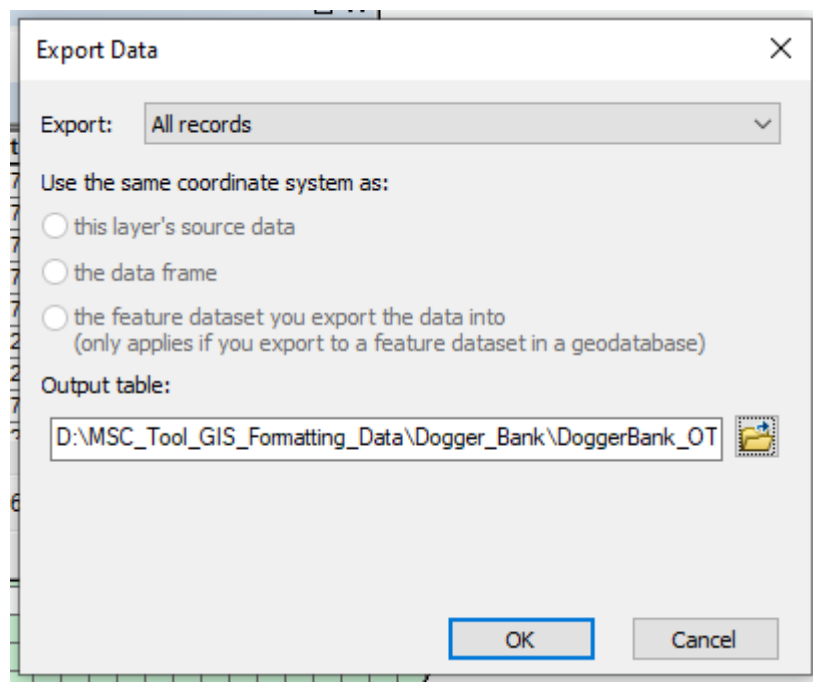
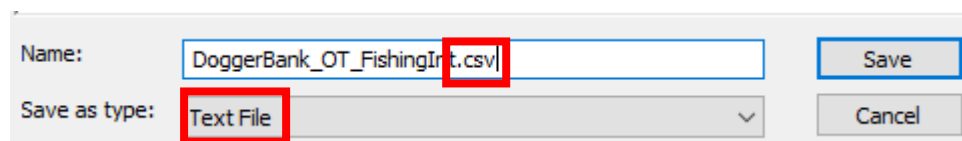
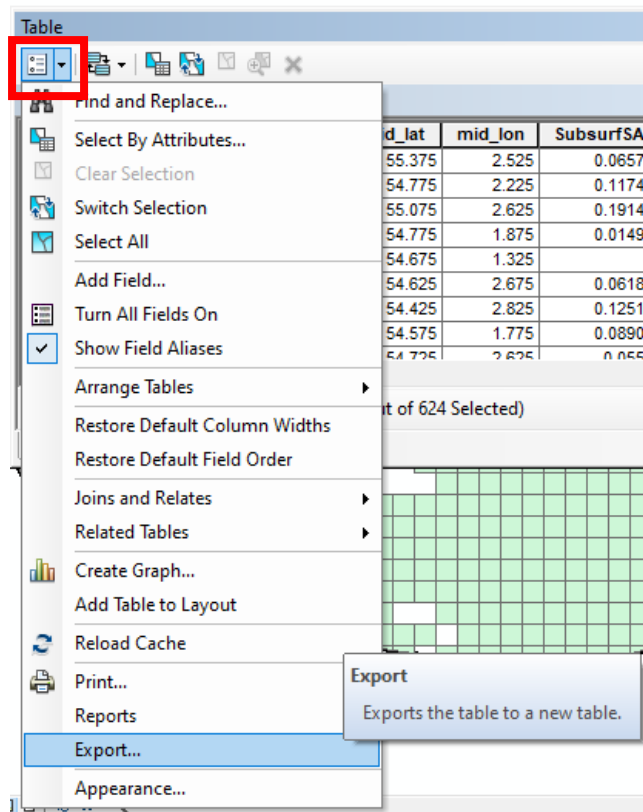
The clipped fishing intensity data will be added as a layer to the map. To export the fishing intensity data shown on the map to a .csv file right click on the clipped fishing intensity data layer and select 'Open Attribute Table'.



DoggerBank_OT_FishingIntensity						
	FID	Shape *	c_square	mid_lat	mid_lon	SubsurfSAR
▶	0	Polygon	1500:352:235:3	55.375	2.525	0.065775
	1	Polygon	1500:142:372:3	54.775	2.225	0.117496
	2	Polygon	1500:352:206:3	55.075	2.625	0.191448
	3	Polygon	1500:141:478:4	54.775	1.875	0.014995
	4	Polygon	1500:141:363:3	54.675	1.325	-9
	5	Polygon	1500:142:466:2	54.625	2.675	0.061808
	6	Polygon	1500:142:248:1	54.425	2.825	0.125174
	7	Polygon	1500:141:457:4	54.575	1.775	0.089071
	8	Polygon	1500:142:476:1	54.775	2.625	0.05523

(0 out of 624 Selected)

Then click the 'Table Options' button in the top left corner and from the drop down menu select 'Export'. Save this in an appropriate folder, under a recognisable name. Ensure to add '.csv' at the end of this. Make sure to set 'Save as type:' to 'Text File'. This fishing intensity data will then be saved as a .csv file in the folder that you selected.



DoggerBank_HabitatMap.shx	14/10/2021 16:48	SHX File	11 KB
DoggerBank_OT_FishingInt.csv	14/10/2021 17:33	Microsoft Excel C...	119 KB
DoggerBank_OT_FishingInt.csv.xml	14/10/2021 17:33	XML Document	2 KB

The saved .csv file will not be correctly formatted for the BIT. Open the .csv and removed all columns apart from the latitude, longitude and swept area, in the example these are named 'mid_lat', 'mid_lon' and 'SurfSA'. Rename these 'Latitude', 'Longitude' and 'AreaSwept'.

