Cumulative Impact Mapping Model - Toolbox User Guide

Fisheries and Oceans Canada

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1. Introduction

1.1. Cumulative Impact Mapping

Cumulative impact mapping is an established, spatially-explicit method to analyse and illustrate the cumulative effects of human activities on marine ecosystems. Essentially, the model identifies areas where activities and components intersect, applies a vulnerability metric to determine the impact score for each intersection, and then sums the impacts across all activities and components for each grid cell to produce a cumulative impact map. The method can be applied to study areas of varying size and can accommodate data of varying detail and resolution. Cumulative impact mapping can have various applications; it can be used to identify hotspots of high and low impact, analyze how increased protection in certain areas might help alleviate pressures on any habitats or species of interest, to inform marine spatial planning, and to stratify survey effort across a gradient of impact (Murray et al. 2022).

The model is a relatively simple additive cumulative effects model originally developed by Halpern and colleagues (Halpern et al. 2008b) and has since been applied at global scales (Halpern et al. 2007; Halpern et al. 2008a; Halpern et al. 2019; Halpern et al. 2015; O'Hara et al. 2021) and regionally around the world (Afflerbach et al. 2017; Agbayani et al. 2015; Andersen et al. 2015; Andersen et al. 2017; Ban et al. 2010; Clarke Murray et al. 2015a; Clarke Murray et al. 2015b; Halpern et al. 2009; Kappel et al. 2012; Micheli et al. 2013; Perry 2019; Selkoe et al. 2009; Singh et al. 2020).

The model requires three types of spatially-explicit data: i) human activities, ii) ecosystem components of interest (e.g., habitats, species, ecosystem services), and iii) the vulnerability of each component to each activity.

The human activities that affect marine ecosystems can originate in the ocean, at the coastal interface and on land. Further, the human activity data can take different forms, from the point location of mining operations to the lines of shipping tracks, and the footprint of aquaculture farms. Thus, these activity types are treated differently in the cumulative impact mapping toolbox; prepared in different ways and run through separate tools.

The majority of applications focus on impacts to habitats, as useful proxies for the ecosystems they support. Benthic (seafloor), pelagic (water column), and biogenic (living) habitats, such as seagrass and kelp, have typically been included in the model. A limited number of applications have applied the model to species ranges, food webs, and ecosystem services (Beauchesne et al. 2021; Hammar et al. 2020; Maxwell et al. 2013; O'Hara et al. 2021; Singh et al. 2020; Trew et al. 2019).

The vulnerability metric translates the impact of an activity on a species ecosystem component and in this method, takes the form of a matrix of semi-quantitative scores. Most vulnerability scores have been developed through expert elicitation (Halpern et al. 2007; Murray et al. 2022; Teck et al. 2010) and/or literature review (Maxwell et al. 2013).

The Cumulative Impact Mapping (CIM) tool can model cumulative effects for three different scenarios (current, future, protected) across all activities and habitats of interest, and is based on an analysis conducted by Clarke Murray et al. (2015a; 2015b). The user can apply any or all of the scenarios during the analysis (see Section 8.3).

The goal of this cumulative impact mapping toolbox is to automate and standardize the application of the method, allowing users to produce cumulative impact maps more easily for a variety of applications. Here we detail the toolbox and its components for a user with moderate GIS skills and access to ESRI's ArcGIS Pro with the Spatial Analyst extension (ESRI 2021).

1.2. Structure of the User Guide

The purpose of the user guide is to provide guidance for users on how to run the Cumulative Impact analysis using the CI toolboxes. The first chapters are dedicated to outlining the data structure of the tool and explaining what the inputs represent. This is followed by four chapters that outline the analysis steps of each of the toolboxes, including detailed descriptions of each input variable.

Please note that redundancy is built into the structure of the User Guide so that a user can follow along in the analysis, through Help Documentation within the toolboxes, without having to flip pages of the User Guide. This means that details for input variables that are used across multiple steps in the analysis are described multiple times in the Help Documentation.

Glossaries on codes and abbreviations are provided in Chapter 8.

1.3. Cumulative Impact Mapping Python Toolboxes

Four toolboxes were developed to standardize the cumulative impacts model:

- Data Preparation: pre-processing for use of other tools
- Land Impacts (LI) on the marine: used for kernel density analysis from estuaries
- Coastal Kernel Density (KD): used for cumulative impacts on marine coast (line and point data).
- Marine Footprint (MF): used to model cumulative impacts from activities that occur over a specific area and therefore have a "footprint effect" on habitats occurring in the same area.

Note: Users must enable the Spatial Analyst Extension for ArcGIS to be able to run the Coastal Kernel Density and Marine Footprint Toolboxes.

2. Python Toolboxes and Data Requirements

This section is dedicated to descriptions of the structure of each python toolbox and the data necessary to run the tool.

The analysis is run via multiple Python toolboxes (.pyt), one for each analysis type. The **CI_Data_Preparation** toolbox is available to help users prepare the data for use in the **CI_Land_Index**, **CI_MarineFootprint** and **CI_Coastal_Kernel_Density** toolboxes.

The Land Index and Coastal Kernel Density Toolboxes were designed to process data so that the outputs can be included as inputs in Step 3 of the **CI_MarineFootprint** toolbox.

The main toolbox is the **CI_MarineFootprint** toolbox.

2.1. Structure of each Python Toolbox

Each of the models consists of several tools or “Steps”, which have all been packaged into one Python toolbox (.pyt file) as seen in Figure 1. To use this tool, connect ArcGIS Pro to the folder that contains the .pyt file. Clicking the right-facing triangle ‘ ‘ symbol on the left margin of the .pyt filename will expand the toolbox and display all the tools contained within the toolbox.

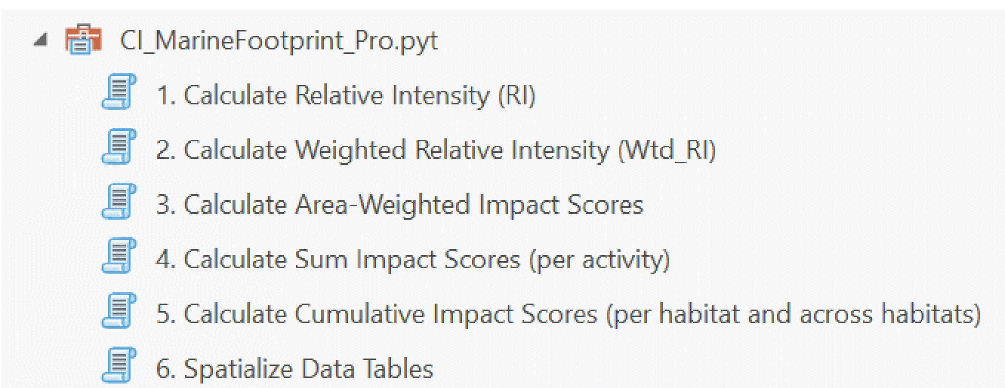

Figure 1. Marine footprint model python toolbox

2.2. Structure of each Python Tool

When the user clicks on a tool in the python toolbox, a dialog box will open, and the user will need to fill in some input variables. The user can hover over the help “” symbol to display Help Documentation describing the purpose of the tool guidance on each of the input variables (Figure 2). Hovering over the information “” symbol next to an input variable will display additional help documentation specific to that variable (Figure 3).

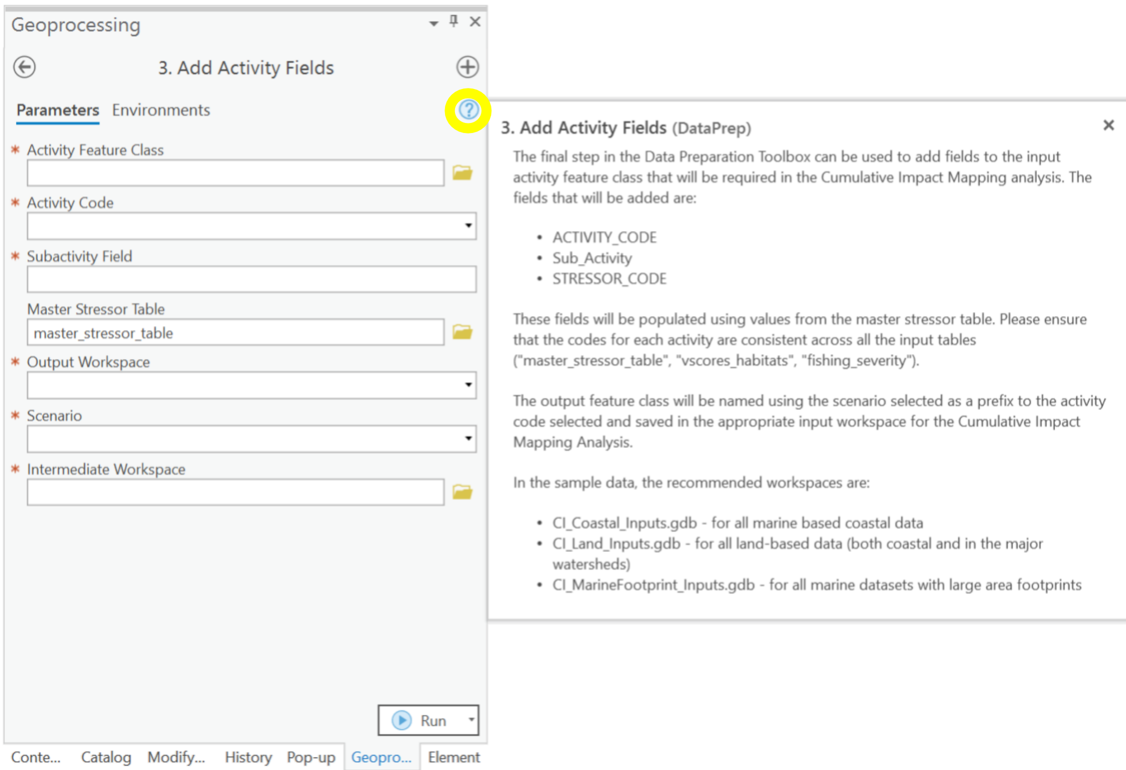

Figure 2. User interface of one tool. Hover over the "?" to show the pop-up help window. Required inputs are denoted with red asterisks "*".

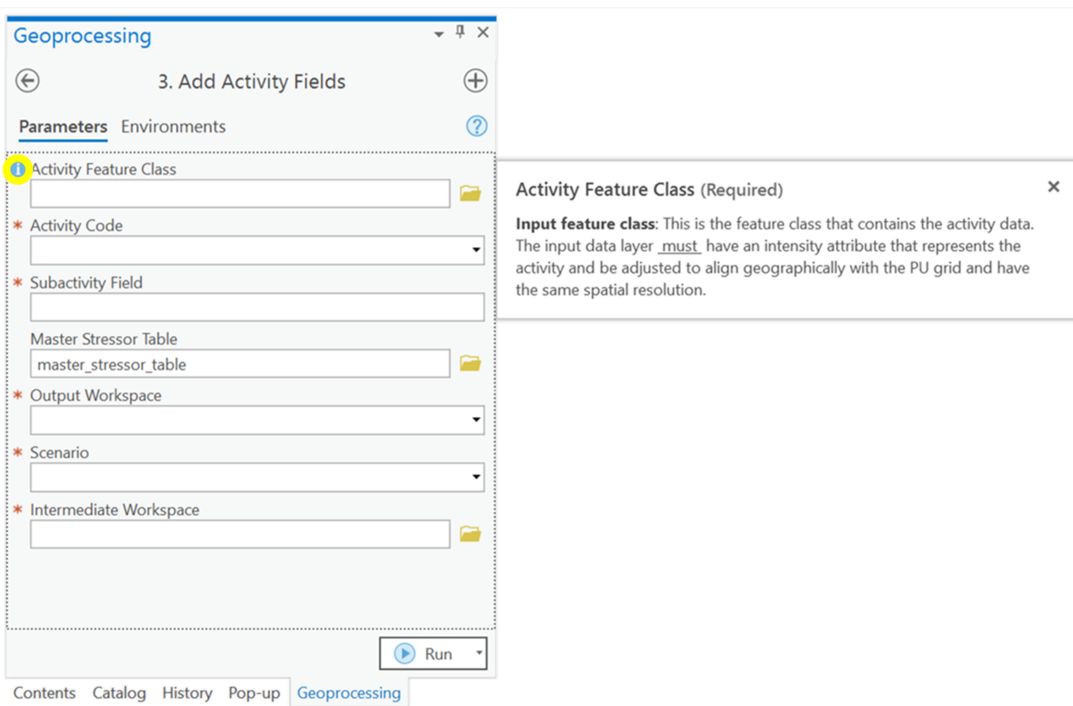

Figure 3. User interface of one tool. Hover over the left side of each parameter to show the pop-up parameter help tips. Required inputs are denoted with red asterisks "*".

Parameters errors are indicated by a white X in a red circle (Figure 4). Hovering over the symbol will show the pop-up windows that contain information about the error.

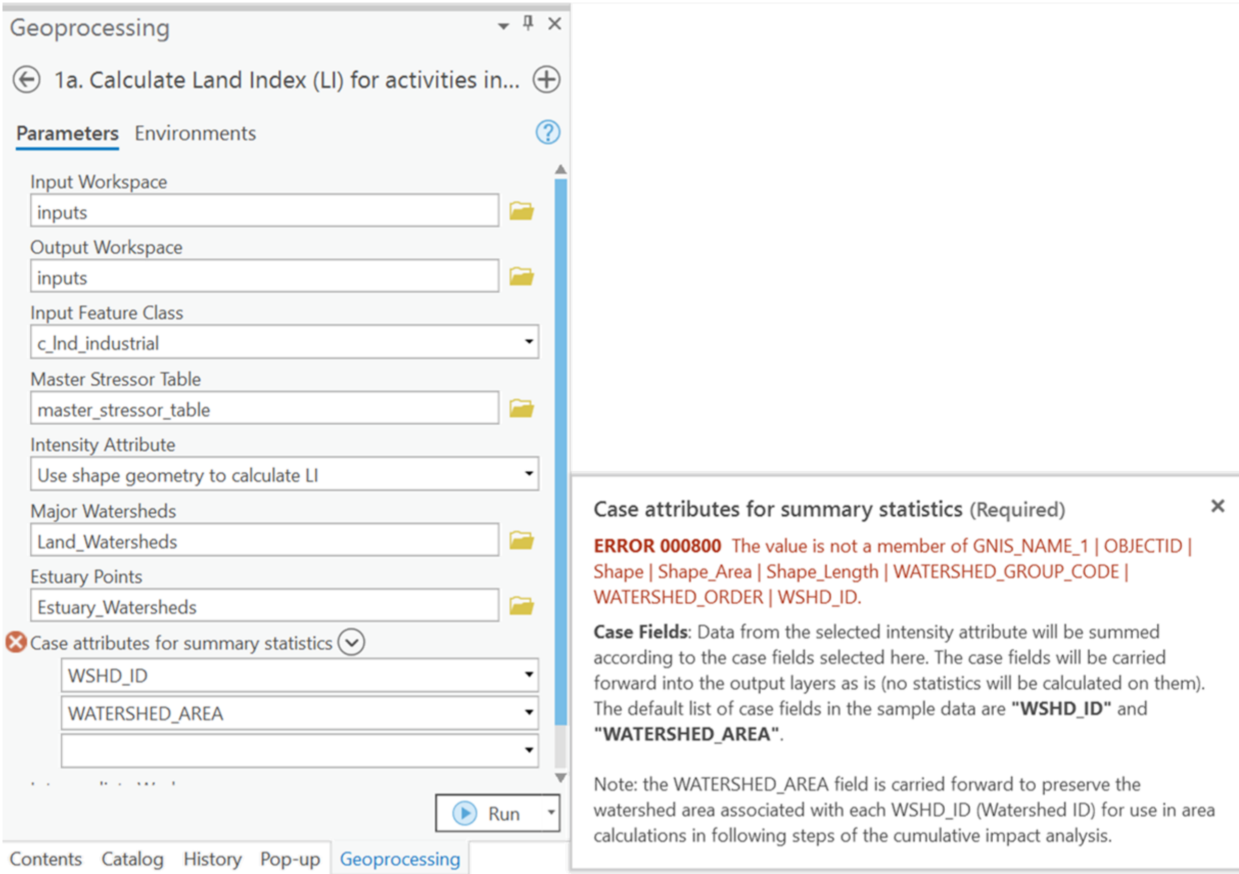

Figure 4. Parameter errors are indicated with a white X in a red circle. Hover over the red and white symbol to show the help tips pop-up with details regarding the error. In the example shown, the field "WATERSHED_AREA" is missing from one of the input datasets (Land_Watersheds or Estuary_Watershed).

Once the user enters all the required parameters, and clicks "Run", the progress of the tool can be found by clicking the "View Details" link at the bottom of the dialog (Figure 5). In the pop-up window, the "Parameters" tab shows the user-entered parameters for that run, and the "Messages" tab shows custom user messages indicating real-time progress, including warnings and error messages.

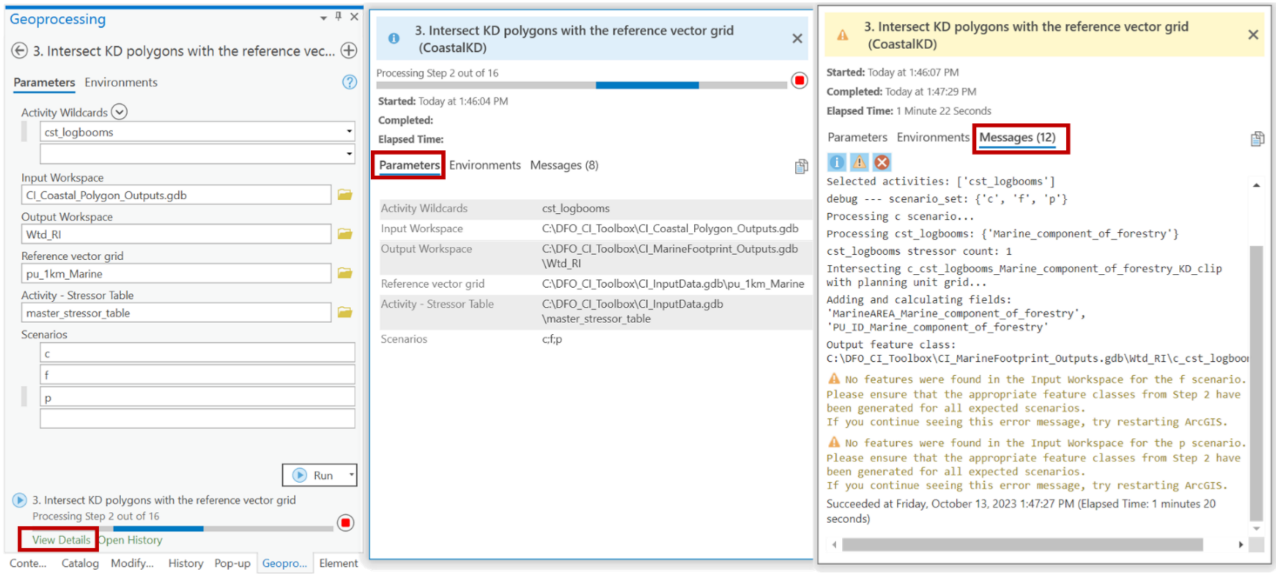

Figure 5. Screenshots of Details pop-up window, showing parameter and user messages. Click on the View Details link at the bottom of the Geoprocessing window to show the Details pop-up. Click on the Parameters tab to show the parameter values and click the Messages tab to show all user messages, including warning and error messages.

2.3. File structure: DFO_CI_Toolbox

The toolboxes are coded using relative paths, therefore all the toolboxes and associated spatial data must be saved in a directory named "DFO_CI_Toolbox". It is recommended that this folder be saved in a parent directory with a short path (e.g., C:\ or C:\WORK) to keep the data path lengths manageable throughout the analysis.

Note: All the python toolboxes (.pyt) must be placed in the same directory as the spatial datasets. Each python toolbox is accompanied by a series of .xml files which contain help metadata (Figure 6). Please do not delete these files – this will result in deleting the help information in the pop-up windows in the user interface of the tool.

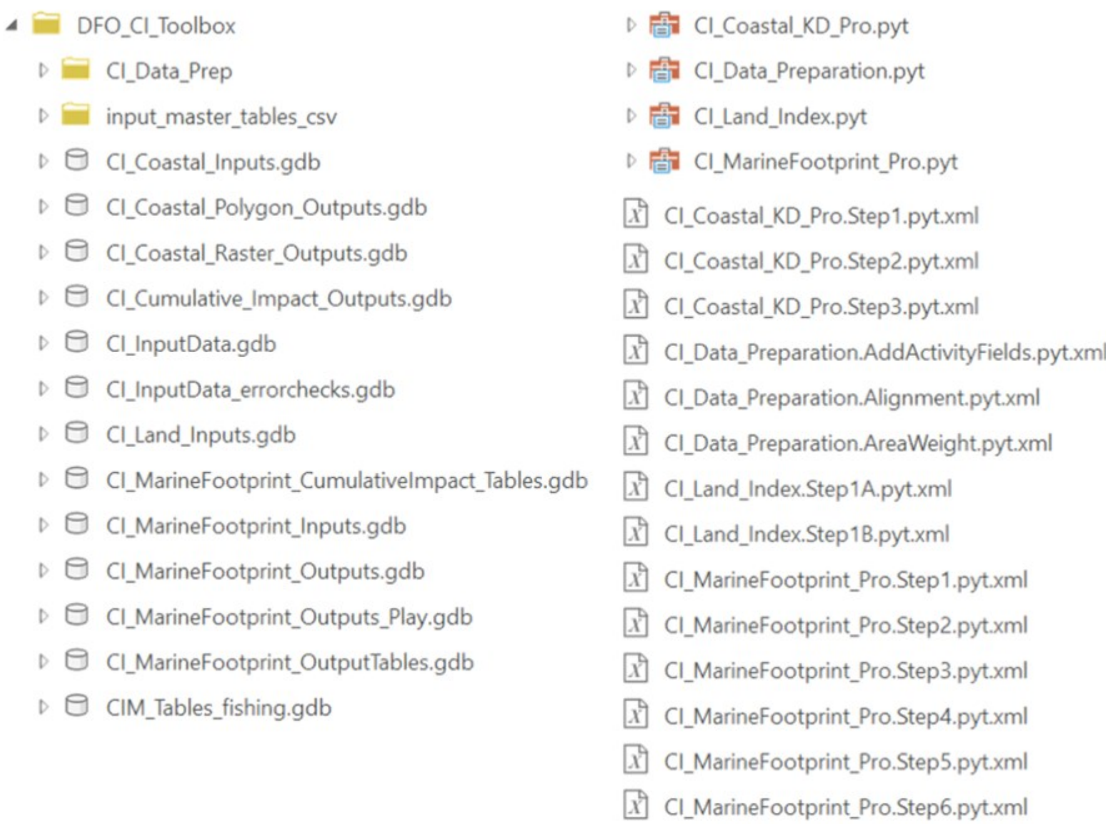

Figure 6. Screenshots of sample folder setup. with python toolboxes and the associated geodatabases. Note: The xml files associated with each .pyt contain the help metadata for the toolboxes—please do not delete the xml files.

2.4. Input Data

Master input datasets

There are a number of master input datasets that are required for the analysis. These are saved in the main input workspace "CI_InputData.gdb" (Figure 7). This geodatabase contains base layers such as the reference grids (vector and raster), estuaries, and watersheds, habitat feature classes, activity limit features, and the master input tables (vulnerability scores matrix, the master stressor table, and the fishing severity table).

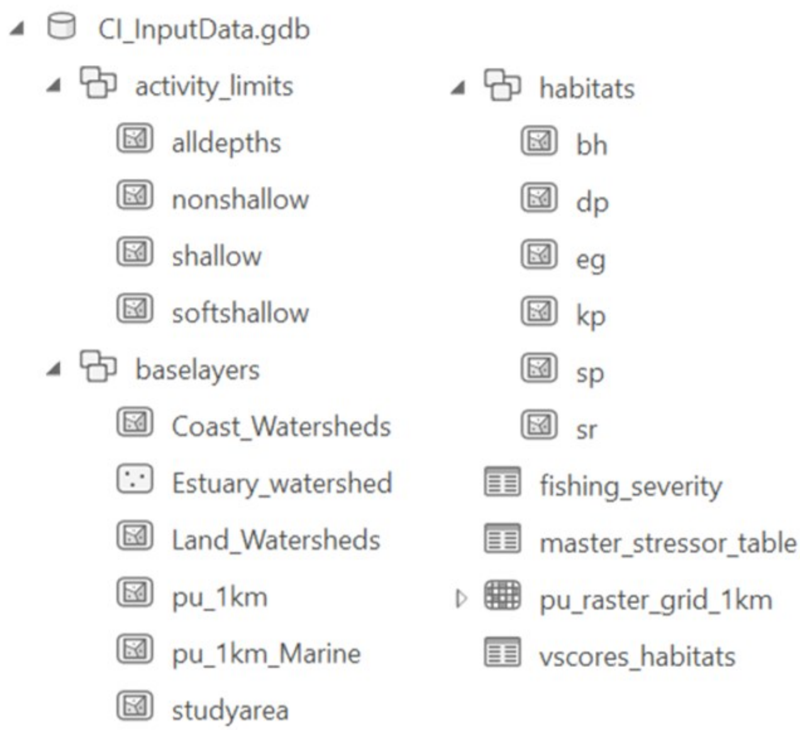

Figure 7. Screenshot of the sample datasets within the input workspace "CI_InputData.gdb".

Base layers

The baselayers feature dataset contains:

- the reference vector grids, i.e., the 1km Planning Unit grids (pu_1km and pu_1km_Marine),
- watersheds along the coast of stream order 6 or less (coastal_watersheds),
- major watersheds of stream order 7 or greater that flow into the Canadian Pacific (land_watersheds),
- estuary locations for the land_watersheds (estuary_points).

Each of the base layer feature classes (baselayers) have specific fields that will be used in the analysis, which are described in Table 1.

Table 1. Descriptions of important fields in baselayers feature classes.

Feature class	Key Field names	Description
pu_1km	UNIT_ID	Unique identifier for each planning unit
	PU_AREA	Area (m^2) of a 1x1 km planning unit, including areas that may fall on land.
pu_1km_Marine	UNIT_ID	Unique identifier for each planning unit
	MarineAREA	Area (m^2) of the planning unit when land is excluded.

Feature class	Key Field names	Description
Coast_Watersheds	WATERSHED_GROUP_CODE	4-digit code associated with the watershed where the estuary is located.
	WATERSHED_ORDER	Watershed order (the largest stream order within the watershed).
Land_Watersheds	WATERSHED_GROUP_CODE	4-digit code associated with the watershed where the estuary is located.
	GNIS_NAME_1	Common Name of the river system associated with the estuary.
	WATERSHED_ORDER	Watershed order (the largest stream order within the watershed).
	WSHD_ID	Unique identifier assigned to a watershed. Used to join estuary to watershed during land index analysis.
Estuary_watershed	NAME	Name of the watershed from which streams flow into the estuary.
	L_ORDER	Watershed order (the largest stream order within the watershed).
	WATERSHED_AREA	Area of the watershed (m^2).
	BUFFER_DIST	Estimated maximum distance (m) from the estuary that impacts may travel.
	WSHD_ID	Unique identifier assigned to a watershed. Used to join estuary to watershed during land index.

The land index base layers represent coastal watersheds, major watersheds inland, and all the associated estuaries. The "**Coast_Watersheds**" base layer represents watersheds of stream order 6 or less with estuaries flowing into the Canadian Pacific, while the "**Land_Watersheds**" represent major watersheds with stream order 7 or higher, with estuaries flowing into the Canadian Pacific. The "**Estuary_watershed**" base layer represents the point locations of the estuaries for each of the major watersheds represented in "**Land_Watersheds**". These base layers were derived from BC Freshwater Atlas (Province of British Columbia 2008).

The "**pu_1km**" base layer is equivalent to the DFO_1km_grid feature class. The grid is used by DFO Oceans Management for managing data in planning, and fisheries data management. The area covered by the PU grid covers the entirety of the Canadian Pacific Economic Exclusion Zone (EEZ). A complementary raster grid "**pu_raster_grid_1km**" is also available in the

CI_InputData.gdb to support alignment of raster datasets to the "**pu_1km_grid**" in the analysis.

The "**pu_1km_Marine**" base layer was created by intersecting the Pacific Ocean Polygon with the DFO_1km_grid. Represents the PU grid, but only considering areas that are marine (i.e., any portion of a grid cell that is on land is removed).

The "**studyarea**" base layer creates a large polygon overlapping much of the BC coast.

Habitats

The habitat classes provided in the sample dataset is a coastwide dataset which includes biogenic, benthic, and pelagic habitats (Agbayani and Murray, in prep). These data are in the habitats feature dataset of the "CI_Input_Data.gdb" geodatabase in the sample dataset.

The cumulative impact toolboxes will process each habitat feature class under the assumption that the features within each feature class are spatially exclusive with no overlaps. **Please separate any features that may overlap into a different habitat feature class**.

For example, all biogenic habitats are separated into their own feature class because they overlap with the benthic feature classes. All pelagic habitats are separated into their own feature classes because they overlap with the biogenic and benthic feature classes.

Descriptions of the codes used to name the habitat feature classes provided in the sample dataset are listed in Table 2, and the descriptions of the habitat codes for spatially exclusive habitats within each feature class are listed in Table 3.

Table 2. Code descriptions for habitat feature classes in the habitats feature dataset.

Habitat feature class	Description
bh	Benthic habitats
dp	Deep pelagic (>30m)
eg	Eelgrass
kp	Kelp
sp	Shallow pelagic / surface waters (<30m)
sr	Sponge reefs

Table 3. Code descriptions for HabitatCODE field in habitat feature classes.

Habitat type	Habitat feature class	HabitatCODE	Description
Biogenic habitats	eg	SEAG	Eelgrass
	kp	KELP	Kelp

Habitat type	Habitat feature class	HabitatCODE	Description
	sr	SPONGE	Sponge Reefs
Benthic habitats	bh	SITDL	Soft intertidal
		MITDL	Mixed Intertidal
		HITDL	Hard intertidal
		UITDL	Undefined intertidal
		SSHLW	Soft Shallow
		MSHLW	Mixed Shallow
		HSHLW	Hard Shallow
		USHLW	Undefined Shallow
		SSHLF	Soft Shelf
		MSHLF	Mixed Shelf
		HSHLF	Hard Shelf
		USHLF	Undefined Shelf
		SCANYON	Soft Canyons
		MCANYON	Mixed Canyons
		HCANYON	Hard Canyons
		UCANYON	Undefined Canyons
		SSLOPE	Soft Slope
		MSLOPE	Mixed Slope
		HSLOPE	Hard Slope
		USLOPE	Undefined Slope
		SDEEP	Soft Deep
		MDEEP	Mixed Deep
		HDEEP	Hard Deep
		UDEEP	Undefined Deep
		SHILL	Soft Hill
		MHILL	Mixed Hill
		HHILL	Hard Hill
		UHILL	Undefined Hill
		SKNOLL	Soft Knoll
		MKNOLL	Mixed Knoll
		HKNOLL	Hard Knoll
		UKNOLL	Undefined Knoll
		SSEAMT	Soft Seamount

Habitat type	Habitat feature class	HabitatCODE	Description
		MSEAMT	Mixed Seamount
		HSEAMT	Hard Seamount
		USEAMT	Undefined Seamount
Pelagic habitats	sp	SPELAGIC	Shallow Pelagic
	dp	DPELAGIC	Deep Pelagic

Activity Limits

Activity Limits (activity_limits) are polygon features representing the potential spatial boundaries of activities. These data can be used to spatially refine activity data for area-weighting. Limiting activity data is useful where data available are coarse in resolution and it may be helpful to limit the area of the activity to areas where they may logically occur. For example, geoduck fishing may occur in soft shallow habitats only, or sablefish trap or longline fishing may occur in non-shallow areas (deeper than 30 metres) only.

- The "softshallow" activity limits are areas shallower than 30 metres, with soft or mixed substrates.
- The "shallow" activity limits are areas shallower than 30 metres, regardless of substrate.
- The "nonshallow" activity limits are areas deeper than 30 metres, regardless of substrate.
- The "alldepths" feature class represents the entire study area, regardless of depth.

Master Input Tables

Also included in the Input Data geodatabase are three tables which contain the master lists of activities and stressors, their associated codes, the relative weights of each stressor by sub-activity, relative severity rankings of fishing activities, and the vulnerability scores of habitats (Table 4).

Table 4. Descriptions of contents of each table in the main Input Data geodatabase.

Table Name	Description
master_stressor_table	Lists the stressors associated with each activity, the relative weights of each stressor between sub-activities, and the maximum distance stressors are assumed to travel from point/line sources, or estuaries.
fishing_severity	Relative severity rankings of effects of fishing gear on habitats (Fuller et al. 2008).

Table Name	Description
vscores_habitats	Matrix of vulnerability scores derived from expert elicitation (Murray et al. 2022).

Activity input datasets

Input activity datasets must be pre-processed using the tools in the Data Preparation Toolbox because the Toolboxes require input data to have specific fields and standardized projections. The sections below describe the unique requirements for input data in each Toolbox analysis.

Land Index Analysis

Input data for the land index analysis consists of data on activities occurring within the watershed generating stressors that travel downstream.

For land-based activities, Coastal Kernel Density tool can be run from estuaries, using a calculated land index for relative intensity, and impact distances based on the stream order of the watershed upland of the estuary.

The Land Index (LI) represents intensity of use in a watershed, and can be an intensity attribute chosen by the user (e.g., tonnes of rock mined from quarries per unit area of each watershed), or the land index can be calculated using feature geometries, for example:

- number of facilities per unit area (e.g., mines),
- distance in km per unit area (e.g., roads), or
- area of activity per unit area of watershed (e.g., agriculture).

Impact distances in this case are dependent on the stream order or volume of flow coming through the estuary. Impact distances around estuaries are included in the "Estuary_watershed" feature class, where stream order is represented under the sub-activity of the estuary point feature classes representing land-based activities in major watersheds. The required fields for each activity input dataset to be run through the Land Index Toolbox are described in Table 5.

Table 5. Required and optional fields for activity input datasets for the Land Index Analysis.

Field names	Description
Activity	Activity Code. This code must match the activity codes in the tables in the CI_InputData.gdb.
Sub_Activity	Different categories within each activity that result in different stressors or stressor intensities and have a different relative impact on your habitat. For example, a *quarry* would result in sedimentation, vs. a mine that results in the *acid rock drainage* stressor. Another example is that *paved roads* would

Field names	Description
	result in lower sedimentation levels compared to *unpaved forest resource roads*.
Stressor code	The stressor code indicates the stressor associated with the activity and sub-activity represented by the activity data. Stressor codes and the associated stressor weights by sub-activity must be entered into the master stressor table. Stressor codes can be added to the activity data using Data Prep Step 3.
Stressor weight	Stressor weights are relative intensity weights (e.g., "stressor weights") that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. Stressor weights must be entered into the master stressor table. Stressor weights can be added to the activity data using Data Prep Step 3.
{intensity field}	A measure of relative intensity for the activity is optional for the land index analysis. For example, intensity can be quantified as the annual amount of material extracted from mining facilities. If an intensity field is not available, relative intensity can be assigned using the geometry of the feature, e.g. no. of facilities, length of roads, or total area logged per unit area of watershed.

Coastal Kernel Density Analysis

Input activity data for the Coastal Kernel Density Analysis will be saved in the CI_Coastal_Inputs.gdb as an output of Step 3 of the Data Preparation Toolbox, or as an output of Step 1a or Step 1b of the Land Index Toolbox. The data appropriate for this analysis are for activities that occur in or adjacent to the marine environment.

Activities appropriate for the Coastal Kernel Density Analysis are activities known to generate stressors that are highest in intensity/concentration in the immediate vicinity of the activity and disperse away from the activity, decreasing in intensity/concentration a certain distance away. These distances are called impact distances.

Every activity dataset in the Coastal Kernel Density Analysis must also have impact distances listed in the Master Stressor table for every stressor associated with that activity. The distances listed in the table should be in units consistent with the unit of the projection of the spatial data. The required fields for activity input dataset to be run through the Coastal Kernel Density Toolbox are described in Table 6.

Table 6. Required fields for activity input datasets for the Coastal Kernel Density Analysis.

Field names	Description
Activity	Activity Code. This code must match the activity codes in the tables in the CI_InputData.gdb.
Sub_Activity	Different categories within each activity that result in different stressors or stressor intensities and have a different relative impact on your habitat. For example, sewage outfalls may release both *organic* and *inorganic* contaminants.
Stressor code	The stressor code indicates the stressor associated with the activity and sub-activity represented by the activity data. Stressor codes and the associated stressor weights by sub-activity must be entered into the master stressor table. Stressor codes can be added to the activity data using Data Prep Step 3.
Stressor weight	Stressor weights are relative intensity weights (e.g., "stressor weights") that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. Stressor weights must be entered into the master stressor table. Stressor weights can be added to the activity data using Data Prep Step 3.
{stressor weighted relative intensity/land index field}	A measure of relative intensity (RI) or land index (LI) for the activity multiplied by the stressor weight for the associated sub-activity. For example, intensity can be quantified as the no. slips in a marina, or no. of ships/container vessels that a coastal port could accommodate. The stressor weighted intensity is the RI multiplied by the relevant stressor weight for each sub-activity. For coastal marine datasets, these fields can be calculated using Data Prep Step 3 – the resultant field(s) will be named "*RI_{stressor name}*". For land-based datasets, these fields can be calculated using Land Index Step 1a (land activities in major watersheds) or 1b (land activities in coastal watersheds) – the resultant fields will be named "LI_*{stressor name}*".
Impact distance	An impact distance value must be entered in the master stressor table. For land-based activities in major watersheds, the impact distance will be assigned based on the stream order of the watershed.

Each activity feature class in the Coastal Kernel Density Analysis must be in a line or point feature class. If the original data exists in a polygon format, consider whether the data is better suited to be run through the Marine Footprint tool. If the Coastal Kernel Density tool is the most appropriate tool considering the way the stressor interacts with the system, the tool will convert the feature class to polylines before running the activity feature class through the kernel density analysis.

Marine Footprint Analysis

Input data for the Marine Footprint Analysis are activity datasets that are characterized to have an area-based footprint in marine habitats. The Land Index Toolbox and the Coastal Kernel Density Toolbox transform activity data from the watersheds and the coast into polygon features and these outputs are inserted into the Marine Footprint Analysis at Step 3.

The required fields for activity input datasets are listed in Table 7.