Then add a column called 'Gear'. Fill the column with the correct abbreviation for the gear type you are assessing: hydraulic dredge (HMD), towed dredge (DRB), beam trawl (TBB), otter trawl (OT) and seine netting (SEINE).

	A	B	C	D	E	F	G	H	I	J	K
1	FID	c_square	mid_lat	mid_lon	SubsurfSA	SurfSAR	SurfSA	totweight	totvalue	KWfishing	FishingH
2	0	1500:352:2	55.375	2.525	0.065775	0.843272	14.8107	4115.989	7346.811	15093.74	10.785
3	1	1500:142:3	54.775	2.225	0.117496	1.353539	24.13193	4034.064	6290.31	19046.2	22.197
4	2	1500:352:2	55.075	2.625	0.191448	2.454467	43.435	31562.06	54453.04	43164.17	31.463
5	3	1500:141:4	54.775	1.875	0.014995	0.192239	3.427388	1510.58	2648.831	3738.85	2.021

	A	B	C
1	mid_lat	mid_lon	SurfSA
2	55.375	2.525	14.8107
3	54.775	2.225	24.13193
4	55.075	2.625	43.435
5	54.775	1.875	3.427388

	A	B	C	D
1	Latitude	Longitude	Gear	AreaSwept
2	55.375	2.525	OT	14.81069517
3	54.775	2.225	OT	24.13192611
4	55.075	2.625	OT	43.43499577
5	54.775	1.875	OT	3.427387954

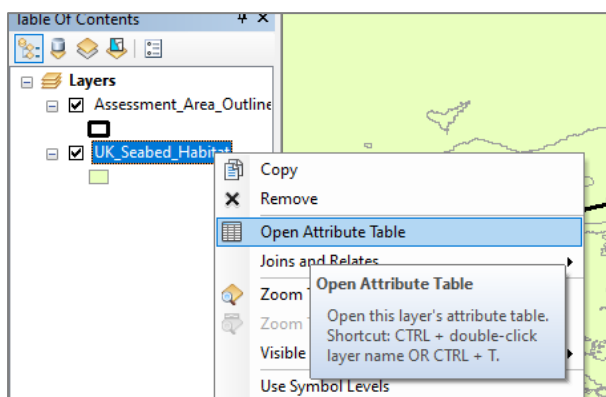
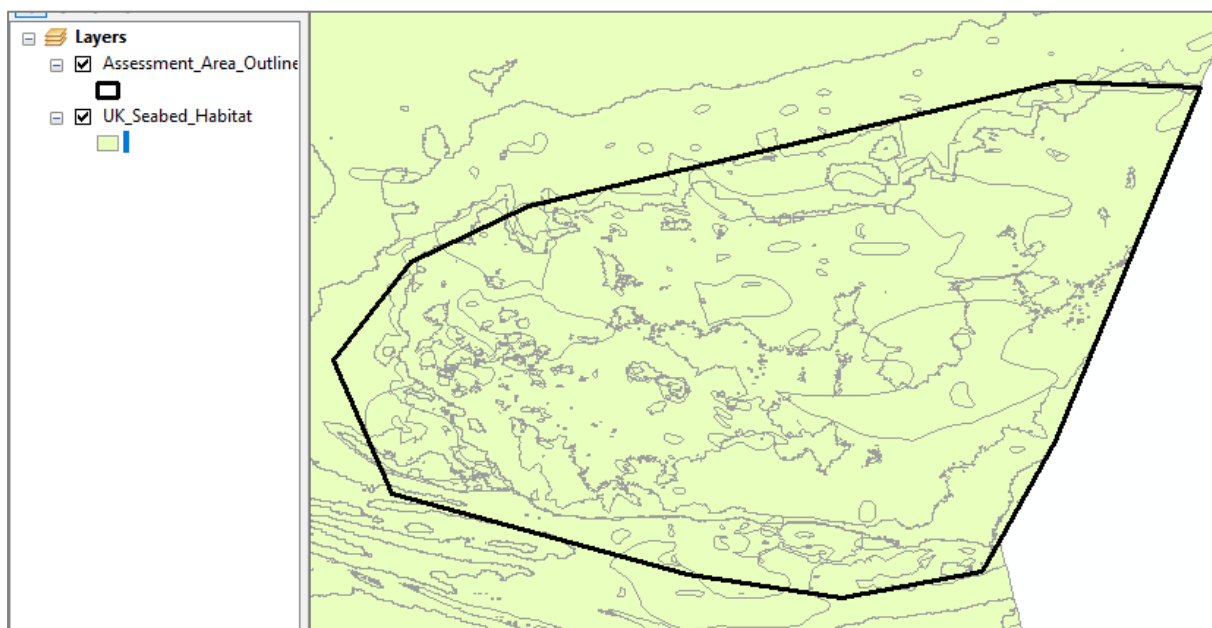
Save the changes. Now your fishing intensity data should be correctly formatted for input to the BIT.