Before being run through the Marine Footprint Toolbox, each activity dataset in the Marine Footprint Analysis must be run through the area-weighting tool in the Data Preparation Toolbox. The activity data will be intersected with the marine planning units feature class (not including land) and the geometry area or "SHAPE@AREA" of each feature will be calculated to "Shape_AREA". The MarineAREA_WT of the activity is the proportion of the *marine area of the activity,* i.e., "Shape_AREA" in relation to the *marine area of the reference vector grid,* i.e., "MarineAREA", a field inherited from the reference vector grid "**pu_1km_marine**". The "MarineAREA_WT" is then calculated by dividing the activity's "Shape_AREA" with the "MarineAREA" field.

Table 7. Required fields for activity input datasets for the Marine Footprint Analysis.

Field names	Description
Activity	Activity Code. This code must match the activity codes in the tables in the CI_InputData.gdb.
Sub_Activity	Sub_Activity represents the different practices within each activity which result in different stressor intensities. Each sub-activity will have a different relative impact on your habitat/species of interest.
Activity_MarineAREA	The area covered by the activity in the marine area of the reference vector grid. (Calculate using Data Prep Step 2)
Activity_MarineAREA_WT	The proportion of the activity marine area in relation to the marine area of the reference vector grid. (Calculate using Data Prep Step 2).
{area weighted intensity field}	An area weighted measure of the relative intensity for the activity. For example, fishing intensity can be quantified as the no. of hours of fishing effort (EFFORT_HRS), or no. of fishing events. The area weighted intensity can be calculated using Data Prep Step 2. The resulting field will

Field names	Description
	be named with the prefix "ADJ_" – e .g., "ADJ_EFFORT_HOURS".
Stressor code	The stressor code indicates the stressor associated with the activity and sub-activity represented by the activity data. Stressor codes and the associated stressor weights by sub-activity must be entered into the master stressor table. Stressor codes can be added to the activity data using Data Prep Step 3.
Stressor weight	Stressor weights are relative intensity weights that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. Stressor weights must be entered into the master stressor table. Stressor weights can be added to the activity data using Data Prep Step 3.

2.5. Output Data

Each of the python toolboxes will save outputs to different output workspaces in the "DFO_CI_Toolbox" folder depending on the analysis (Table 8).

Table 8. List of output workspaces that for each analysis.

Analysis	Workspace Name	Description
Data Preparation	CI_Data_Prep*Sector*.gdb\Intermediates	Output workspace or feature dataset for Steps 1-2.
Land Index	CI_Land_Inputs\Intermediates	Intermediate workspace or feature dataset.
	CI_Coastal_Inputs\inputs	Output workspace for Step 1a and 1b.
Coastal Kernel Density	CI_Coastal_Inputs.gdb\Intermediates	Intermediate workspace (feature dataset).
	CI_Coastal_Polygon_Outputs.gdb	Output workspace for polygon outputs from Step 2.

	CI_Coastal_Raster_Outputs.gdb	Output workspace for raster outputs from Step 1.
Marine Footprint	CI_Marine_Footprint_Outputs.gdb	Output workspace for Step 3.
	CI_Marine_Footprint_OutputTables.gdb	Intermediate output tables from Step 4.
	CIM_Tables_*SectorDescriptor*.gdb	Final Cumulative Impact Tables by Sector from Step 5.

2.6. Analysis Workflow

The Cumulative Impact Toolboxes have been created to accommodate different types of data. Some datasets would need to be run through some toolboxes, but not others. Figure 8 outlines the recommended workflow for the Cumulative Impact Analysis. Detailed recommendations on which datasets should be run through each toolbox are available in each Toolbox section below.

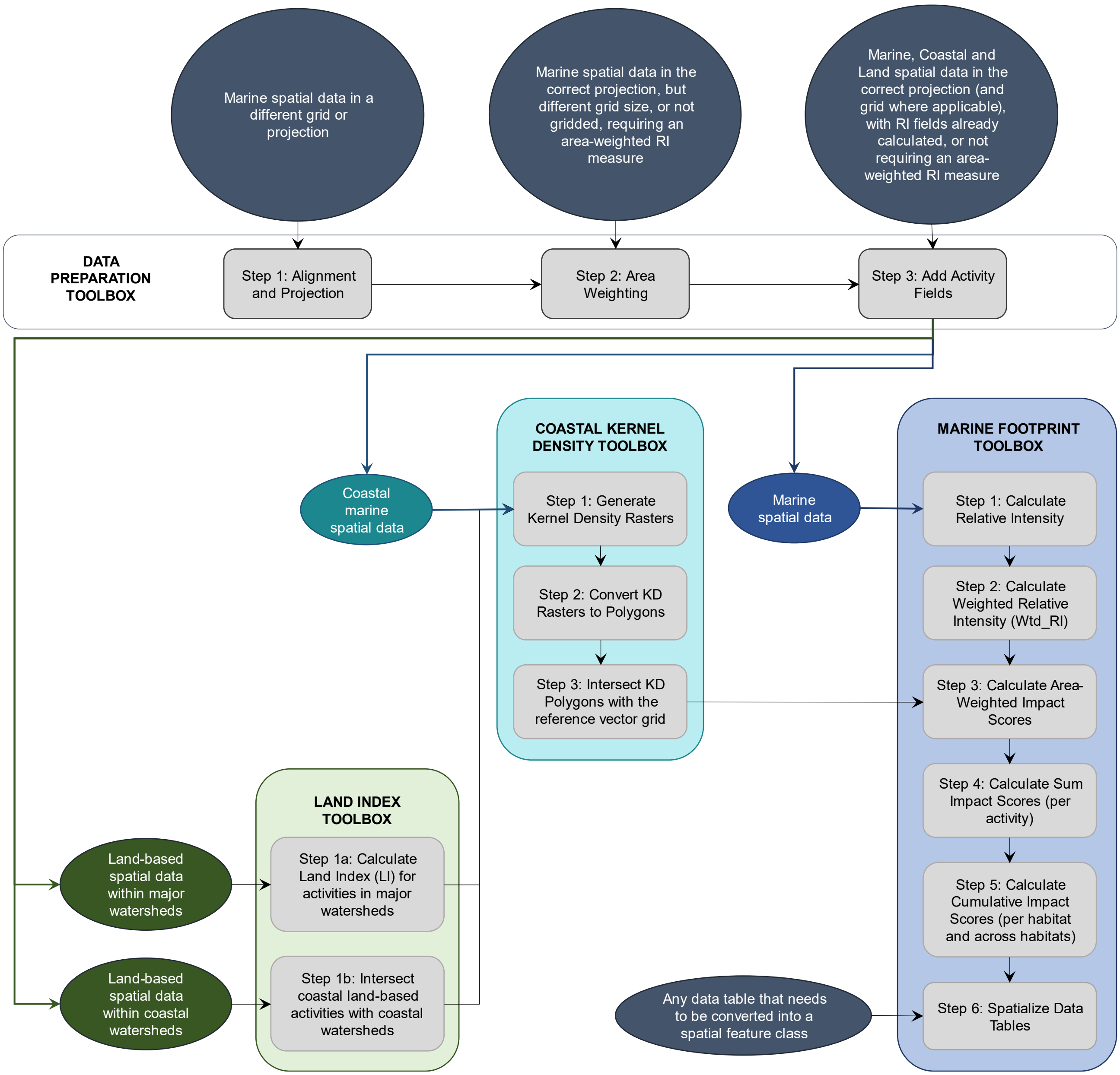

Figure 8. Flowchart of recommended analysis workflow through the Cumulative Impact Toolboxes.

3. Data Preparation Toolbox

This toolbox contains a set of tools to support the preparation of spatial data for input into the Cumulative Impact Mapping Toolboxes. The tools can be used to manipulate raw input activity data into the format expected by the CE toolboxes. The toolbox contains three tools:

- Alignment and Projection
- Area Weighting
- Add Activity Fields

It is important to note that **the tools need to be used in order**, but not all the tools will be needed for all datasets. Data may need to be processed through all steps (1,2,3), only steps 2 and 3, or only through step 3, depending on the nature of the data.

The input workspaces for the Data Preparation Toolbox should be separate from the input workspaces for the Cumulative Impact Mapping Analysis. The equivalent workspaces in the sample data are in **"\CI_DFO_Toolbox\CI_Data_Prep"** (Figure 9). Intermediate workspaces should also be distinct from input workspaces to minimize confusion related to data versions.

When tools are used sequentially, the data for Steps 2 and 3 will be located in the workspace geodatabase that is specified in the previous Step.

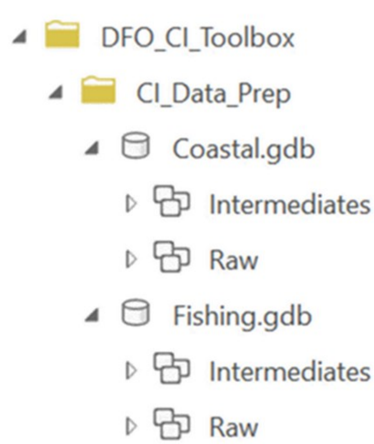

Figure 9. Input and intermediate workspaces for the Data Preparation Toolbox in the sample data.

Step 1: Alignment and Projection

The first step of the data preparation toolbox (Figure 10) can be used for an activity dataset that

- are not in the same projected coordinate system as the planning unit/reference vector grid (pu_1km), or
- are vector grids that do not line up with the reference vector grid (pu_1km).

The tool transforms the data to match the projection and alignment of the reference vector grid. If the activity feature class is considerably smaller in extent compared to the reference vector grid, please check the Data Masking checkbox. If selected, the tool will run the process using the extent of the activity feature class.

Values from the selected fields will be pulled into the centroid of each planning unit (pu) using extract multi-values to points and copied into the reference vector grid using spatial join. The output feature class will be a planning unit feature class containing data from the selected fields.

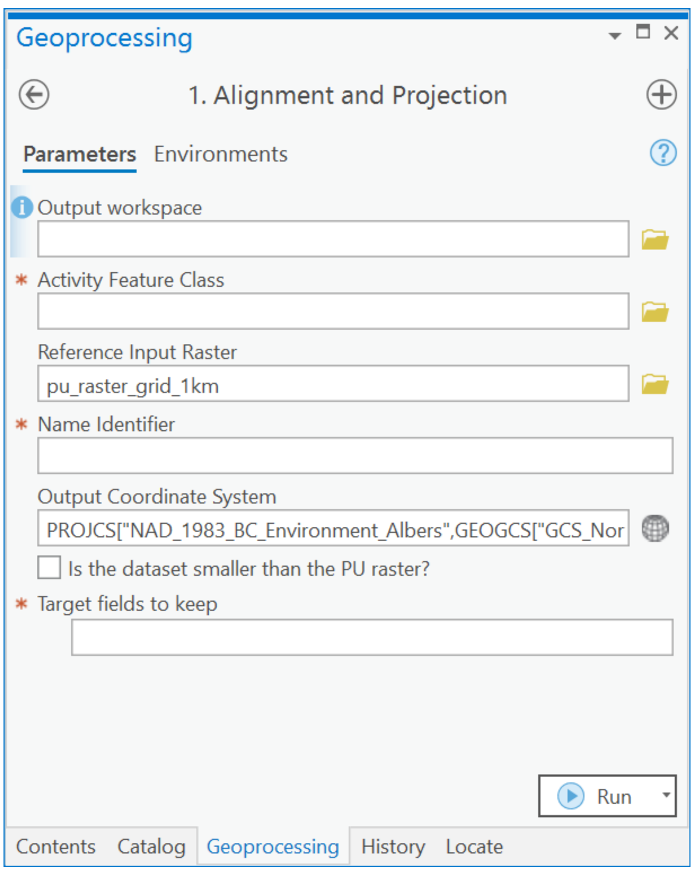

Figure 10. Screenshot of Step 1. Alignment and Projection of the Data Preparation Toolbox.

Syntax

Alignment_ (outputWorkspace, inFC, inRaster, nameVariable, outCoordSys, {isMaskNeeded}, keepFields)

Parameter	Explanation	Data Type
outputWorkspace	Dialog Reference **<u>Output workspace</u>**: The output workspace is a geodatabase or feature dataset where all outputs of the tools will be saved. In the sample data, **this workspace is an "Intermediates" feature dataset in the geodatabases within the Data Prep folder**, separate from the rest of the CE toolbox inputs/outputs. This is because the products of the first step are intermediate products to be used in subsequent tools before being used in the Cumulative Impact Mapping Analysis. There is no python reference for this parameter.	Workspace or Feature Dataset
inFC	Dialog Reference **<u>Input feature class</u>**: The input feature class is the raw dataset that has a **different projection and grid alignment from the planning unit grid** used in the Cumulative Impact Mapping Analysis. Please ensure that this input data layer has an intensity attribute that represents the activity. There is no python reference for this parameter.	Feature Class
inRaster	Dialog Reference **<u>Reference Input Raster</u>**: This is a raster version of the vector reference grid used in the Cumulative Impact Mapping Analysis. It is used as a “snap raster” to ensure that all input data processed for used in the analysis are consistently aligned. The reference grid is also used to define the spatial extent of the outputs of this step. **Please ensure that the grid cell size and the spatial extent of the reference grid matches the vector grid.** The equivalent reference grids (raster and vector) in the sample data are: "CI_InputData.gdb\pu_raster_grid_1km" and "C:\DFO_CI_Toolbox\CI_InputData.gdb\baselayers\pu_1km". There is no python reference for this parameter.	Raster Layer
nameVariable	Dialog Reference **<u>Name identifier</u>**: This is a unique identifier that will be used as a prefix to name the output feature class. Please choose a	String

	name identifier that will clearly indicate what activity your data represents. For example, a raw dataset from the tuna commercial fishery called "Tuna_2006_2016" might be given a name identifier of "comm_tuna". Do not use the activity codes from the master stressor table at this point, to distinguish between intermediate outputs from the Data Prep toolbox and the outputs that are ready to be run through the Cumulative Impact Toolboxes. There is no python reference for this parameter.	
outCoordSys	Dialog Reference **Output Coordinate System**: This is the spatial reference that will be assigned to the output feature class. **By default, the tool will use the spatial reference of the Reference Input Raster.** Please use a consistent spatial reference for all spatial data inputs used in the Cumulative Impact Mapping Analysis. There is no python reference for this parameter.	Spatial Reference
isMaskNeeded (Optional)	Dialog Reference **Flag to detect smaller spatial extents**: Click this option if your input feature class is considerably smaller in extent compared to Reference Input Raster. One of the primary tools used in step 1 is extract multi values to points. In order for the tool to work, the PU raster must be the same size or smaller than the input data layer. The checkbox triggers an "extract by mask" to reduce the extent of the reference raster to the extent of the input feature class. If the input feature class has a larger spatial extent compared to the reference input raster, the outputs of this step will be limited to the extent of the reference raster. There is no python reference for this parameter.	Boolean
keepFields	Dialog Reference **Target fields to keep:** Select the intensity attributes to be processed and saved to the output feature class. Only numerical fields will be processed. There is no python reference for this parameter.	Multiple Value

Step 2: Area Weighting

The second step of the data preparation toolbox (Figure 11) can be used for activity feature classes that are in vector grids that have larger cell sizes compared to the reference vector grid (e.g., 10x10 km grids vs 1x1 km grids), and/or are polygon features that are not vector grids.

The activity feature class will be clipped to the coastline and study area and a new field for "Activity Marine Area" will be calculated using shape geometry. Then the clipped data is intersected with the planning unit grid to apply the data to the planning unit grid. The activity area weight is calculated by dividing the planning unit grid area by the activity marine area. Finally, the adjusted intensity attribute is calculated by multiplying intensity by the activity area weight.

The result is the distribution of relative intensity values by area to prevent double counting of calculated impact across planning units. The output feature class will be named with a suffix "pu_aligned", and the area weighted or "adjusted" relative intensity fields will be named with a prefix: "ADJ_".

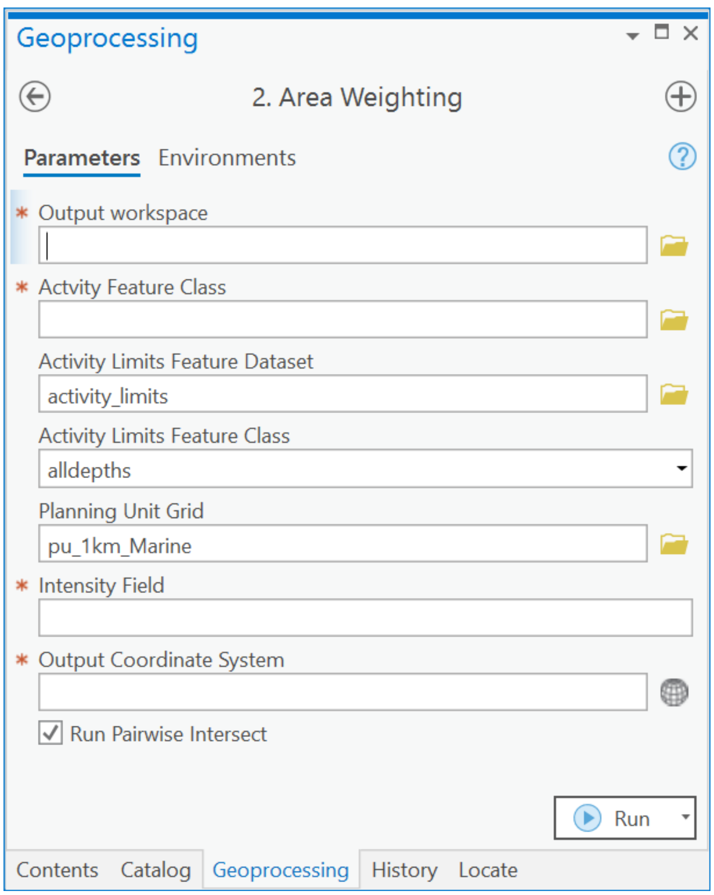

Figure 11. Screenshot of Step 2. Area weighting of Data Preparation Toolbox.

Syntax

AreaWeight_ (outputWorkspace, inFC, inDS, inLimit, inPlnUnit, inField, outCoordSys, {pairwise})

Parameter	Explanation	Data Type
outputWorkspace	Dialog Reference **Output workspace**: The output workspace is a geodatabase or feature dataset where all outputs of the tools will be saved. In the sample data, **this workspace is an "Intermediates" feature dataset in the geodatabases within the Data Prep folder**, separate from the rest of the CE toolbox inputs/outputs. This is because the products of this step are intermediate products to be used in subsequent tools before being used in the Cumulative Impact Mapping Analysis. There is no python reference for this parameter.	Workspace or Feature Dataset
inFC	Dialog Reference **Input feature class**: This is the feature class that contains the data to be area weighted. **The input data layer must have an intensity attribute** that represents the activity and must be aligned with the pu grid and in the same projected coordinate system. If the activity feature class was run through Step 1 of the Data Preparation Toolbox, the feature class will have a suffix **"pu_Aligned"**. There is no python reference for this parameter.	Feature Class
inDS	Dialog Reference **Activity limits workspace:** This is the feature dataset that contains the limit boundary feature classes that will be used to clip the input feature class. In the sample data, this feature dataset is **"CI_InputData.gdb\activity_limits".** There is no python reference for this parameter.	Feature Dataset
inLimit	Dialog Reference	String

<table>
<tr><th></th><th></th><th></th></tr>
<tr><td></td><td>
<u>Activity limits feature class</u>: This is the feature class containing the boundary layer for the activity. The dropdown menu pulls the relevant feature classes from the activity limits feature dataset.
In the sample data, the options are:

alldepths - feature class representing the entirety of the study area, representing all depths.
softshallow – feature class representing all areas 30m in depth or less, with soft substrates
shallow - feature class representing areas 30m in depth or less.
nonshallow - feature class representing areas deeper than 30m.