14.3 Processing the habitat map

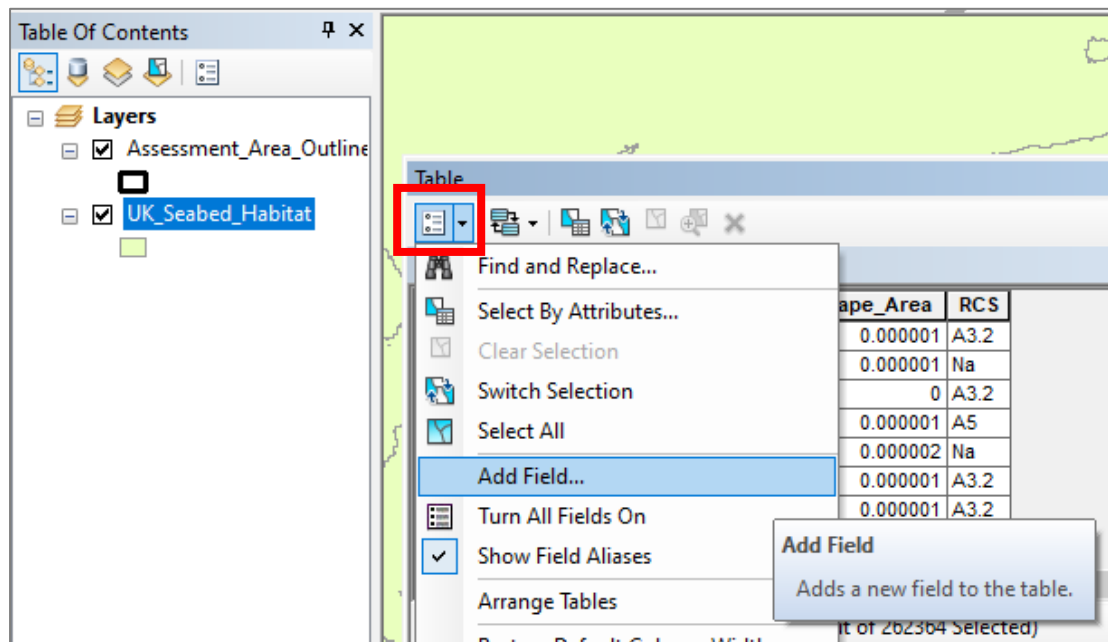
Upload the assessment area outline shapefile and your habitat data shapefile.

You must first change the name of the habitat type column to 'HabitatID'. To do this on ArcMap you must add a new column and copy the data from the habitat type column to this.

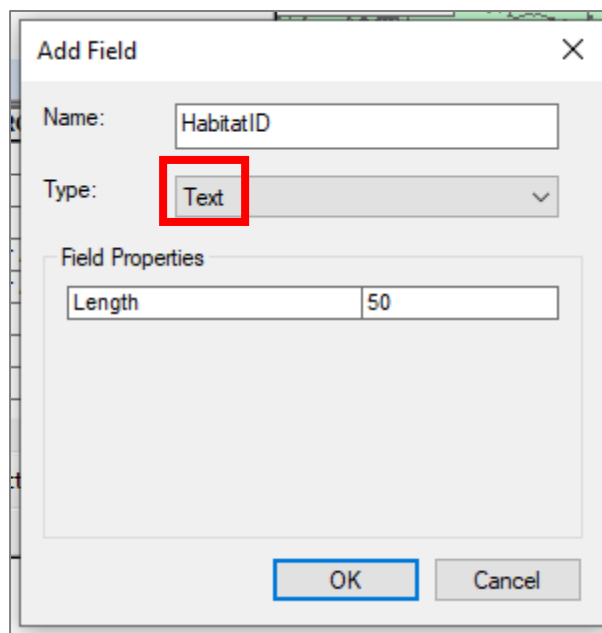
First you must right click on the habitat data layer and select 'Open Attribute Table'.



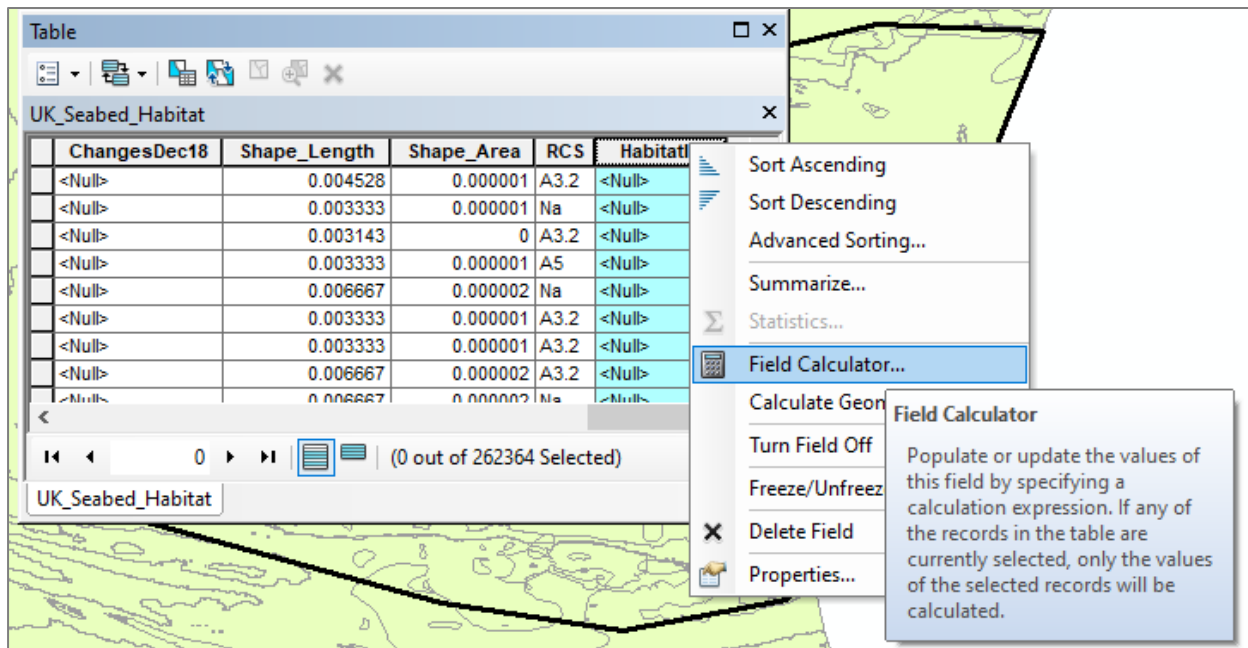
When the attribute table opens click the 'Table Options' button in the top left corner and select 'Add Field'.



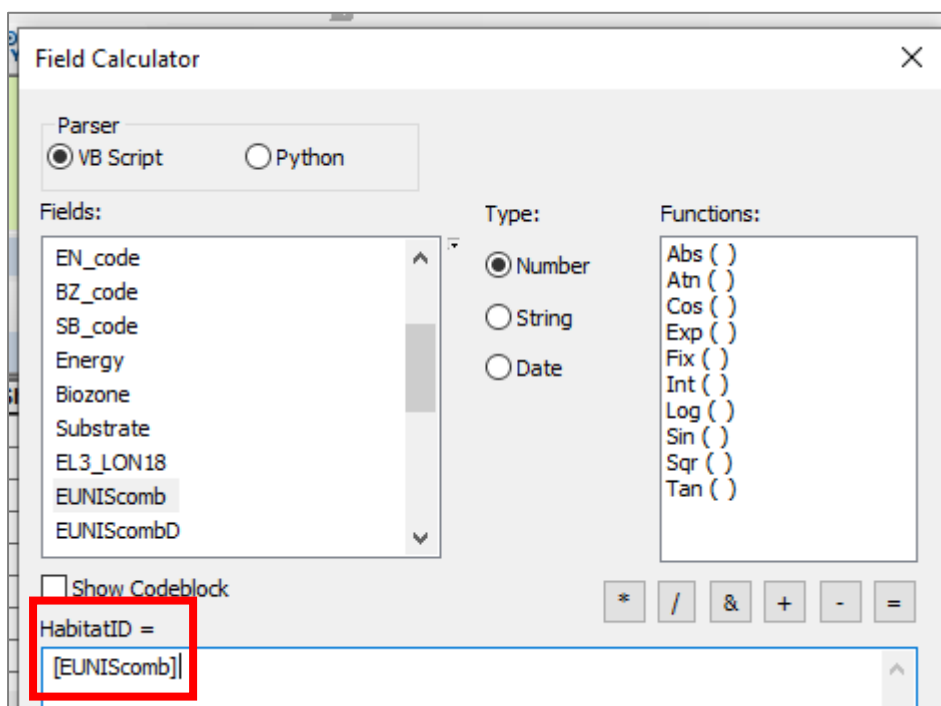
Name the field 'HabitatID' and change the 'Type' from 'Short Integer' to 'Text', using the drop down menu.



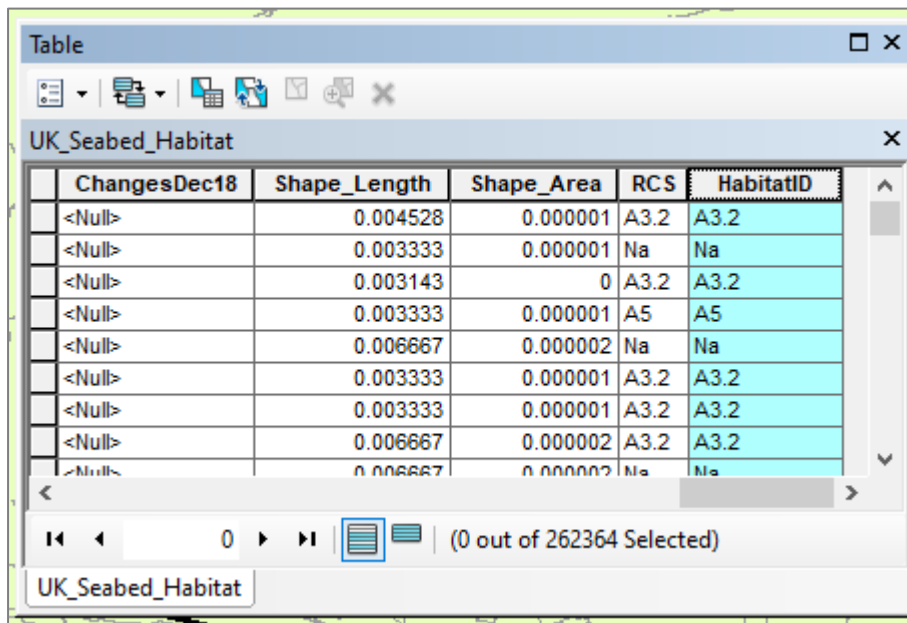
When you click OK a blank 'HabitatID' column will be added to the end of the attribute table. Right click on the 'HabitatID' column heading and select 'Field Calculator...'.



When the field calculator opens double click on the heading for the column that contains the habitat type data you want to copy to your 'HabitatID' column. This should appear in the white box below 'HabitatID='. Alternatively you could type the column heading into this box, note the square brackets around the example. Then select OK.