Please select the option that is relevant for your activity. For example, dive fisheries may be limited to shallow areas only because diver fishers are not likely to dive deeper than 30m.
There is no python reference for this parameter.
</td><td></td></tr>
<tr><td>inPlnUnit</td><td>
Dialog Reference
<u>Reference vector grid</u>: The vector reference grid represents the smallest unit of analysis and the extent of the study area.
Required fields:

UNIT_ID: the unique identifier for each grid cell.
MarineArea: the area of each grid cell excluding land.

In the sample data, the reference vector grid is the 1x1 km Planning Unit grid from DFO Oceans Management, clipped to the coastline: "CI_InputData.gdb\baselayers\pu_1km_Marine"
There is no python reference for this parameter.
</td><td>Feature Class</td></tr>
<tr><td>inField</td><td>
Dialog Reference
<u>Intensity Field:</u> Select a field from the dropdown menu that represents the relative intensity of the activity. This field will be used to calculate an area weighted relative intensity after the feature class is
</td><td>String</td></tr>
</table>

	intersected with the planning unit grid. The field must be numerical. If the input feature class was run through Step 1 of the Data Preparation toolbox, the field will have a prefix of the name identifier entered in Step 1. For example, if the "target field to keep" was "COUNT", and the "name identifier" entered was "shipping", the resultant feature class will have a field named "shipping_COUNT" which can be used as an input field for this tool. There is no python reference for this parameter.	
outCoordSys	Dialog Reference **Output coordinate system:** Please select an **area-based projection** for the analysis because the analysis will be calculating areas based on geometry. *An unprojected Coordinate Reference System (CRS) such as WGS 1984 is not recommended.* The sample data is projected in **NAD83 BC Environment Albers (EPSG 3005)**. There is no python reference for this parameter.	Spatial Reference
pairwise (Optional)	Dialog Reference **Run Pairwise Intersect:** If this box is checked, the tool will run the Pairwise Intersect tool in the analysis. If this box is unchecked, the tool will run the Intersect tool instead. If the tool fails when the pairwise intersect is checked, please uncheck the box and try running the tool again. If the tool continues to fail, please check your data for topology errors. There is no python reference for this parameter.	Boolean

Step 3: Add Activity Fields

The final step in the Data Preparation Toolbox (Figure 12) can be used to add fields to the input activity feature class that will be required in the Cumulative Impact Mapping analysis. The fields that will be added are:

- **ACTIVITY_CODE**

- **Sub_Activity**
- **STRESSOR_CODE**
- **Str_Wt**

These fields will be populated using values from the master stressor table. Please ensure that the codes for each activity are consistent across all the input tables ("master_stressor_table", "vscores_habitats", "fishing_severity").

The output feature class will be named using the scenario selected as a prefix to the activity code selected and saved in the appropriate input workspace for the Cumulative Impact Mapping Analysis.

In the sample data, the recommended workspaces are :

- **CI_Coastal_Inputs.gdb** - for all marine based coastal data
- **CI_Land_Inputs.gdb** - for all land-based data (both coastal and in the major watersheds)
- **CI_MarineFootprint_Inputs.gdb** - for all marine datasets with large area footprints

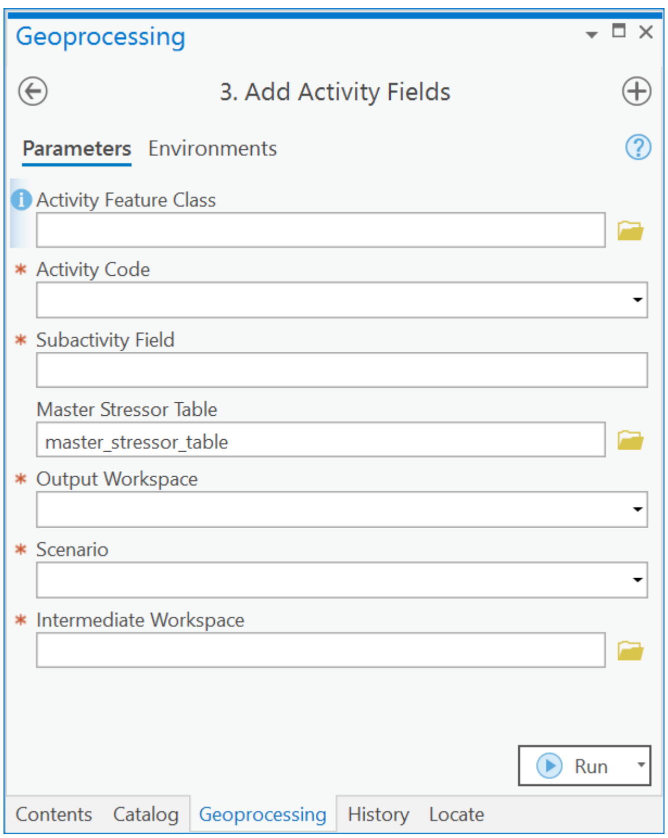

Figure 12. Screenshot of Step 3. Add Activity Codes of the Data Preparation Toolbox.

Syntax

AddActivityFields_ (inFC, inAct, inSub, masterStressorTable, outputWorkspace, scn, intermedWorkspace)

Parameter	Explanation	Data Type
inFC	Dialog Reference **Input feature class**: This is the feature class that contains the activity data. The input data layer must have the same projection as the reference vector grid. If the data is gridded, the data must also be adjusted to align geographically with the reference vector grid and have the same grid size. There is no python reference for this parameter.	Feature Class
inAct	Dialog Reference **Activity code**: This is the activity code associated with the activity as found on the master stressor table. Select the appropriate activity code from the automatically populated drop down list of codes from the master stressor table. **If your activity code is not listed, please add it to the master stressor table.** There is no python reference for this parameter.	String
inSub	Dialog Reference **Subactivity field**: This is the sub-activity associated with the activity feature class. If a 'Sub_Activity' field does not exist in your activity feature class, select the appropriate field from the drop-down list of fields from your selected activity feature class. There is no python reference for this parameter.	String
masterStressorTable	Dialog Reference **Master Stressor Table:** The master-stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. **At least one stressor must be assigned to each activity.** Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables.	Table

	Please ensure that the codes for each activity are consistent across all these datasets. The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination. Stressor weights are relative intensity weights that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. If an activity-stressor combination exists, **the value in the stressor-weights field must not be <Null>**. In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity. Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor combination exists, **the value in the impact distances field must not be <Null>**. In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose an arbitrary distance (in metres), because the distance variable is a required input for the kernel density tool. **NOTE: The master stressor table must be stored in a file geodatabase.** The equivalent table in the sample data is: "CI_InputData.gdb\master_stressor_table" There is no python reference for this parameter.	
outputWorkspace	Dialog Reference **<u>Output workspace</u>**: This is the workspace that the output of the tool will be saved to. Select an appropriate workspace from the dropdown list. The workspace selected should be a geodatabase or feature dataset where the processed Cumulative Impact Mapping input data will be saved. In the sample data the appropriate workspaces are listed below:	String

	• All land-based activity data ("lnd" and "cst"): "CI_Land_Inputs.gdb\inputs". • All coastal marine activity data ("cst"): "CI_Coastal_Inputs.gdb\inputs". • All area-based marine activity data ("mar"): "CI_MarineFootprint_Inputs.gdb\inputs". There is no python reference for this parameter.	
scn	Dialog Reference **Scenario**: The input feature classes may be named according to the scenario naming convention, where the scenario is identified by a prefix: • "c" for current scenarios • "f" for future scenarios • "p" for increased protection scenarios The script will identify the scenario based on the filename of the input dataset and automatically fill in the scenario variable. The scenario variable will be used to name the output feature class. There is no python reference for this parameter.	String
intermedWorkspace	Dialog Reference **Intermediate workspace**: The Intermediate workspace is a geodatabase or feature dataset where intermediate outputs of the tool will be saved. It is recommended that the Intermediate workspace be kept in the CI_Data_Prep folder, to keep data prep intermediate outputs separate from the processed input datasets. In the sample data, the workspaces are feature datasets called "Intermediates" within the relevant sector geodatabase. For example: "DFO_CI_Toolbox\CI_Data_Prep\Coastal.gdb\Intermediates" There is no python reference for this parameter.	Workspace or Feature Dataset

4. Land Index Toolbox

The Land Index toolbox (Figure 13) processes land-based activity data, depending on whether the activities occur within the boundaries of major watersheds, or whether the activities occur in coastal areas within impact distance of the ocean. The outputs of both tools will be pulled into the Coastal Kernel Density analysis at Step 1.

Step 1a is used for activity data that falls within major watersheds of stream order 7 or higher. These represent the most significant river systems and data from the headwaters of each drainage basin is included. A Land index (LI) value will be saved to point features representing the main estuaries of each major watershed. These points are then used in the coastal kernel density tool to determine impact.

Step 1b is used to process coastal land-based activity data that falls within coastal watersheds of stream order less than 7. The Cumulative Impact Mapping analysis will model the impact of these land-based activities within a specified impact distance from the coastline.

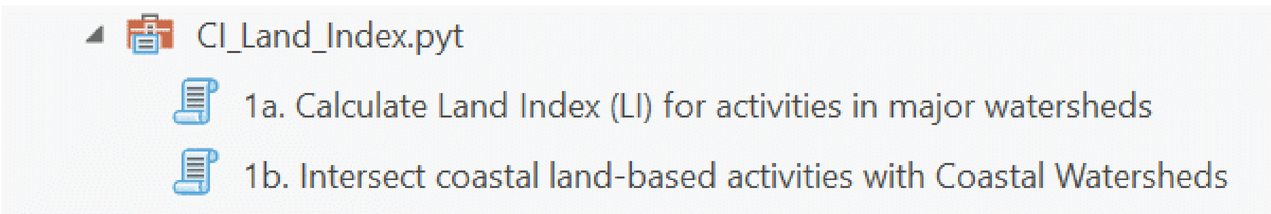

Figure 13. Screenshot of the two tools in the Land Index Toolbox.

Step 1a: Calculate Land Index (LI) for activities in major watersheds

Step 1a (Figure 14) is used to process land-based activity data that falls within major watersheds with stream order 7 or higher. These represent the most significant river systems and data from the headwaters of each drainage basin is included.

The Land Index (LI) is calculated by summing the relative intensity field, dividing the result by the area of the watershed, and multiplying the value by 10,000 to avoid infinitesimal LI values.

If no relative intensity field is available, the shape geometry of the feature class can be used to calculate the LI:

- Points - number of points / watershed area
- Lines - length of lines / watershed area
- Polygons - area of polygons / watershed area.

The LI value will then be saved to the point feature representing the main estuary of the watershed. The output feature class will be named with the scenario and activity code and saved in the Output Workspace: **"DFO_CI_Toolbox\CI_Coastal_Inputs.gdb\inputs"**. These estuary points are then used as input features for the coastal kernel density tool to model decreasing impact from the estuary up to a maximum impact distance .

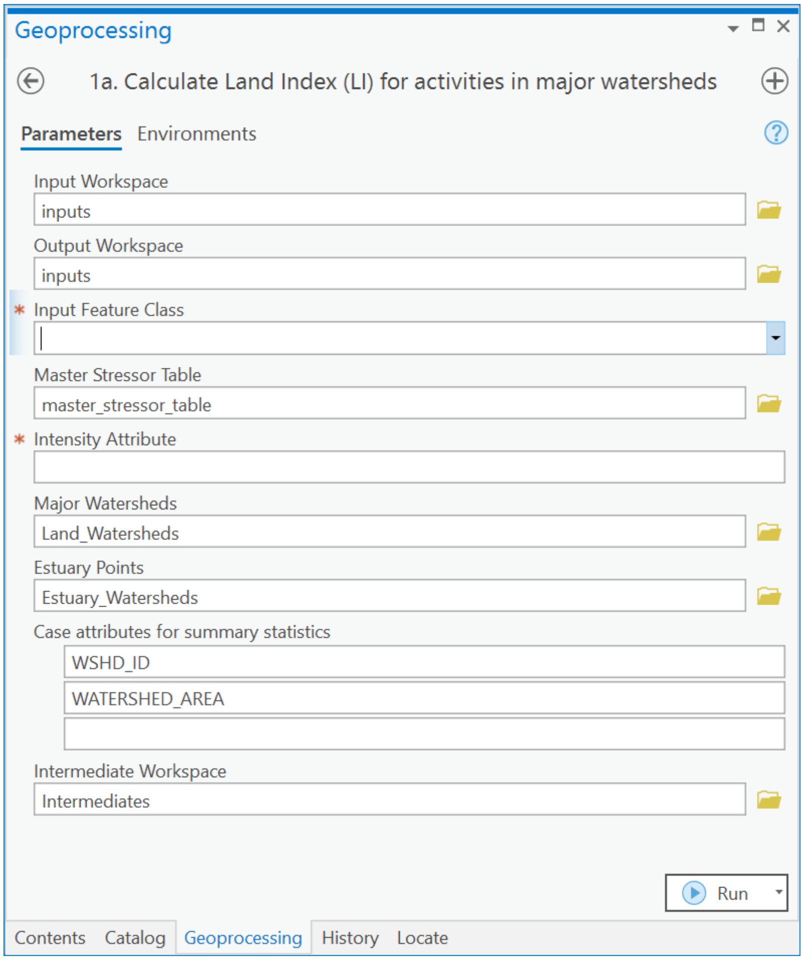

Figure 14. Screenshot of Step 1a: Calculate Land Index (LI) for activities in major watersheds from Land Index Toolbox.

Syntax

Step1A_ (inputWorkspace, outputWorkspace, inputFC, stressorTable, intensity, watersheds, estuaries, caseFields, intermedWorkspace)

Parameter	Explanation	Data Type
inputWorkspace	Dialog Reference **Input workspace**: The geodatabase or feature dataset that will contain all the land input data for the Cumulative Impact Analysis. In the sample data, the input workspace is located here: "DFO_CI_Toolbox\CI_Land_Inputs.gdb\inputs". There is no python reference for this parameter.	Workspace or Feature Dataset

outputWorkspace	Dialog Reference **<u>Output workspace</u>**: The geodatabase or feature dataset that will contain all the processed land index data for the Cumulative Impact Analysis. All land index outputs will be processed as inputs through the Coastal Kernel Density tool. Therefore, in the sample data, the output workspace is located here: "DFO_CI_Toolbox\CI_Coastal_Inputs.gdb\inputs". There is no python reference for this parameter.	Workspace or Feature Dataset
inputFC	Dialog Reference **<u>Input feature class</u>**: An activity feature class that has been run through Step 3. of the Data Preparation toolbox. The dropdown menu pulls the relevant feature classes from the input workspace. **Note: Only "Ind" feature classes can be run through Step 1a.** There is no python reference for this parameter.	String
stressorTable	Dialog Reference **<u>Master stressor table</u>**: The master stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. **At least one stressor must be assigned to each activity**. Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables, and (iv) the fishing severity table. **Please ensure that the codes for each activity are consistent across all the input tables.** The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination. Stressor weights are relative intensity weights that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. If an activity-stressor combination exists, the value in the stressor-weights field must not be <Null>. In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights	Table

	field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity. Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor combination exists, the value in the impact distances field must not be <Null>. In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose an arbitrary distance in the appropriate distance unit of the projection (e.g., in metres for BC Environment Albers), because the distance variable is a required input for the kernel density tool. NOTE: The master stressor table must be stored in a file geodatabase. The equivalent table in the sample data is: "CI_InputData.gdb\master_stressor_table" There is no python reference for this parameter.	
intensity	Dialog Reference **Intensity attribute:** This attribute of the Activity Feature Class will be used to calculate the Land Index (LI). Select the appropriate field from the drop-down menu. If you would like to use the geometry of the feature (e.g., no. of points, area of polygon, or length of lines) to represent relative intensity, please select the option: **"Use shape geometry to calculate LI".** The tool will calculate the Land Index value by dividing the intensity value by the area of the watershed. That value will then be multiplied by a factor of 10,000 to reduce the probability of infinitesimal LI values. **Please ensure you are selecting an appropriate intensity attribute for your selected dataset.** There is no python reference for this parameter.	String
watersheds	Dialog Reference **Land Index Watersheds:** Select the feature class representing the land index watersheds (stream order 7 or higher, including headwaters). In the sample data, the land index watersheds are: "DFO_CI_Toolbox\CI_InputData.gdb\baselayers\Land_Watersheds". There is no python reference for this parameter.	Feature Class

estuaries	Dialog Reference **<u>Estuaries</u>**: This is a point feature class representing the estuaries of each major watershed in the Land Index watersheds (stream order 7 or higher) feature class. This is used to summarize the land index data to this single point for kernel density. **Please ensure that all input watershed features have a matching point in the estuaries feature class.** In the sample data, estuaries feature class is: "**CI_InputData.gdb\baselayers\Estuary_Watershed**" There is no python reference for this parameter.	Feature Class
caseFields	Dialog Reference **<u>Case Fields</u>**: Data from the selected intensity attribute will be summed according to the case fields selected here. The case fields will be carried forward into the output layers as is (no statistics will be calculated on them). The default list of case fields in the sample data are **"WSHD_ID"** and **"WATERSHED_AREA"**. Note: the WATERSHED_AREA field is carried forward to preserve the watershed area associated with each WSHD_ID (Watershed ID) for use in area calculations in following steps of the cumulative impact analysis. There is no python reference for this parameter.	Multiple Value
intermedWorkspace	Dialog Reference **<u>Intermediate workspace</u>**: This is a workspace where the intermediate outputs of the tool are saved. In the sample data, the intermediate workspace is here: "DFO_CI_Toolbox\CI_Land_Inputs.gdb\Intermediates" There is no python reference for this parameter.	Workspace or Feature Dataset

Step 1b: Intersect coastal land-based activities with Coastal Watersheds

Step 1b (Figure 15) is used to process coastal land-based activity data that falls within coastal watersheds of stream order less than 7. The Cumulative Impact Mapping analysis will model the impact of these land-based activities within a specified impact distance from the coastline.

The tool will intersect the activity data with the coastal watersheds and the output feature classes, named with user-specified scenario and activity codes will be saved in the Output

Workspace: "CI_Coastal_Inputs.gdb\inputs" to be run through the Coastal Kernel Density toolbox.

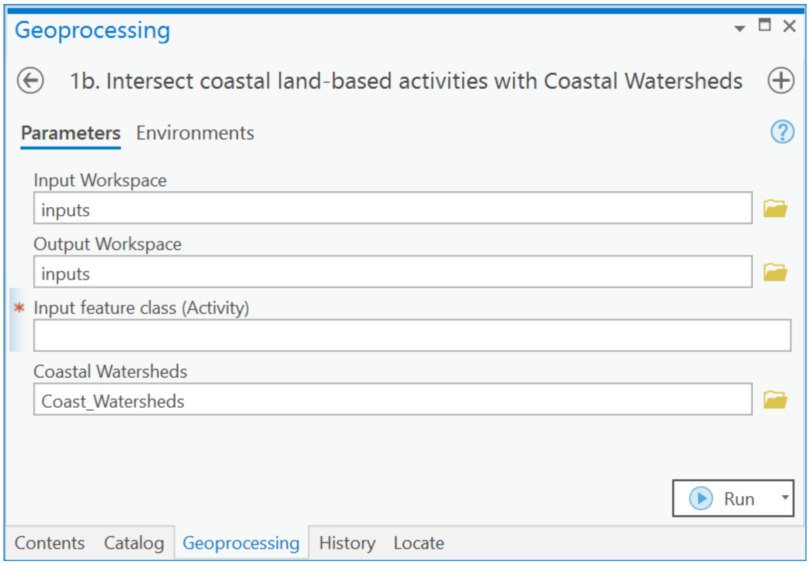

Figure 15. Screenshot of Step 1b: Intersect coastal land-based activities with coastal watersheds of Land Index Toolbox.