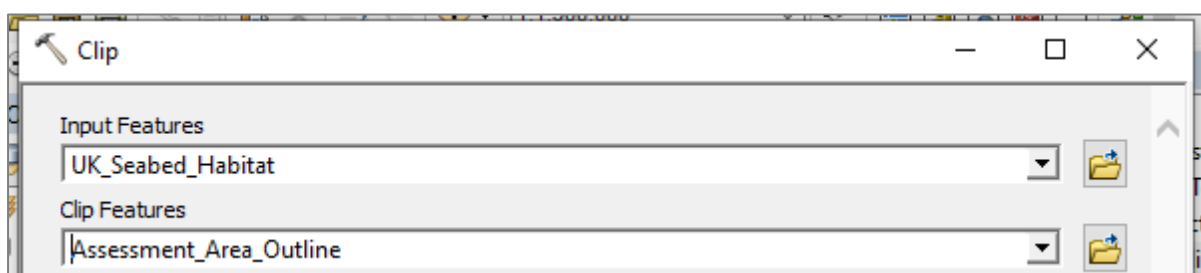
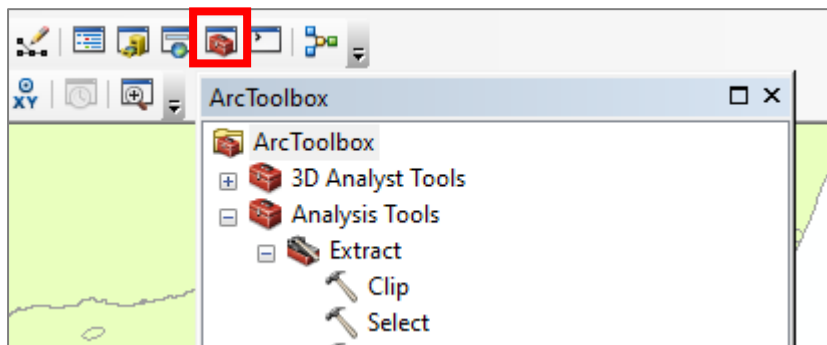


This will fill the 'HabitatID' column with the relevant data.

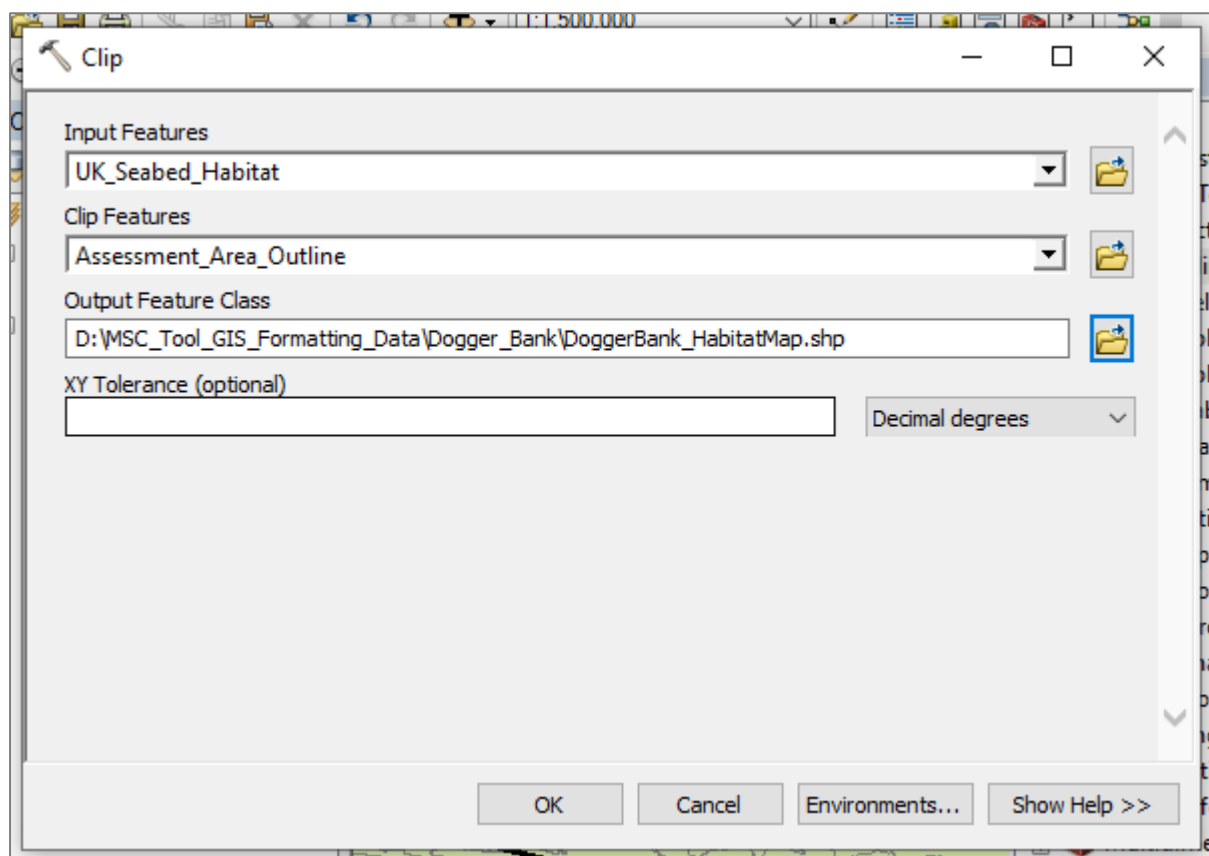
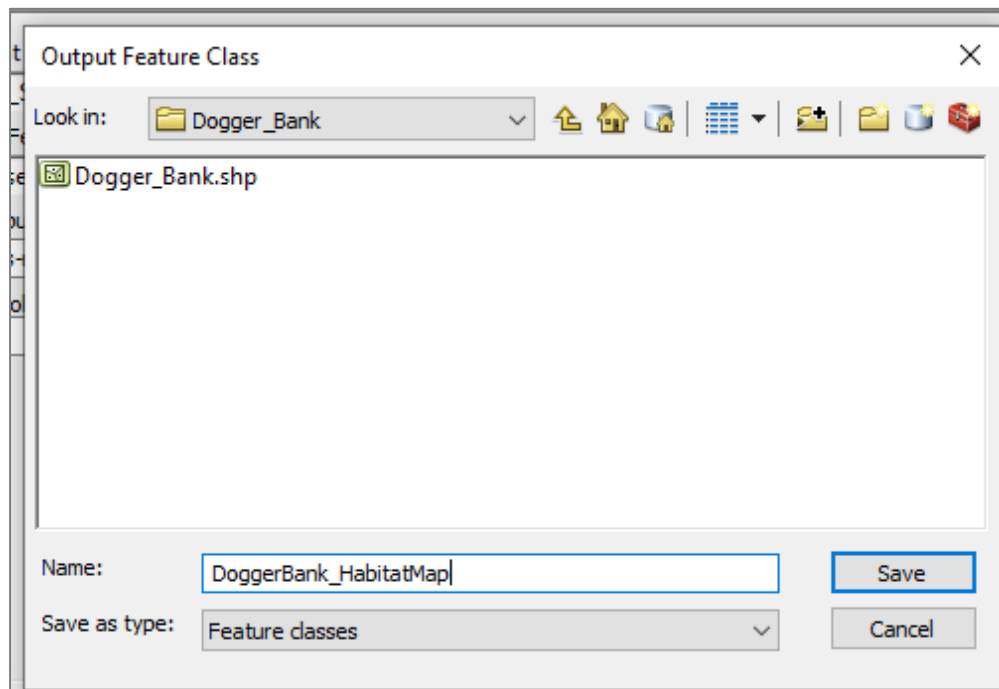


ChangesDec18	Shape_Length	Shape_Area	RCS	HabitatID
<Null>	0.004528	0.000001	A3.2	A3.2
<Null>	0.003333	0.000001	Na	Na
<Null>	0.003143	0	A3.2	A3.2
<Null>	0.003333	0.000001	A5	A5
<Null>	0.006667	0.000002	Na	Na
<Null>	0.003333	0.000001	A3.2	A3.2
<Null>	0.003333	0.000001	A3.2	A3.2
<Null>	0.006667	0.000002	A3.2	A3.2
<Null>	0.006667	0.000002	Na	Na
<Null>	0.006667	0.000002	Na	Na

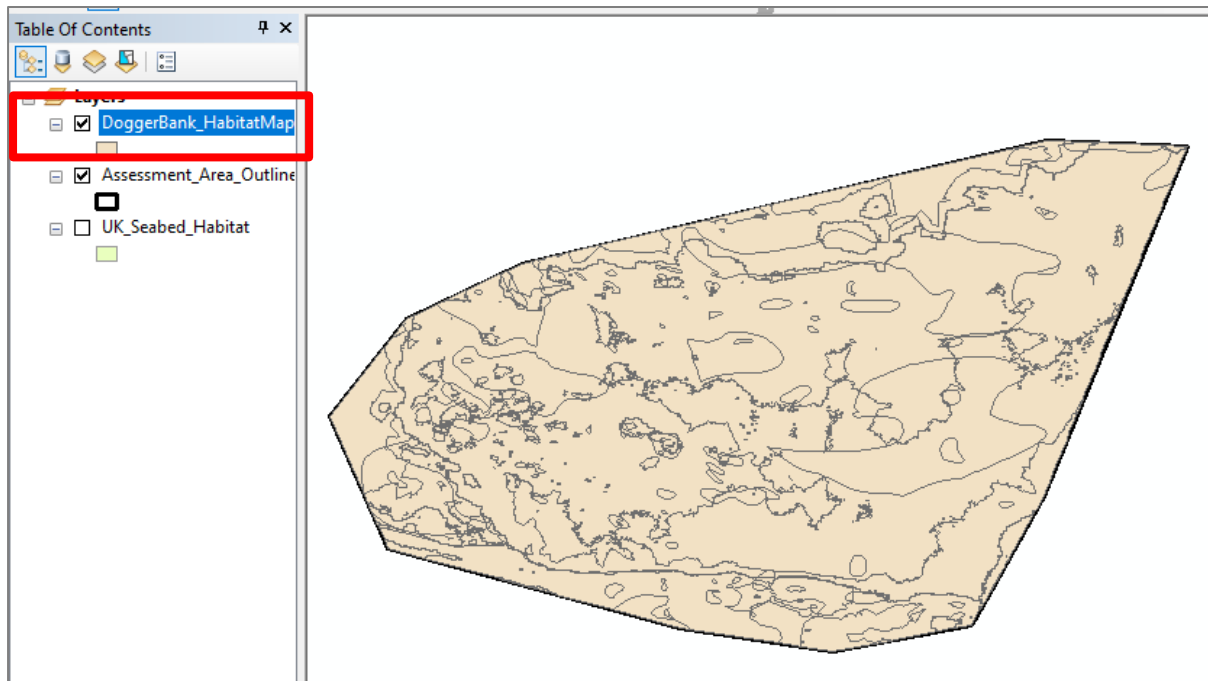
You then want to clip the habitat data to the assessment area outline. Click on the 'Arc Toolbox', select 'Analysis Tools', 'Extract' and then 'Clip'. Then from the 'Input Features' drop down menu select your habitat data and from the 'Clip Features' drop down menu select your assessment area data.



Next select the output feature class and select an appropriate folder for your new habitat data shapefile. Name this something clear and recognisable.



If you select to add the exported data to the map as a layer then you will see the habitat data clipped to the assessment area outline. You will find the shapefile and all relevant accessory files in the folder you selected.



al Disk (D:) > MSC_Tool_GIS_Formatting_Data > Dogger_Bank

Name	Date modified	Type	Size
Dogger_Bank.cpg	05/06/2021 11:36	CPG File	1 KB
Dogger_Bank.dbf	05/06/2021 11:36	DBF File	3 KB
Dogger_Bank.prj	05/06/2021 11:36	PRJ File	1 KB
Dogger_Bank.sbn	05/06/2021 11:36	SBN File	1 KB
Dogger_Bank.sbx	05/06/2021 11:36	SBX File	1 KB
Dogger_Bank.shp	05/06/2021 11:36	SHP File	1 KB
Dogger_Bank.shp.OAMACR111.3164.122...	14/10/2021 16:48	LOCK File	0 KB
Dogger_Bank.shp.xml	05/06/2021 11:36	XML Document	23 KB
Dogger_Bank.shx	05/06/2021 11:36	SHX File	1 KB
DoggerBank_HabitatMap.cpg	14/10/2021 16:48	CPG File	1 KB
DoggerBank_HabitatMap.dbf	14/10/2021 16:48	DBF File	4,445 KB
DoggerBank_HabitatMap.prj	14/10/2021 16:48	PRJ File	1 KB
DoggerBank_HabitatMap.sbn	14/10/2021 16:48	SBN File	14 KB
DoggerBank_HabitatMap.sbx	14/10/2021 16:48	SBX File	2 KB
DoggerBank_HabitatMap.shp	14/10/2021 16:48	SHP File	581 KB
DoggerBank_HabitatMap.shp.xml	14/10/2021 16:48	XML Document	25 KB
DoggerBank_HabitatMap.shx	14/10/2021 16:48	SHX File	11 KB