Syntax

Step1B_ (inputWorkspace, outputWorkspace, inputFC, watersheds)

Parameter	Explanation	Data Type
inputWorkspace	Dialog Reference **Input workspace**: The geodatabase or feature dataset that will contain all the land input data for the Cumulative Impact Analysis. In the sample data, the input workspace is located here: "DFO_CI_Toolbox\CI_Land_Inputs.gdb\inputs". There is no python reference for this parameter.	Workspace or Feature Dataset
outputWorkspace	Dialog Reference **Output workspace**: The geodatabase or feature dataset that will contain all the processed land input data for the Cumulative Impact Analysis. In the sample data, the input workspace is located here: "DFO_CI_Toolbox\CI_Coastal_Inputs.gdb\inputs". There is no python reference for this parameter.	Workspace or Feature Dataset

inputFC	Dialog Reference **<u>Input feature class</u>**: A land-based activity feature class that has been run through Step 3. of the Data Preparation toolbox. The dropdown menu pulls the relevant feature classes from the input workspace. **Note: Only "cst" feature classes can be run through Step 1b.** There is no python reference for this parameter.	String
watersheds	Dialog Reference **<u>Coastal Watersheds:</u>** Select the feature class containing the coastal watersheds (watersheds adjacent to ocean of stream order 6 or lower). In the sample data, the coastal watersheds are: "DFO_CI_Toolbox\CI_InputData.gdb\baselayers\Coast_Watersheds". There is no python reference for this parameter.	Feature Class

5. Coastal Kernel Density Toolbox

The Coastal Kernel Density Toolbox (Figure 16) models decreasing relative intensity of a stressor around a point/line source activity with increasing distance, up to a maximum distance. This toolbox will run the coastal kernel density analysis for all coastal marine activities, coastal land-based activities, and land-based activities in major watersheds (represented by Land Index values at estuaries).

Land-based activities represented at estuary points will have impact distances based on stream order and coastal activities with multiple or different stressors per sub-activity will have impact distances noted in the master stressor table.

The Coastal KD Toolbox outputs will be saved in the Wtd_RI feature dataset of the CE_MarineFootprint_Inputs.gdb, for insertion into the Marine Footprint Toolbox at Step3.

The Spatial Analyst Extension is required to run the tools.

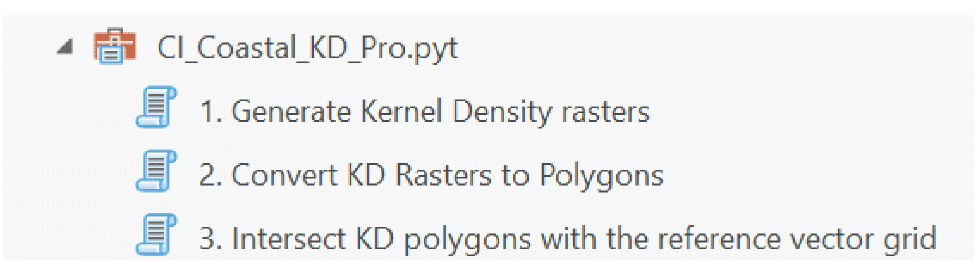

Figure 16. Screenshot of the three tools in Coastal Kernel Density Toolbox.

Step 1: Generate Kernel Density (KD) Rasters

The first step in the Coastal Kernel Density toolbox (Figure 17) will model the decreasing relative intensity of activity-specific stressors up to maximum impact distance from the source.

This step will run the Kernel Density tool from the Spatial Analyst toolbox. **Please enable the Spatial Analyst extension to run the tool:** navigate to the ArcGIS Pro Licensing menu and select "Spatial Analyst" from the Extensions list.

The following fields will be added to the activity feature class:

- Stressor Weight (prefix "StrWt_")
- Stressor-specific Relative Intensity ("RI_*{stressorcode}*")
- Stressor-specific Impact Distance (prefix "ImpactDist_")

If the input activity feature class is a polygon, the tool will convert the feature class to polylines before running the activity feature class through the kernel density analysis. The tool will use the stressor-specific relative intensity field as the "population field" parameter and the stressor-specific or estuary-specific impact distance as the "search radius" parameter.

The output from this step will be stressor-specific intermediate output rasters named with the scenario, activity code, associated stressor, and an impact distance. If multiple impact distances apply for different features or stressors, an output raster will be generated for each impact distance. Note: Land-based activities represented at estuary points will have impact distances based on stream order and activities with multiple or different stressors per sub-activity will have impact distances noted in the master stressor table.

In the sample data, the raster outputs from this step are saved in the Output Workspace: "DFO_CI_Toolbox\CI_Coastal_Raster_Outputs.gdb"

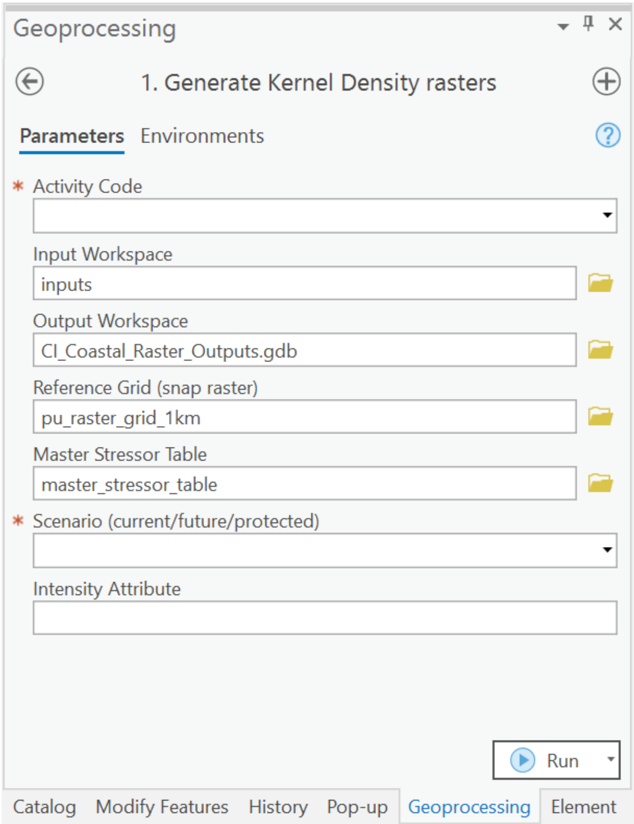

Figure 17. Screenshot of Step 1: Generate Kernel Density (KD) rasters from Coastal Kernel Density Toolbox.

Syntax

Step1_ (act, inputworkspace, outputWorkspace, snap_raster, stressorTable, scn, {strIntensity}, {impactDistField})

Parameter	Explanation	Data Type
act	Dialog Reference **Activity Code**: The activity code represents the activity. This is the code entered in the “Activity” field of the activity feature class. **A drop-down menu for this variable will be made available once the paths for the activity-stressor table inputs have been entered.** The activity code will be used in naming the output feature class. It will also be used to relate each activity to its relevant stressors. Therefore, the activity code appears in (i) the activity feature class, (ii) the activity-stressor inputs table, (iii) the stressor weights table, and (iv) the impact distances table.	String

	Please ensure that the codes for each activity are consistent across all these datasets. There is no python reference for this parameter.	
inputworkspace	Dialog Reference **Input Workspace**: This workspace is the geodatabase or feature dataset that contains the input data. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_Coastal_Inputs.gdb" There is no python reference for this parameter.	Workspace or Feature Dataset
outputWorkspace	Dialog Reference **Output Workspace**: The output workspace can be a feature dataset or a geodatabase. The output from this step will be a set of rasters generated from the Kernel Density tool. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_Coastal_Raster_Outputs.gdb" There is no python reference for this parameter.	Workspace or Feature Dataset
snap_raster	Dialog Reference **Snap Raster**: The reference grid is a raster version of the vector grid. It is used as a "snap raster" to ensure that all intermediate raster outputs from the kernel density tool are perfectly aligned. The reference grid is also used to define the spatial extent of the analysis. **Please ensure that the grid cell size and the spatial extent of the reference grid matches the vector grid.** The equivalent reference grids (raster and vector) in the sample data are: "DFO_CI_Toolbox\CI_InputData.gdb\pu_raster_grid_1km" and "DFO_CI_Toolbox\CI_InputData.gdb\baselayers\pu_1km". There is no python reference for this parameter.	Raster Dataset
stressorTable	Dialog Reference **Master stressor table:** The master stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. **At least one stressor must be assigned to each activity.** Each activity is represented by an activity code, and	Table

	each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables. **Please ensure that the codes for each activity are consistent across all the input tables ("master_stressor_table", "vscores_habitats", "fishing_severity").** The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination. Stressor weights are relative intensity weights that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. If an activity-stressor combination exists, **the value in the stressor-weights field must not be <Null>**. In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity. Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor combination exists, **the value in the impact distances field must not be <Null>**. In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose an arbitrary distance (in metres), because the distance variable is a required input for the kernel density tool. NOTE: The master stressor table must be stored in a file geodatabase. The equivalent table in the sample data is: "DFO_CI_Toolbox\CI_InputData.gdb\master_stressor_table" There is no python reference for this parameter.	
scn	Dialog Reference **Scenarios:** The input feature classes may be named according to the scenario naming convention, where the scenario is identified by a prefix: • "c" for current scenarios • "f" for future scenarios • "p" for increased protection scenarios	String

	The script will identify the scenario based on the filename of the input dataset and automatically fill in the scenario variable. The scenario variable will be used to name the output feature class. There is no python reference for this parameter.	
strIntensity (Optional)	Dialog Reference **Intensity attribute**: The user must specify an intensity field so that relative intensity (RI) can be calculated and used as population field in Kernel Density tool. By default, this will be set as "No intensity attribute present in input dataset, set RI for all entries to 1". This will instruct the tool to add an attribute for RI and calculate it as 1 for all entries. Otherwise, the RI will be set to the attribute as specified by the user. There is no python reference for this parameter.	String
impactDistField (Optional)	Dialog Reference **Impact Distance:** The impact distance values will be used as input for the "search radius" parameter in the kernel density tool. If the activity code chosen is a coastal dataset (**"cst"**), the impact distances used for this analysis will be automatically pulled from the master stressor table. If the activity chosen is a land-based activity represented at estuary points (**"lnd"**), the parameter will be enabled, and the user will be prompted to select a field from a dropdown list. In the sample data the impact distances from each estuary will be in the **"BUFFER_DIST"** field. There is no python reference for this parameter.	String

Step 2: Convert KD Rasters to Polygon

The second step in the Coastal Kernel Density Toolbox (Figure 18) will reclassify the output rasters from Step 1, and convert them into polygons, with fields containing the relative intensity of activity-specific stressors which decrease linearly with increasing distance from the source up to a maximum impact distance.

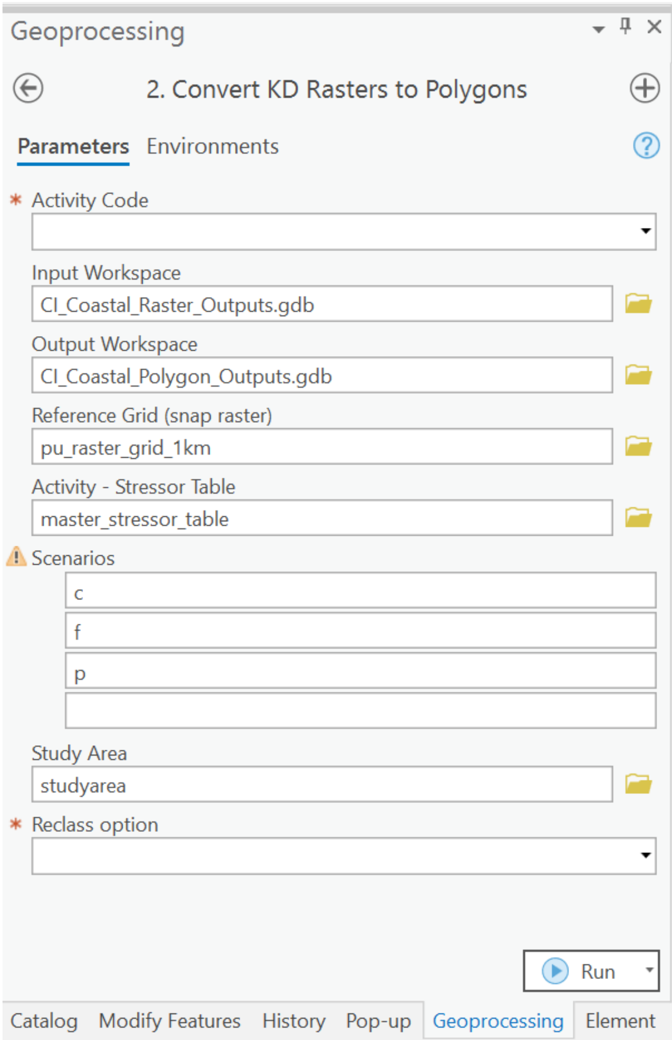

Figure 18. Screenshot of Step 2: Convert rasters to polygons of the Coastal Kernel Density Toolbox.

This step will run the Slice and Reclassify Tools under the Spatial Analyst Toolbox. Please ensure that you have enabled the Spatial Analyst Extension (navigate to the ArcGIS Pro Licensing menu and select "Spatial Analyst" from the Extensions list).

This step will obtain a maximum value from all three scenarios of an activity and reclassify the kernel density raster from either

- 0.5 to 1.5 (3 categories using Natural Breaks),
- or rescale it from 0 to 1 (10 equal interval bins) by dividing the raster values with the maximum value.

If multiple stressor intensity rasters exist for a specific stressor, the relevant Stressor Intensity KD rasters will be added together before they are reclassified/rescaled and converted into polygon feature classes.

The outputs from this step are:

- Stressor Intensity KD Polygons: a set of intermediate output polygons, saved in output workspace, named with the activity code, the stressor, and a suffix "_KD". These output feature classes will have a new field: Stressor-specific, reclassified Relative Intensity (prefix "RI_"), which will be populated with either 3 classes (0.5, 1.0, 1.5) or 10 classes (0.1 to 1.0), depending on user selection.
- Clipped Stressor Intensity KD Polygons: a set of output polygons clipped to the study area, and named with the activity code, the associated, stressor, and a suffix "_clip".

Syntax

Step2_ (act, inputworkspace, outputWorkspace, snap_raster, stressortable, scenarios, studyarea, reclass_option, userClasses, {expression})

Parameter	Explanation	Data Type
act	Dialog Reference **Activity Code**: The activity code represents the activity. This is the code entered in the "Activity" field of the activity feature class. **A drop-down menu for this variable will be made available once the paths for the activity-stressor table inputs have been entered.** The activity code will be used in naming the output feature class. It will also be used to relate each activity to its relevant stressors. Therefore, the activity code appears in (i) the activity feature class, (ii) the activity-stressor inputs table, (iii) the stressor weights table, and (iv) the impact distances table. **Please ensure that the codes for each activity are consistent across all these datasets.** There is no python reference for this parameter.	String
inputworkspace	Dialog Reference **Input Workspace**: This workspace is the geodatabase containing the raster output data from Step 1. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_Coastal_Raster_Outputs.gdb" There is no python reference for this parameter.	Feature Dataset or Workspace

outputWorkspace	Dialog Reference **Output Workspace**: The output workspace can be a feature dataset or a geodatabase. The output from this step will be polygon feature classes containing The equivalent workspace in the sample data is: "DFO_CI_Toolbox\Coastal_Polygon_Outputs.gdb" There is no python reference for this parameter.	Feature Dataset or Workspace
snap_raster	Dialog Reference **Snap Raster**: The reference grid is a raster version of the vector grid. It is used as a "snap raster" to ensure that all intermediate raster outputs from the kernel density tool are perfectly aligned. The reference grid is also used to define the spatial extent of the analysis. **Please ensure that the grid cell size and the spatial extent of the reference grid matches the vector grid.** The equivalent reference grids (raster and vector) in the sample data are: "DFO_CI_Toolbox\CI_InputData.gdb\pu_raster_grid_1km" and "DFO_CI_Toolbox\CI_InputData.gdb\baselayers\pu_1km". There is no python reference for this parameter.	Raster Dataset
stressortable	Dialog Reference **Master stressor table:** The master stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. **At least one stressor must be assigned to each activity.** Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables. **Please ensure that the codes for each activity are consistent across all the input tables ("master_stressor_table", "vscores_habitats", "fishing_severity").** The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination. Stressor weights are relative intensity weights that will be applied to sub-activities within each activity-stressor	Table

	combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. If an activity-stressor combination exists, **the value in the stressor-weights field must not be <Null>**. In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity. Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor combination exists, **the value in the impact distances field must not be <Null>**. In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose an arbitrary distance (in metres), because the distance variable is a required input for the kernel density tool. NOTE: The master stressor table must be stored in a file geodatabase. The equivalent table in the sample data is: "DFO_CI_Toolbox\CI_InputData.gdb\master_stressor_table" There is no python reference for this parameter.	
scenarios	Dialog Reference **<u>Scenarios</u>**: The input feature classes may be named according to the scenario naming convention, where the scenario is identified by a prefix: • "c" for current scenarios • "f" for future scenarios • "p" for increased protection scenarios The script will identify the scenario based on the filename of the input dataset and automatically fill in the scenario variable. The scenario variable will be used to name the output feature class. There is no python reference for this parameter.	Multiple Value
studyarea	Dialog Reference **<u>Study area:</u>** The study area is the polygon boundary for cumulative impact map.	Table

	In the sample data, the study area is the extent of the Canadian Pacific Exclusive Economic Zone (EEZ) and the British Columbia coastline: "DFO_CI_Toolbox\CI_InputData.gdb\studyarea" There is no python reference for this parameter.	
reclass_option	Dialog Reference **<u>Reclassification option:</u>** The second step in the Marine/Coastal Kernel Density Analysis will reclassify the output rasters from Step 1 (Kernel Density), and convert the reclassified rasters into polygons, generating a set of output feature classes with information on the modeled relative intensity of activity-specific stressors, which decreases with increasing distance from the source. This step will obtain a maximum value from all three scenarios of an activity and reclassify the kernel density raster from either 0.5 to 1.5 (3 categories using Natural Breaks) or rescale it from 0 to 1 (10 equal interval bins) by dividing the raster values with the maximum value. The reclassified/rescaled rasters will then be converted into polygon feature classes. This step will run the Slice and Reclassify Tools in the Spatial Analyst Toolbox. **Please ensure that the Spatial Analyst Extension is enabled.** The outputs from this step are stressor intensity KD polygons: 1. **a set of intermediate output kernel density polygons**, saved in the output workspace, named with the activity code, the stressor, and a suffix "***_KD***". These output feature classes will have a new field: Stressor-specific, reclassified Relative Intensity (prefix "***RI_***"), which will be populated with either 3 classes (0.5 to 1.5) or 10 classes (0.1 to 1.0), depending on user selection. 2. **a set of kernel density polygons clipped to the coastline,** named with the activity code, the associated stressor, and a suffix "*_clip*". If multiple impact distances exist for a specific stressor, the relevant Stressor Intensity KD rasters will be added together before they are reclassified. There is no python reference for this parameter.	String
userClasses	Dialog Reference **<u>No. of classes:</u>** This parameter is enabled only if the user selects a Natural Breaks reclassification. This value is the number of classes the data will be classified into.	String

	If the user selects a Natural Breaks classification, the default no. of values will be 3, unless changed. If the user selects a 0-1 classification, the default no. of classes will be 10. There is no python reference for this parameter.	
expression (Optional)	Dialog Reference **Expression:** This parameter is enabled only if the user selects a Natural Breaks reclassification. This is the mathematical expression that will convert the tools output from integers to an RI classification scale. • If the user selects an option of Natural Breaks and 3 classes, the default expression is **"!gridcode!*0.5"** to return a classification scale of 0.5, 1.0, 1.5. • If the user selects an option of 10 equal interval bins, the default expression is **"!gridcode!/10"** to return a classification scale of 0.1-1.0. Click reset parameters to return parameter inputs to default expressions. There is no python reference for this parameter.	String

Step 3. Intersect KD polygons with reference vector grid

The third step in the Coastal Kernel Density Analysis (Figure 19) will intersect the output polygon from Step 2 with the reference vector grid. The equivalent layer in the sample data is the 1km Planning Unit grid used by DFO Oceans Management for the Pacific Region. The tool will create an output feature class which is then used as an input dataset in Step 3 of the Marine Footprint Analysis.