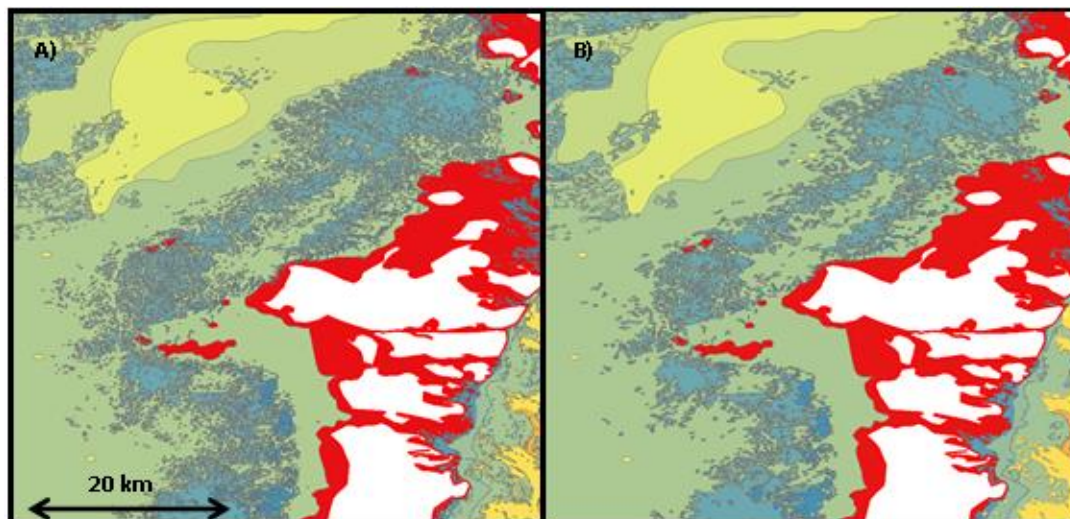
15 Methods for handling large datasets

15.1 Further habitat layer pre-processing where the Tool crashes

The below preprocessing of the habitat data can be used if the BIT crashes with your data sets. It may not be necessary for all assessments, particularly if the assessment area is small and/or the habitat data is not complex (i.e. does not have thousands of small polygons).

Some basic knowledge of using ArcMap GIS will be needed to follow this method. When using ArcMap tools always select your output location and file name first before select your input layers to increase efficiency. The following pre-processing has been tested with ArcMap 10.6 and 10.8 with an 'Advanced' licence.

The habitat data (euseamap_2021_arctic_atlantic or similar) downloaded from EMODnet may need preprocessing to make it suitable for use with the BIT (Benthic Impact Tool). If the BIT fails during SAR or RBS calculation or plotting, then it indicates your habitat data will likely need preprocessing. The preprocessing consists of removing polygons $<0.25 \text{ km}^2$ (or any size you decide is appropriate) due to the large number of extremely small polygons that can be present in the habitat data from both processing artifacts in producing the data by EMODnet or the data providers and un-needed data detail such as exposure and energy categories for each EUNIS habitat. It must be considered that the below processing will change the habitat data areas. The effect of the preprocessing on the area of each EUNIS habitat type can be easily compared quantitatively by comparing the 'raw' data habitat areas with those of the final processed data to be used in the BIT. For example, the changes from preprocessing were not significant for the habitats involved in the *Nephrops* fishery assessment which is focussed on muddy sublittoral habitats. However, the removal of small polygons conducted during the below preprocessing steps has more of an effect on very patchy habitats in the data such as hard substrata EUNIS A3 and A4, and so the preprocessing may not be suitable for all BIT applications.



Example of the outcome of the habitat data pre-processing A) before removal of $<0.25 \text{ km}^2$ polygons and B) afterwards. The blue circalittoral rock substrata can be seen to have consolidated with less patchy habitats not affected. The white areas are land and the red polygons are 'Na' classed habitats.

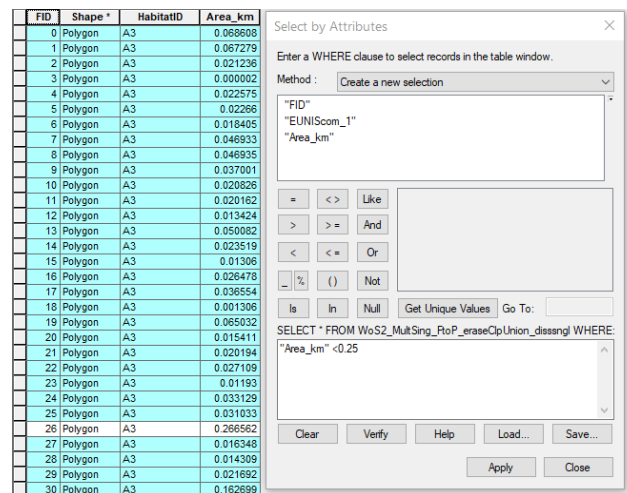
1. Use the 'Multipart to Singlepart' tool (Data Management toolbox>Features toolset>Multipart To Singlepart) to make sure all polygons in you habitat layer are singlepart features, and therefore have a row in the attributes table and can have their area calculated. Use your 'Hab_clip.shp' as input. You can save the output as 'Hab_clip_MtoS.shp'.