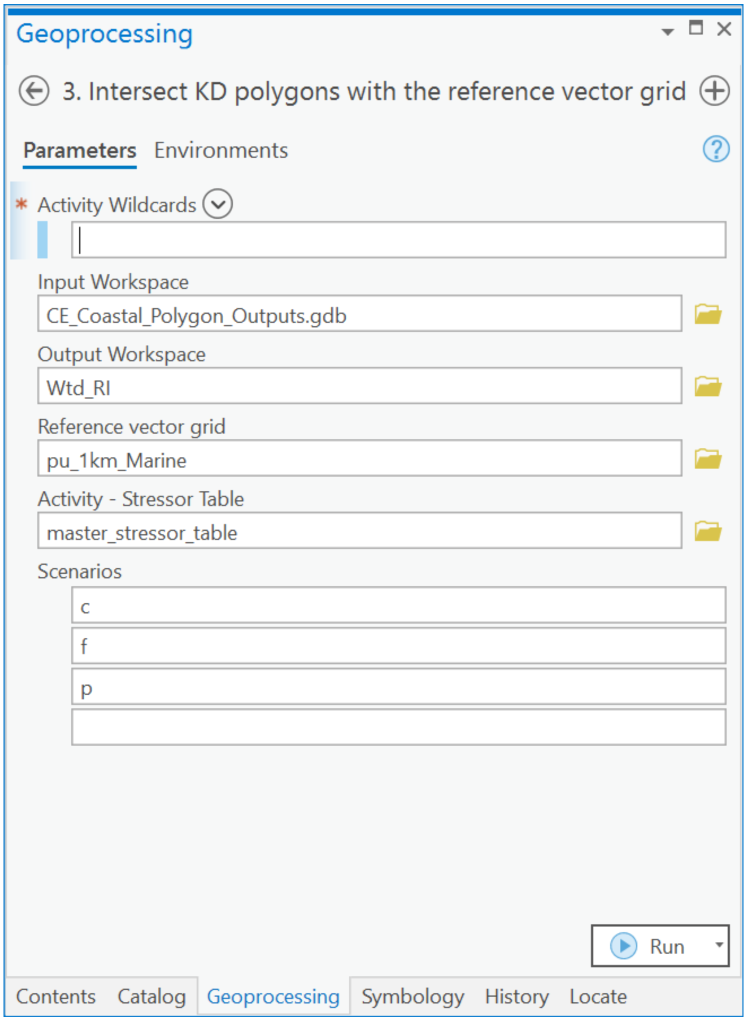

Figure 19. Screenshot of Step 3: Intersect KD polygons with reference vector grid.

Syntax

Step3_ (act, inputworkspace, outputWorkspace, pu_grid, stressortable, scenarios)

Parameter	Explanation	Data Type
act	Dialog Reference **<u>Activity code</u>:** The activity code represents the activity. Multiple activity codes may be selected. The dropdown options for the activity code are pulled from the input workspace. If there are no activity codes available, please run Step 2. The activity code will be used to identify relevant stressors and to name the output feature classes. **Please ensure that activity codes are consistent across all relevant feature classes, the**	Multiple Value

	master stressor stable, the vulnerability scores table, and the fishing gear severity table. There is no python reference for this parameter.	
inputworkspace	Dialog Reference **Input Workspace**: This workspace is the geodatabase or feature dataset that contains the input data. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_Coastal_Raster_Outputs.gdb" There is no python reference for this parameter.	Feature Dataset or Workspace
outputWorkspace	Dialog Reference **Output Workspace:** The output workspace can be a feature dataset or a geodatabase. The output from this step will be a set of KD polygons clipped to the study area (suffix: ***"_KD_clip"***). The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_Coastal_Polygon_Outputs.gdb" There is no python reference for this parameter.	Feature Dataset or Workspace
pu_grid	Dialog Reference **Reference vector grid:** The vector reference grid represents the smallest unit of analysis and the extent of the study area. Required fields: • **UNIT_ID**: the unique identifier for each grid cell. • **MarineArea**: the area of each grid cell excluding land. The sample grid provided are the 1 x 1 km Planning Units used by DFO Oceans Management for the Pacific Region: "DFO_CI_Toolbox\CI_InputData.gdb\baselayers\pu_1km_Marine" There is no python reference for this parameter.	Feature Class
stressortable	Dialog Reference **Master stressor table**: The master stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. At least one stressor must be assigned to each activity.	Table

	Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables, and (iv) the fishing severity table. **Please ensure that the codes for each activity are consistent across all the input tables.** The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination. Stressor weights are relative intensity weights that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. If an activity-stressor combination exists, **the value in the stressor-weights field must not be <Null>**. In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity. Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor combination exists, **the value in the impact distances field must not be <Null>**. In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose an arbitrary distance in the appropriate distance unit of the projection (e.g., in metres for BC Environment Albers), because the distance variable is a required input for the kernel density tool. **NOTE: The master stressor table must be stored in a file geodatabase.** The equivalent table in the sample data is: "DFO_CI_Toolbox\CI_InputData.gdb\master_stressor_table" There is no python reference for this parameter.	
scenarios	Dialog Reference The input feature classes may be named according to the scenario naming convention, where the scenario is identified by a prefix: • "c" for current scenarios • "f" for future scenarios	Multiple Value

- "p" for increased protection scenarios

The script will identify the scenario based on the filename of the input dataset and automatically fill in the scenario variable. The scenario variable will be used to name the output feature class.

There is no python reference for this parameter.

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6. Marine Footprint Toolbox

The Marine Footprint Toolbox (Figure 20) calculates the cumulative impact from activities that have an impact over a specific area and are represented by polygon spatial data.

Data for all activities and habitats must go through Marine Footprint Steps 3-5 to be included in the cumulative impact score. Outputs from the Land Index and Coastal Kernel Density Toolboxes are used as inputs in Step 3 of the Marine Footprint Toolbox.

Calculating Impact Scores:

Step 1 calculates the relative intensity (RI), and Step 2 calculates the stressor weighted RI (Wtd_RI) which will be used in Step 3 to calculated area weighted impact scores. Outputs from the Land Index and Coastal Kernel Density Toolboxes are converted into polygons representing the footprint of the impact of coastal and land activities on the marine. Therefore, these outputs are inserted into the Marine Footprint toolbox at Step 3.

Calculating Cumulative Impact Scores:

Step 4 calculates sum impact scores per activity across all habitats. Step 5 is run in two parts. Part 1 calculates sum impact scores across activities per habitat, and Part 2 calculates cumulative impact scores across all activities and all habitats.

To calculate cumulative impact scores for sectors (i.e., a subset of activities such as fishing or coastal), Step 5 can be run for a subset of activities which are identified with a unique sector descriptor to identify sector specific output geodatabases and prefixes to identify sector specific output tables.

The Marine Footprint Toolbox consists of 6 separate steps outlined below.

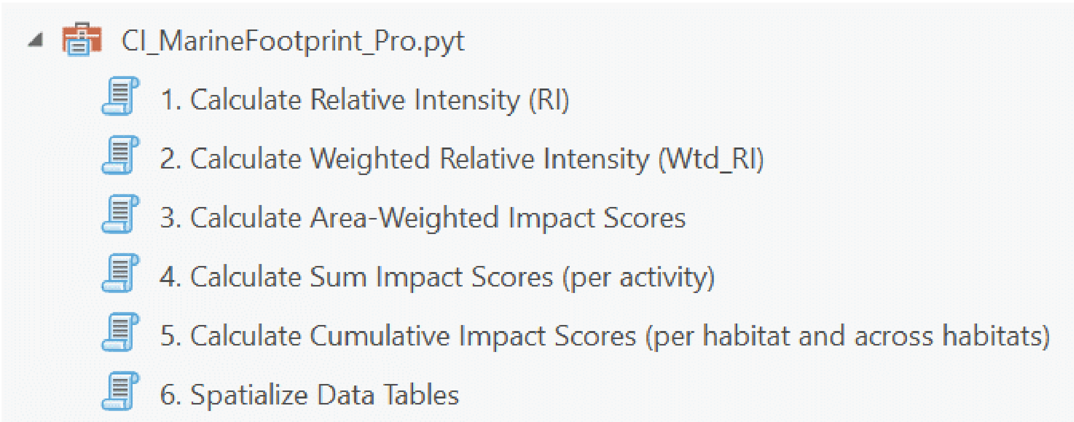

Figure 20. Screenshot of the tools in the Marine Footprint Toolbox.

Step 1: Calculate Relative Intensity (RI)

The first step of the Marine footprint analysis (Figure 21) is calculating a relative intensity (RI) value. Relative intensities are a quantification of the amount of activity occurring within each planning unit in the study area relative to the rest of the study area.

In order to run the cumulative effects analysis, the intensity (e.g., effort hours, frequency of occurrence) of each activity must be standardized across all scenarios.

The following options are provided:

- **Rescale from 0-1**: all values will be divided by the max value in the dataset to produce a continuous classification from 0-1.
- **Reclassify using Natural Breaks**: values will be reclassified using the natural breaks method using a user-specified no. of classes and a reclass expression to further modify the output classes. If this option is selected, the default value for **number of classes is 3**, and the default reclass expression is **"!RI_reclass!*0.5"** to convert the classes to 0.5, 1.0, and 1.5.
- **Do not rescale**: Please use this option if the data has been pre-processed and there is a pre-determined RI field available. **Please ensure that your RI values are relative across all scenarios you plan to run.**

Important notes:

If the data needs to be log transformed before rescaling, **the log transformation needs to be applied before the data is run through this step**.

If you are planning on running multiple scenarios for your analysis, **please ensure that data for all relevant scenarios have been run through the appropriate Data Preparation toolbox steps**.

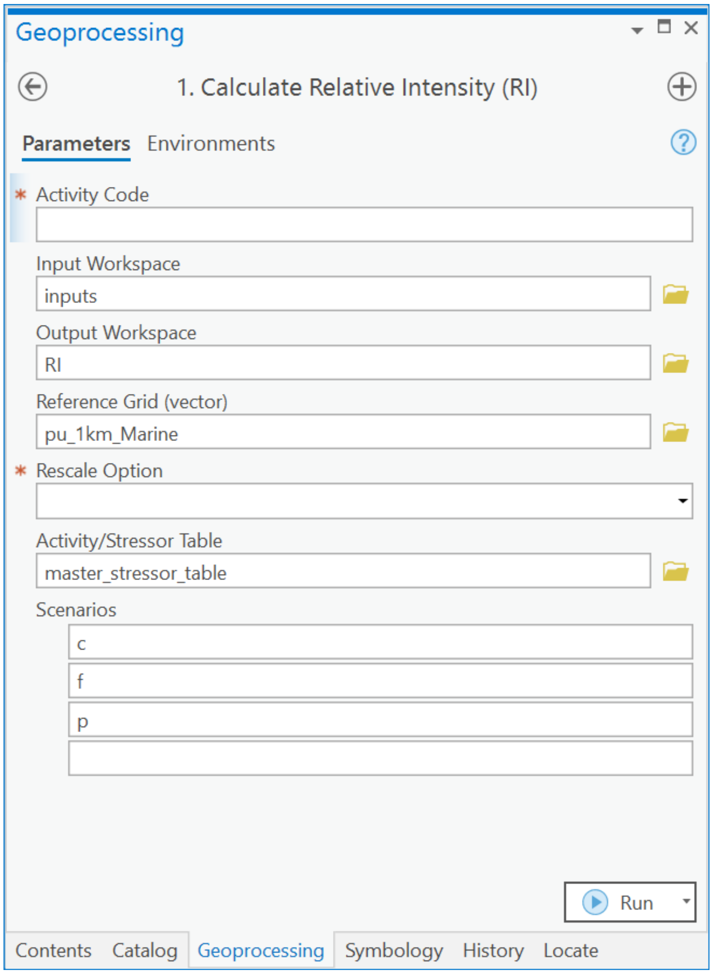

Figure 21. Screenshot of Step 1: Calculate Relative Intensity (RI) of Marine Footprint Toolbox.

Syntax

Step1 (activity, inputWorkspace, outputWorkspace, vector_grid, intensity_attr, rescale_option, stressortable, {classCount}, {userExpression}, scenarios)

Parameter	Explanation	Data Type
activity	Dialog Reference **Activity Code**: The activity code represents the activity. This is the code entered in the “Activity” field of the activity feature class. A drop-down menu for this variable will be made available once the paths for the activity-stressor table inputs have been entered. The activity code will be used in naming the output feature class. It will also be used to relate each activity to its relevant	String

	stressors. Therefore, the activity code appears in (i) the activity feature class, (ii) the activity-stressor inputs table, (iii) the stressor weights table, and (iv) the impact distances table. **Please ensure that the codes for each activity are consistent across all these datasets.** There is no python reference for this parameter.	
inputWorkspace	Dialog Reference **Input Workspace**: This workspace is the geodatabase or feature dataset that contains the input data. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_MarineFootprint_Inputs.gdb\inputs" There is no python reference for this parameter.	Workspace or Feature Dataset
outputWorkspace	Dialog Reference **Output Workspace**: The output workspace can be a feature dataset or a geodatabase. The output from this step will be feature classes containing the calculated RI values. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_MarineFootprint_Outputs.gdb\RI" There is no python reference for this parameter.	Workspace or Feature Dataset
vector_grid	Dialog Reference **Reference grid (vector):** The vector reference grid represents the smallest unit of analysis and the extent of the study area. Required fields: • **UNIT_ID**: the unique identifier for each grid cell. • **MarineArea**: the area of each grid cell excluding land. The sample grid provided are the 1 x 1 km Planning Units used by DFO Oceans Management for the Pacific Region: "DFO_CI_Toolbox\CI_InputData.gdb\baselayers\pu_1km_Marine" There is no python reference for this parameter.	Feature Class
intensity_attr	Dialog Reference **Intensity attribute**: This attribute of the Activity Feature Class will be used to calculate the Relative Intensity (RI). Please select the relevant attribute from the drop-down menu.	String

	Note: If this input dataset was run through the Data Preparation toolbox Step 3, the appropriate intensity attribute may be one with a prefix of **"ADJ_"** representing area weighted intensity values. **Please ensure you are selecting the correct intensity attribute for your selected dataset.** There is no python reference for this parameter.	
rescale_option	Dialog Reference **Rescale option**: The rescale option is selected at the discretion of the user and must be consistent across all the data inputs. Select the appropriate option from the dropdown menu: • **Rescale from 0-1:** all values will be divided by the max value in the dataset to produce a continuous classification from 0-1. • **Reclassify using Natural Breaks**: values will be reclassified using the natural breaks method using a user-specified no. of classes and a reclass expression to further modify the output classes. If this option is selected, the **default value for number of classes is 3**, and the **default reclass expression is "!RI_reclass!*0.5"** to convert the classes to 0.5, 1.0, and 1.5. • **Do not rescale:** Please use this option if the data has been pre-processed and there is a pre-determined RI field available. **Please ensure that your RI values are relative across all scenarios you plan to run.** **Note:** If the data needs to be log transformed before rescaling, the log transformation needs to be applied before the data is run through this step. There is no python reference for this parameter.	String
stressortable	Dialog Reference **Master stressor table**: The master stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. **At least one stressor must be assigned to each activity.** Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables.	Table

	Please ensure that the codes for each activity are consistent across all the input tables ("master_stressor_table", "vscores_habitats", "fishing_severity"). The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination. Stressor weights are relative intensity weights (e.g., “stressor weights”) that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. Please refer to the User Guide for detailed examples. If an activity-stressor combination exists, **the value in the stressor-weights field must not be <Null>**. In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity. Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor combination exists, **the value in the impact distances field must not be <Null>**. In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose an arbitrary distance (in metres, or other unit depending on the projection of your data), because the distance variable is a required input for the kernel density tool. **NOTE:** The master stressor table must be stored in a file geodatabase. The equivalent table in the sample data is: "DFO_CI_Toolbox\CI_InputData.gdb\master_stressor_table" There is no python reference for this parameter.	
classCount (Optional)	Dialog Reference **No. of classes**: This parameter is enabled only if the user selects a Natural Breaks reclassification. This value is the number of classes the data will be classified into. If the user selects a Natural Breaks classification, **the default value will be 3**, unless changed. There is no python reference for this parameter.	Long

userExpression (Optional)	Dialog Reference **Expression**: This parameter is enabled only if the user selects a Natural Breaks reclassification. This is the mathematical expression that will convert the tools output from integers to an RI classification scale. If the user selects an option of **Natural Breaks** and **3 classes**, the default expression is **"!gridcode!*0.5"** to return a classification scale of 0.5, 1.0, 1.5. **Click reset parameters to return parameter inputs to default expressions.** There is no python reference for this parameter.	String
scenarios	Dialog Reference **Scenarios:** The input feature classes may be named according to the scenario naming convention, where the scenario is identified by a prefix: • "c" for current scenarios • "f" for future scenarios • "p" for increased protection scenarios The script will identify the scenario based on the filename of the input dataset and automatically fill in the scenario variable. The scenario variable will be used to name the output feature class. There is no python reference for this parameter.	Multiple Value

Step 2: Calculate Weighted Relative Intensity (Wtd_RI)

The second step of the Marine Footprint Toolbox (Figure 21) takes the RI feature class created in Step 1 and applies stressor weights to the relative intensity of the activity based on sub-activities. Stressor weights are relative intensity weights (e.g., "stressor weights") that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available.

If there are no sub-activities for an activity, the stressor weight applied will be 1. The output feature class from this step is the weighted relative intensity (Wtd_RI).

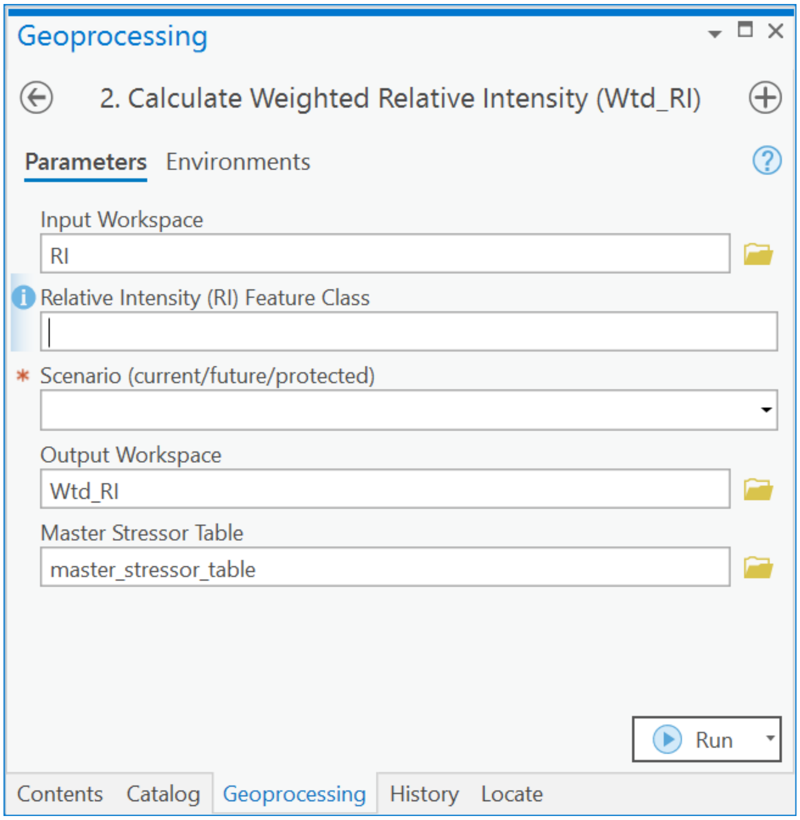

Figure 22. Screenshot of Step 2: Calculate Weighted Relative Intensity (Wtd_RI) of Marine Footprint Toolbox.

Syntax

Step2 (inputWorkspace, RI_fc, scn, outputWorkspace, stressortable)

Parameter	Explanation	Data Type
inputWorkspace	Dialog Reference **Input Workspace:** The input workspace must be a geodatabase or a feature dataset containing the features classes that were created in Step 1. In the sample data, the input workspace is: "DFO_CI_Toolbox\CI_MarineFootprint_Outputs.gdb\RI" There is no python reference for this parameter.	Workspace or Feature Dataset
RI_fc	Dialog Reference **RI feature class:** This is a feature class that has been run through Step 1. The dropdown menu pulls the relevant feature classes from the input workspace. These feature classes must have the following fields:	String

	• **"RI":** the relative intensity field calculated in Step 1 • **"AREA_WT":** the proportion of the planning unit covered by the activity There is no python reference for this parameter.	
scn	Dialog Reference **Scenarios:** The input feature classes may be named according to the scenario naming convention, where the scenario is identified by a prefix: • "c" for current scenarios • "f" for future scenarios • "p" for increased protection scenarios The script will identify the scenario based on the filename of the input dataset and automatically fill in the scenario variable. The scenario variable will be used to name the output feature class. There is no python reference for this parameter.	String
outputWorkspace	Dialog Reference **Output Workspace**: The output workspace can be a feature dataset or a geodatabase. The output from this step will be a set of feature classes generated from the Kernel Density tool. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_MarineFootprint_Outputs.gdb\Wtd_RI" There is no python reference for this parameter.	Workspace or Feature Dataset
stressortable	Dialog Reference **Master stressor table:** The master stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. **At least one stressor must be assigned to each activity.** Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables. **Please ensure that the codes for each activity are consistent across all the input tables**	Table

("master_stressor_table", "vscores_habitats", "fishing_severity").

The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination.

Stressor weights are relative intensity weights (e.g., "stressor weights") that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. Please refer to the User Guide for detailed examples.

If an activity-stressor combination exists, **the value in the stressor-weights field must not be <Null>**. In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity.

Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor combination exists, **the value in the impact distances field must not be <Null>**. In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose an arbitrary distance (in metres), because the distance variable is a required input for the kernel density tool.

NOTE: The master stressor table must be stored in a file geodatabase.

The equivalent table in the sample data is: "DFO_CI_Toolbox\CI_InputData.gdb\master_stressor_table"

There is no python reference for this parameter.

Step 3: Calculate Area-Weighted Impact Scores

The third step of the Marine Footprint Toolbox (Figure 23) calculates the impact scores based on the area weighted RI calculated in the previous step. The input feature class will be intersected with habitat feature classes, and the weighted RI values will be multiplied by the appropriate vulnerability (and fishing gear severity scores where appropriate) to generate a habitat area weighted impact score.

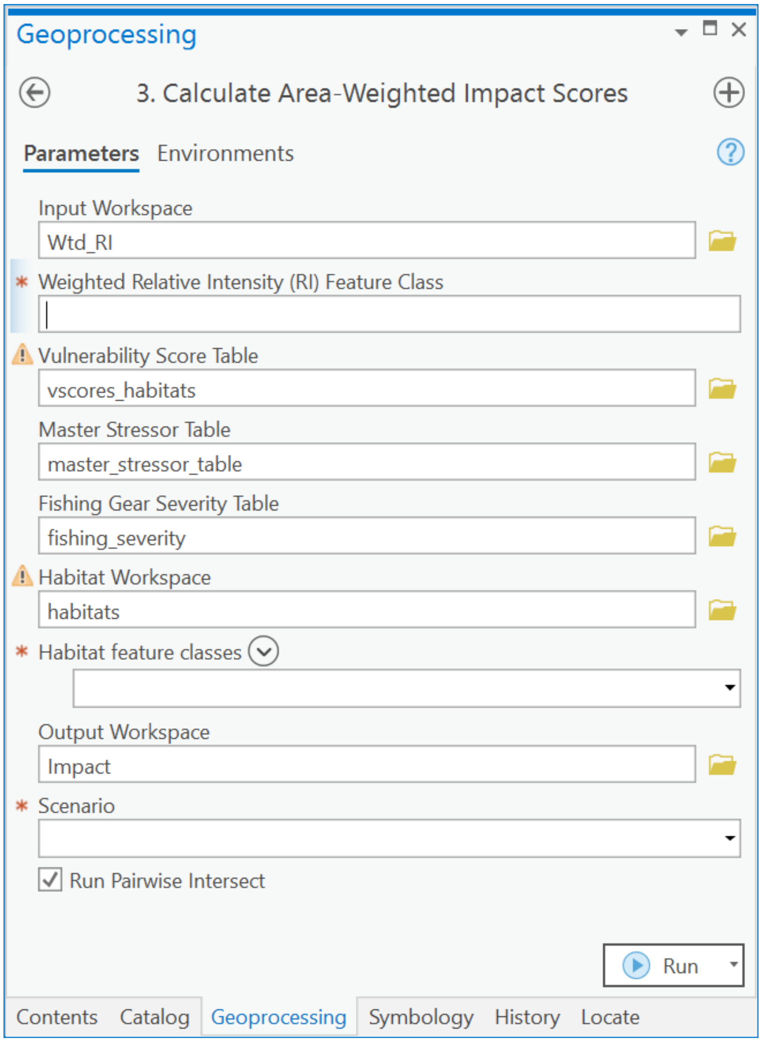

Figure 23. Screenshot of Step 3: Calculate Area-weighted Impact Scores of Marine Footprint Toolbox.

Syntax

Step3 (inputWorkspace, WtdRI_fc, vscoretable, stressortable, fishing_severity, habWorkspace, habitatFCs, outputWorkspace, scn, {pairwise})

Parameter	Explanation	Data Type
inputWorkspace	Dialog Reference **Input Workspace**: This workspace is the geodatabase or feature dataset that contains the input data. The equivalent workspace in the sample data is: "C:\DFO_CI_Toolbox\CI_MarineFootprint_Outputs.gdb\Wtd_RI" There is no python reference for this parameter.	Workspace or Feature Dataset

WtdRI_fc	Dialog Reference **<u>Weighted RI feature class</u>**: This is a feature class that has been run through Step 2 of the Marine Footprint Toolbox, or an output of the Coastal Kernel Density Toolbox. The dropdown menu pulls the relevant feature classes from the input workspace. These feature classes must have the following fields: • "ACTIVITY_CODE": The code representing the activity. Please ensure that this code has a matching entry in the master stressor, vulnerability scores, and fishing gear severity tables. • "RI_*stressor*(s)": Stressor weighted RI fields are created in Step 2. The suffix is the name of a stressor (or stressors) relevant to the activity. There is no python reference for this parameter.	String
vscoretable	Dialog Reference **<u>Vulnerability scores table</u>**: The vulnerability scores table (vscores_table) contains information on the relative vulnerability of each habitat to activity-specific stressors. Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables. **Please ensure that the codes for each activity are consistent across all the input tables ("master_stressor_table", "vscores_habitats", "fishing_severity").** **NOTE: The Vulnerability Scores table must be stored in a file geodatabase.** There is no python reference for this parameter.	Table
stressortable	Dialog Reference **<u>Master stressor table</u>**: The master stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. **At least one stressor must be assigned to each activity.** Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables.	Table

	Please ensure that the codes for each activity are consistent across all the input tables ("master_stressor_table", "vscores_habitats", "fishing_severity"). The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination. Stressor weights are relative intensity weights (e.g., “stressor weights”) that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. Please refer to the User Guide for detailed examples. If an activity-stressor combination exists, **the value in the stressor-weights field must not be <Null>.** In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity. Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor combination exists, **the value in the impact distances field must not be <Null>.** In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose an arbitrary distance (in metres), because the distance variable is a required input for the kernel density tool. NOTE: The master stressor table must be stored in a file geodatabase. The equivalent table in the sample data is: "DFO_CI_Toolbox\CI_InputData.gdb\master_stressor_table" There is no python reference for this parameter.	
fishing_severity	Dialog Reference **Fishing severity table**: This table contains information on the relative severity of the impact of fishing gear on marine habitats (Agbayani et al. 2015). **Each fishery is matched to a gear type, and each gear type is matched to a stressor.** The gear severity score is multiplied with the weighted relative intensity of the fishing activity and the vulnerability score of	Table

	habitats to the stressor to calculate the relative impact of fishing. Each fishing activity is represented by an activity code, and each related stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables. **Please ensure that the codes for each activity are consistent across all the input tables ("master_stressor_table", "vscores_habitats", "fishing_severity").** There is no python reference for this parameter.	
habWorkspace	Dialog Reference **Habitat workspace:** This workspace is the geodatabase or feature dataset that contains the habitat data. Please ensure that only correct habitat feature classes are saved in this workspace. Duplicate or backup feature classes within this workspace may result in double counting within the impact calculations. The equivalent workspace in the sample data is: " DFO_CI_Toolbox\CI_InputData.gdb\habitats" There is no python reference for this parameter.	Feature Dataset or Workspace
habitatFCs	Dialog Reference **Habitat feature classes**: Select the habitat feature classes for which impact scores will be calculated. The dropdown menu pulls the relevant feature classes from the input workspace. This parameter is a multi-value input, and several habitat feature classes may be selected. **Note: if the activity layer is a large or extensive feature class, it may be more efficient to run the tool one habitat at a time, or in small habitat groups.** There is no python reference for this parameter.	Multiple Value
outputWorkspace	Dialog Reference **Output Workspace**: The output workspace can be a feature dataset or a geodatabase. The output from this step will be feature classes containing calculated impact scores. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_MarineFootprint_Outputs.gdb\Impact"	Feature Dataset

	There is no python reference for this parameter.	
scn	Dialog Reference **Scenarios**: The input feature classes may be named according to the scenario naming convention, where the scenario is identified by a prefix: • "c" for current scenarios • "f" for future scenarios • "p" for increased protection scenarios The script will identify the scenario based on the filename of the input dataset and automatically fill in the scenario variable. The scenario variable will be used to name the output feature class. There is no python reference for this parameter.	String
pairwise (Optional)	Dialog Reference **Run Pairwise Intersect**: If this box is checked, the tool will run the Pairwise Intersect tool in the analysis. If this box is unchecked, the tool will run the Intersect tool instead. If the tool fails when the pairwise intersect is checked, please uncheck the box and try running the tool again. If the tool continues to fail, please check your data for topology errors. There is no python reference for this parameter.	Boolean

Step 4: Calculate Sum Impact Scores (per activity)

The fourth step of the Marine Footprint Toolbox (Figure 24) calculates the impact scores for each activity-habitat combination, and calculates the sum impact scores per activity, across all habitats. This tool will generate a large number of output tables, and a separate output workspace is recommended for the outputs of this step.

It is possible to run this step one activity at a time, or in small groups of activities. For activities that are spatially extensive, it may be more efficient to run this step one activity at a time, and in small groups of habitats.

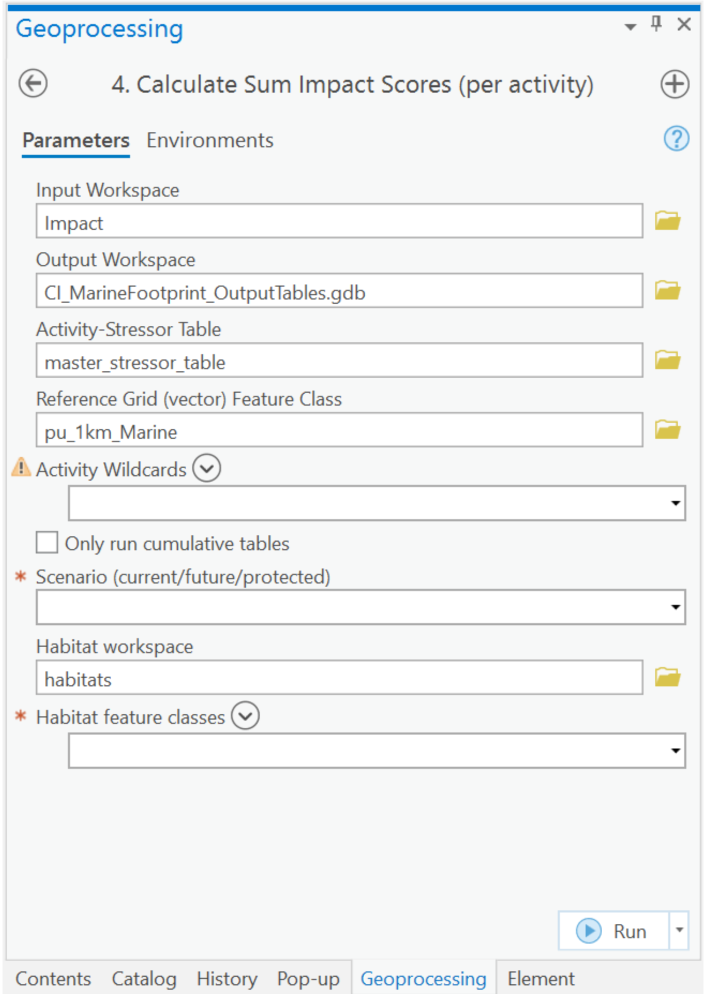

Figure 24. Screenshot of Step 4: Calculate sum impact scores (per activity) for Marine Footprint Toolbox.

Syntax

Step4 (inputWorkspace, outputWorkspace, stressortable, grid, {act}, {cumultablesonly}, scn, habitatWorkspace, habitatFCs)

Parameter	Explanation	Data Type
inputWorkspace	Dialog Reference **Input workspace:** The input workspace must be a geodatabase or a feature dataset. This workspace should contain the feature classes that were created in the previous step. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_MarineFootprint_Outputs.gdb\Impact"	Feature Dataset or Workspace

	There is no python reference for this parameter.	
outputWorkspace	Dialog Reference **<u>Output workspace</u>**: The output workspace must be a geodatabase. The output from this step will be geodatabase tables containing the calculated sum impact scores per activity, across habitats. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_MarineFootprint_OutputTables.gdb" There is no python reference for this parameter.	Workspace
stressortable	Dialog Reference **<u>Master stressor table:</u>** The master stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. **At least one stressor must be assigned to each activity.** Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables. **Please ensure that the codes for each activity are consistent across all the input tables ("master_stressor_table", "vscores_habitats", "fishing_severity").** The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination. Stressor weights are relative intensity weights (e.g., "stressor weights") that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently between sub-activities, but stressor-specific relative intensity data is not available. Please refer to the User Guide for detailed examples. If an activity-stressor combination exists, **the value in the stressor-weights field must not be <Null>.** In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity. Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor	Table

	combination exists, **the value in the impact distances field must not be <Null>.** In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose a reasonable distance (in metres, or other unit depending on the projection of your data), because the distance variable is a required input for the kernel density tool. **NOTE: The master stressor table must be stored in a file geodatabase.** The equivalent table in the sample data is: "DFO_CI_Toolbox\CI_InputData.gdb\master_stressor_table" There is no python reference for this parameter.	
grid	Dialog Reference **Planning unit vector grid**: The vector reference grid represents the smallest unit of analysis and the extent of the study area. **Required fields:** • **UNIT_ID**: the unique identifier for each grid cell. • **MarineArea**: the area of each grid cell excluding land. In the sample data, the reference vector grid is the 1x1 km Planning Unit grid from DFO Oceans Management, clipped to the coastline: "DFO_CI_Toolbox\CI_InputData.gdb\baselayers\pu_1km_Marine". **Note: The MarineAREA field in the sample data is in square metres.** There is no python reference for this parameter.	Feature Class
act (Optional)	Dialog Reference **Activity Wildcards:** These are a list of activity codes that will be used in combination with the scenario parameter to select the feature classes that will be processed by the tool. The drop-down menu pulls the activity codes from feature classes in the impact workspace. The activity code will be to name the output feature classes, and to identify activity-specific stressors for the impact calculations. **Note**: Activity codes appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables, and (iv) the fishing gear severity table. **Please ensure that the codes for each activity are consistent across these tables** There is no python reference for this parameter.	Multiple Value

cumultablesonly (Optional)	Dialog Reference **Run cumulative tables only:** Select this option if you want to calculate the Cumulative Impacts tables per activity across all habitats only. This option is available in the event that the tool fails after all impact tables have been processed, and only the cumulative tables need to be re-run. There is no python reference for this parameter.	Boolean
scn	Dialog Reference **Scenarios:** The input feature classes are named according to the scenario naming convention, where the scenario is identified by a prefix: • "c" for current scenarios • "f" for future scenarios • "p" for increased protection scenarios Select a scenario for the tool to process. The tool will select all feature classes within the input workspace for the scenario and activity codes selected. There is no python reference for this parameter.	String
habitatWorkspace	Dialog Reference **Habitat workspace**: This workspace is the geodatabase or feature dataset that contains the habitat data. Please ensure that only correct habitat feature classes are saved in this workspace. Duplicate or backup feature classes within this workspace may result in double counting within the impact calculations. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_InputData.gdb\habitats" There is no python reference for this parameter.	Feature Dataset or Workspace
habitatFCs	Dialog Reference **Habitat feature classes**: Select the habitat feature classes for which impact scores will be calculated. The dropdown menu pulls the relevant feature classes from the habitat workspace. This parameter is a multi-value input, and several habitat feature classes may be selected.	Multiple Value

Note: if the activity layer is a large or extensive feature class, it may be more efficient to run the tool one habitat at a time, or in small habitat groups.

There is no python reference for this parameter.

Step 5: Calculate Cumulative Impact Scores (per habitat and across habitats)

The fifth step of the Marine Footprint Toolbox (Figure 25) calculates the cumulative impact scores for each habitat across all activities, and across all activities and habitats. In order to calculate a cumulative impact score across all activities and habitats, the tool must be run for all activity codes and habitats in the analysis.