2. You need to create a text 'HabitatID' field in the 'Hab_clip_MtoS.shp' attribute table and populate it with the 'EUNIScomb' field data if this is not already present.
3. Now to consolidate the data so only the EUNIS information is kept, use the 'Dissolve' tool (Geoprocessing Tools>Data Management toolbox>Generalization toolset>Dissolve). Your input will be the product of stage 2 'Hab_clip_MtoS.shp' and save your output as 'Hab_clip_MtoS_diss.shp'. Select 'HabitatID' in the 'Dissolve_Field(s) (optional)' box and make sure 'Create multipart features (optional)' is unchecked.
4. In the attribute table of 'Hab_clip_MtoS_diss.shp' from stage 3 create a new numeric field ('double' works) called 'Area_km2'. Select this field and right click and then use the 'calculate geometry' function (accessed by right clicking) to calculate the area of each polygon with kilometres square selected as the units.

FID	Shape *	HabitatID	Area_km
0	Polygon	A3	0.068608
1	Polygon	A3	0.067279
2	Polygon	A3	0.021236
3	Polygon	A3	0.000002
4	Polygon	A3	0.022575
5	Polygon	A3	0.02266
6	Polygon	A3	0.018405
7	Polygon	A3	0.046933
8	Polygon	A3	0.046935
9	Polygon	A3	0.037001
10	Polygon	A3	0.020826
11	Polygon	A3	0.020162
12	Polygon	A3	0.013424
13	Polygon	A3	0.050082
14	Polygon	A3	0.023519
15	Polygon	A3	0.01306
16	Polygon	A3	0.028478
17	Polygon	A3	0.036554
18	Polygon	A3	0.001306
19	Polygon	A3	0.065032

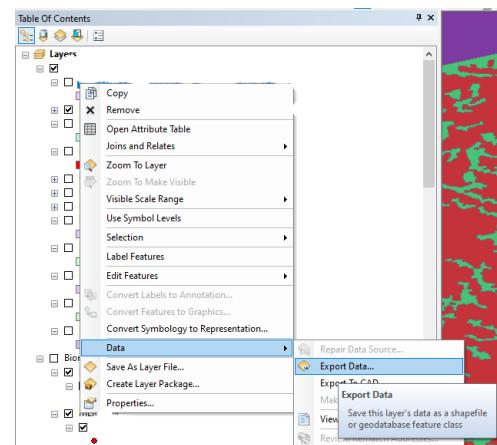
Example of calculating the area of each polygon in km²

5. Now the 'Eliminate' tool will be used twice to remove almost all the polygons that are <0.25 km² in area (or an area appropriate for your data). You must remember to recalculate the polygon areas after each use of the 'Eliminate' tool. In the 'Hab_clip_MtoS_diss.shp' attribute table use the 'select by attributes tool' to enter ' "Area_km2" <0.25 ' to select all polygons with an area less than 0.25 km km². You will notice that this may constitute are a very high proportion of the total number of polygons. Now keeping that selection use the 'Eliminate' tool (Data Management toolbox>Generalization toolset>Eliminate) and use 'Hab_clip_MtoS_diss.shp' with your selection applied as your input and save your output as 'Hab_clip_MtoS_diss_Elim0.25km_1.shp' with 'Eliminating polygon by border (optional)' unchecked, although this can be kept checked as long it is used consistently.



Example of using the 'Select by Attributes' function to select all polygons < 0.25 km²

6. Now with the output of stage 5 you must recalculate the area in the attribute table, select all <0.25 km² polygons and use the 'Eliminate' tool again saving your output as 'Hab_clip_MtoS_diss_Elim0.25km_2.shp'. This is done as more small polygons remain and can even be created during stage 5.
7. Now recalculated the area again in the attribute table of 'Hab_clip_MtoS_diss_Elim0.25km_2.shp' and select the <0.25 km² polygons as above. You should only now see a small number (hopefully less than 20) of polygons remaining. However, the 'Eliminate' tool does not remove isolated polygons which can occur near the boundaries of your assessment area near coast lines, which can still leave large numbers of small polygons. To remove these, select the polygons <0.25 km² in area using 'select by attribute' as before, but this time reverse the selection using the 'Switch Selection' button. You can then right click on the layer in the table of contents and export the selected polygons which will be all the habitat data without the <0.25 km² isolated polygons. You could save the output as 'Hab_clip_MtoS_diss_Elim0.25km_3.shp'
8. The final stage is to use the dissolve tool again as in stage 3. Use the 'Dissolve' tool (Geoprocessing Tools>Data Management toolbox>Generalization toolset>Dissolve). Your input will be the product of stage 7 'Hab_clip_MtoS_diss_Elim0.25km_3.shp' and save your output as 'Hab_clip_MtoS_diss_Elim0.25km_3_diss.shp'. Select 'HabitatID' in the 'Dissolve_Field(s) (optional)' box and make sure 'Create multipart features (optional)' is unchecked. This output shapefile will be what you use in the BIT tool.
9. The BIT tool projects the habitat data into WGS1984 as part of the processing. But you can do this manually beforehand using 'Project' (Data Management toolbox>Projections and Transformations toolset>Project) if desired.



16 Helpdesk information

For help with the use or application of the Benthic Impact Tool, contact fisheries@msc.org.

The Benthic Impacts Tool and User Manual were developed and compiled by Lowri Evans, Jennifer Shepperson, Fiona Gilmour and Jan G. Hiddink (Principal Investigator) at Bangor University.

The Benthic Impacts Tool project was managed and coordinated by Shaun McLennan and Elise Quinn at the Marine Stewardship Council.