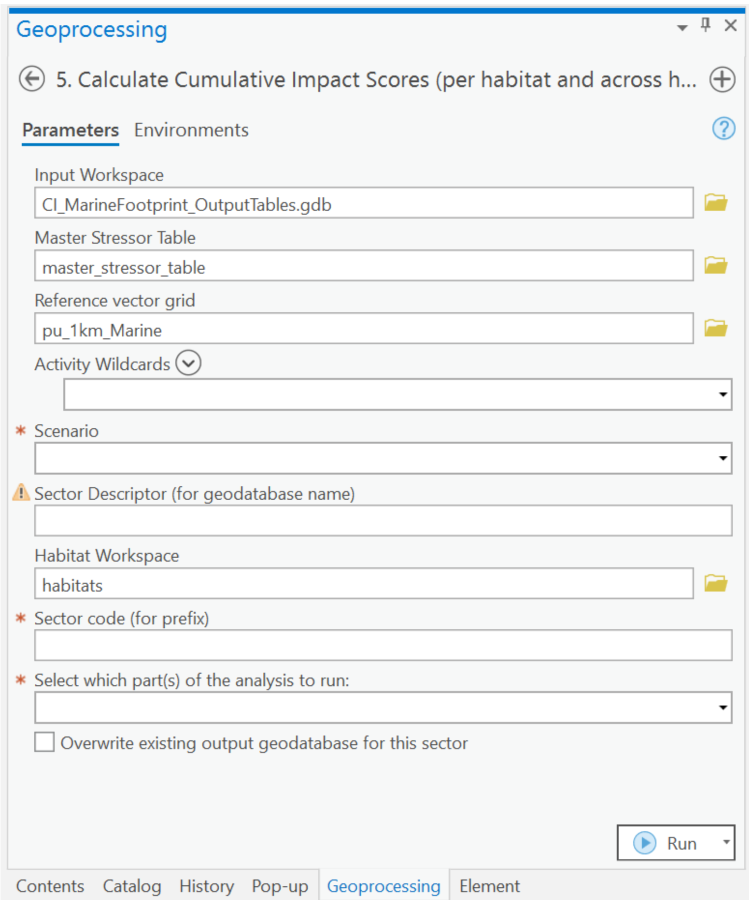

Figure 25. Screenshot of Step 5: Calculate Cumulative Impact Scores (per habitat and across habitats) for Marine Footprint Toolbox.

Cumulative Impacts for Sectors: To calculate the cumulative impact score for a subset of activities, (e.g., a sector), the user must input a sector descriptor to name the output geodatabase and a sector code to be used as a prefix for the output tables.

Cumulative Impacts for all activities: When generating the final cumulative impacts calculation taking into account all activities and all habitats, please use uppercase "ALL" for the sector descriptor and lowercase "all" for the sector code.

Syntax

Step5 (inputWorkspace, stressortable, grid, {activity}, scenario, sectorDesc, habitatWorkspace, {habitatFCs}, sector, runParts, {delGDB})

Parameter	Explanation	Data Type
inputWorkspace	Dialog Reference **Input workspace:** The workspace must be a geodatabase containing output tables created in Step 4. The equivalent workspace in the sample data is: "DFO_CI_Toolbox\CI_MarineFootprint_OutputTables.gdb". There is no python reference for this parameter.	Workspace
stressortable	Dialog Reference **Master stressor table:** The master stressor table contains the information on what stressors are associated with each activity. If an activity-stressor combination exists, then it must be entered as a separate row in the table. Both the activity and stressor fields are required in this step. **At least one stressor must be assigned to each activity.** Each activity is represented by an activity code, and each stressor is represented by a stressor code, which appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables. **Please ensure that the codes for each activity are consistent across all the input tables ("master_stressor_table", "vscores_habitats", "fishing_severity").** The master stressor table also contains information on sub-activities, stressor weights, and impact distances for each stressor-habitat combination. Stressor weights are relative intensity weights that will be applied to sub-activities within each activity-stressor combination. Stressor weights are applied when stressors are known to behave differently	Table

	between sub-activities, but stressor-specific relative intensity data is not available. If an activity-stressor combination exists, **the value in the stressor-weights field must not be <Null>**. In situations where information on the relative behaviour of stressors is not available (i.e., stressor weights need not be applied), the value in the stressor weights field must be 1. If a stressor applies to some sub-activities, but not to others, enter a value > 0 for when the stressor is relevant to a sub-activity, and enter a value of 0 where the stressor is not relevant to the sub-activity. Impact distances are the maximum distance a stressor is assumed to travel from its source. If a coastal activity-stressor combination exists, **the value in the impact distances field must not be <Null>**. In situations where detailed information on impact distances for each stressor are not available, the user will be required to choose an arbitrary distance (in metres, or other unit depending on the projection of your data), because the distance variable is a required input for the kernel density tool. **NOTE: The master stressor table must be stored in a file geodatabase.** The equivalent table in the sample data is: "DFO_CI_Toolbox\CI_InputData.gdb\master_stressor_table". There is no python reference for this parameter.	
grid	Dialog Reference **Reference vector grid**: The reference vector grid represents the smallest unit of analysis and the extent of the study area. Required fields: • **UNIT_ID**: the unique identifier for each grid cell. • **MarineArea**: the area of each grid cell excluding land. The sample grid provided are the 1 x 1 km Planning Units used by DFO Oceans Management for the Pacific Region: "DFO_CI_Toolbox\CI_InputData.gdb\baselayers\pu_1km_Marine". The MarineAREA field in the sample data is in square metres. There is no python reference for this parameter.	Feature Class
activity (Optional)	Dialog Reference **Activity Wildcards**: These are a list of activity codes that will be used in combination with the scenario parameter to select the feature classes that will be processed by the tool. The drop-down menu pulls the activity codes from feature classes in the impact workspace.	Multiple Value

	The activity code will be to name the output feature classes, and to identify activity-specific stressors for the impact calculations. **Note**: Activity codes appear in: (i) the activity feature class, (ii) the master-stressor table, (iii) the Vulnerability Scores tables, and (iv) the fishing gear severity table. **Please ensure that the codes for each activity are consistent across these tables.** There is no python reference for this parameter.	
scenario	Dialog Reference **<u>Scenarios</u>**: The input feature classes may be named according to the scenario naming convention, where the scenario is identified by a prefix: • "c" for current scenarios • "f" for future scenarios • "p" for increased protection scenarios The script will identify the scenario based on the filename of the input dataset and automatically fill in the scenario variable. The scenario variable will be used to name the output feature class. There is no python reference for this parameter.	String
sectorDesc	Dialog Reference **<u>Sector descriptor (for output geodatabase name)</u>**: Please enter a text-based descriptor for the sector you are calculating cumulative impact scores for. This value will be used to name the new output geodatabase that will store the output tables. **This sector descriptor must match the sector code entered below.** For example, in the sample data, the sector descriptor for commercial fishing is "Comm_Fishing" and the matching sector code is "cf". **When generating the final cumulative impacts calculation taking into account all activities and all habitats, please use uppercase "ALL" for the sector descriptor and lowercase "all" for the sector code.** There is no python reference for this parameter.	String
habitatWorkspace	Dialog Reference **<u>Habitat workspace</u>**: This workspace is a feature dataset that contains the habitat feature classes. The sample dataset provided is: "DFO_CI_Toolbox\CI_InputData.gdb\habitats". **Note**: When running **Part 1 only**, the user may run the tool one habitat at a time, or in small habitat groups. When running Part 2, all	Workspace or Feature Dataset

	the habitats feature classes in the habitat workspace will be run through the tool. **Please ensure there are no duplicate / unnecessary habitat feature classes in the workspace before running Part 2.** There is no python reference for this parameter.	
habitatFCs (Optional)	Dialog Reference **Habitat feature classes**: Select the habitat feature classes for which impact scores will be calculated. The dropdown menu pulls the relevant feature classes from the habitat workspace. This parameter is a multi-value input, and several habitat feature classes may be selected. **Note**: Parameter is enabled when running **Part 1 only**. If the activity layer is a large or extensive feature class, it may be more efficient to run the tool one habitat at a time, or in small habitat groups. When running Part 2 only (or Part 1 and 2: all calculations), all the habitats feature classes in the habitat workspace will be run through the tool. **Please ensure there are no duplicate / unnecessary habitat feature classes in the workspace before running Part 2.** There is no python reference for this parameter.	Multiple Value
sector	Dialog Reference **Sector Code (for table name prefix):** Please enter a 2- or 3-character code to identify the sector for each table created in this step. This value will be used as a prefix for the cumulative impact tables. **This sector code must match the sector descriptor entered above**. For example, in the sample data, the sector descriptor for commercial fishing is "Comm_Fishing" and the matching sector code is "cf". **When generating the final cumulative impacts calculation taking into account all activities and all habitats, please use uppercase "ALL" for the sector descriptor and lowercase "all" for the sector identifier.** There is no python reference for this parameter.	String
runParts	Dialog Reference **Select which part(s) of the analysis to run:** Select which parts of the analysis to run. • **Part 1 only**: Calculates sum impact scores across all activities for each habitat. **Note: For this option, the tool can run habitat by habitat, or in small habitat groups.** • **Part 2 only**: Calculates cumulative impact scores across all activities and all habitats. **Note**: **This option will require all**	String

	the outputs for all the activities and habitats from Part 1 to run successfully. • **Part 1 and 2**: Runs all calculations for Part 1 and 2. There is no python reference for this parameter.	
delGDB (Optional)	Dialog Reference **<u>Overwrite existing output geodatabase for this sector:</u>** Select this option if you would like to overwrite an existing output geodatabase (CIM_Tables_*sector_descriptor.gdb*). If this option is selected, **the geodatabase will be deleted and recreated**. **Note:** Do not select this option if you would like to add/append outputs to the output geodatabase (e.g., when running Part 1 habitat by habitat, or in small habitat groups). This option is disabled when running Part 2 only or running Part 1 and 2. There is no python reference for this parameter.	Boolean

Step 6: Spatialize Data Tables

The sixth step of the Marine Footprint Toolbox (Figure 26) will join geodatabase tables to the reference vector grid for spatialization and mapping. The input tables will require a UNIT_ID to be used as a join field. Each table entered will be result in an output feature class that will be saved in the same workspace the table is in.

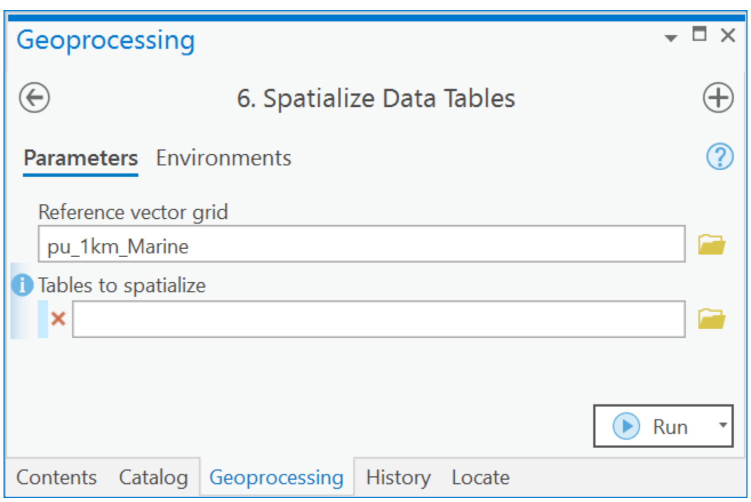

Figure 26. Screenshot of Step 6: Spatialize Data Tables from Marine Footprint Toolbox.

Syntax

Step6 (grid, tables)

Parameter	Explanation	Data Type
grid	Dialog Reference **Reference vector grid**: The vector reference grid represents the smallest unit of analysis and the extent of the study area. Required fields: • **UNIT_ID**: the unique identifier for each grid cell. • **MarineArea**: the area of each grid cell excluding land. The sample grid provided are the 1 x 1 km Planning Units used by DFO Oceans Management for the Pacific Region: "DFO_CI_Toolbox\CI_InputData.gdb\baselayers\pu_1km_Marine" There is no python reference for this parameter.	Feature Class
tables	Dialog Reference **Tables to spatialize**: Select the geodatabase tables to be joined to the reference vector grid. **Required fields for each table**: • **UNIT_ID**: the unique identifier for each grid cell that will be used as the join field. There is no python reference for this parameter.	Multiple Value

7. Tips and Tricks on Common Issues

In this section, users can find tips and tricks to help them run the models. Users can also find common errors that may occur during the running of the various tools of the model.

7.1. Batching

ArcGIS Pro enables users to batch tools by right-clicking on the tool and selecting “Batch” from the menu. However, many of the steps in the Toolboxes already utilize batch processing. Users are encouraged to utilize the batching functionality only when prompted to do so in the tool parameter interface. For example, Step 3 of the Marine Footprint Toolbox allows the user to batch process for multiple habitats (Figure 27). Batching tools that are already designed to iterate through a large number of files may have a detrimental effect on tool performance.

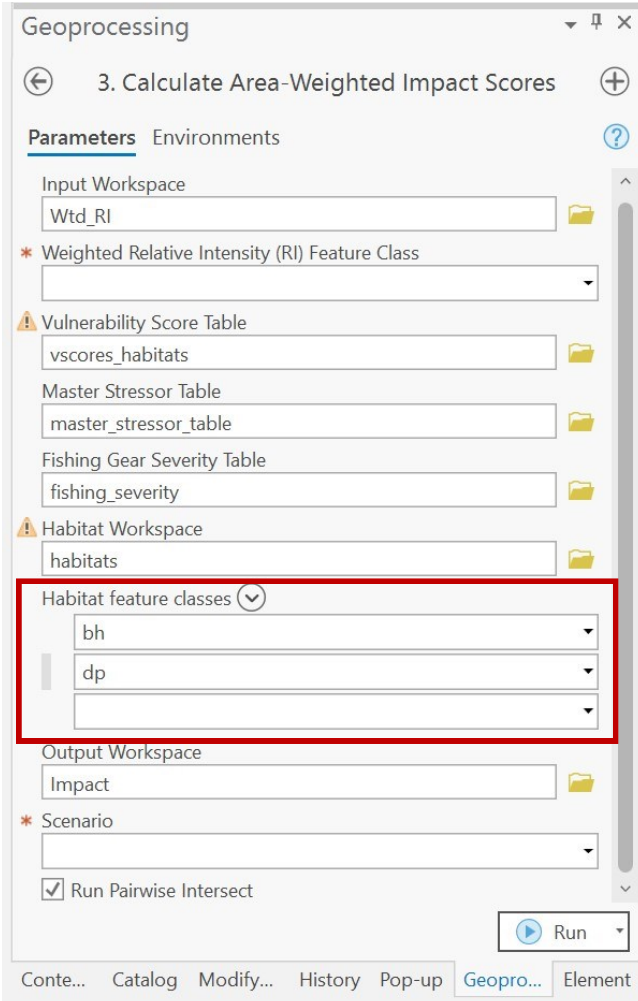

Figure 27. Step 3 of the Marine Footprint Toolbox allows the user to batch run the tool for multiple habitat feature classes.

7.2. Errors in file structure

If users encounter the error message seen in Figure 28, it is due to the fact that paths are partially hard coded as defaults into the Python script. For users without experience in either ArcGIS or Python, it is recommended that these users use the recommended file structure as described earlier in this document. For users that wish to edit the paths coded into the Python script, please find the paths located in the parameter “value” as seen in Figure 29.

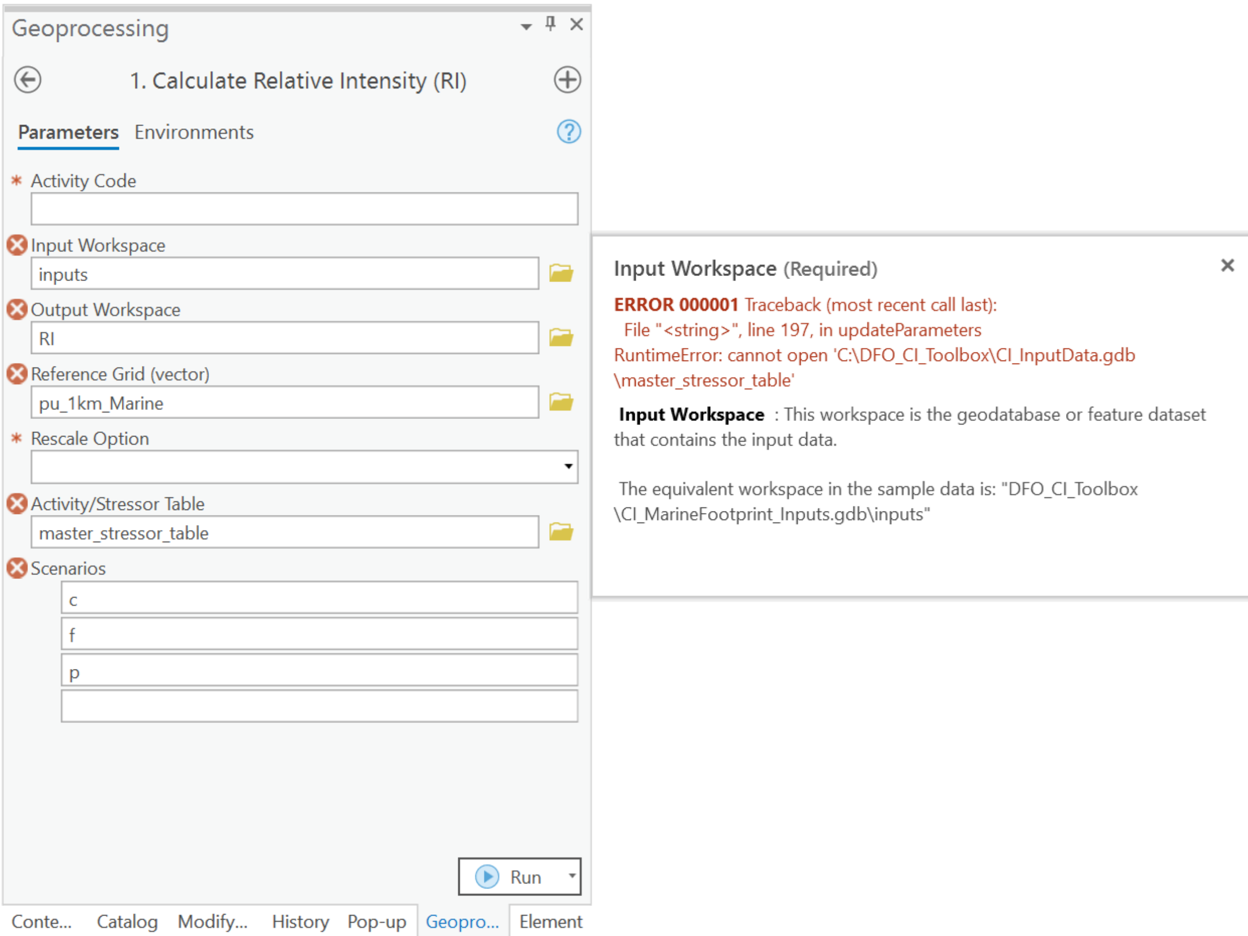

Figure 28. Example of the error message shown by the tool when a default input parameter is not found.

```
param1 = arcpy.Parameter(
    displayName = "Input Workspace",
    name = "inputWorkspace",
    datatype = ["DEWorkspace", "DEFeatureDataset"],
    parameterType = "Required",
    direction = "Input")
param1.value = os.path.join(os.path.dirname(__file__),
                            r'CI_MarineFootprint_Inputs.gdb\inputs')
```

Figure 29. Partially hard-coded file paths in Python script. The tool will work as long as the geodatabases are stored in the same folder as the .pyt files and the naming conventions are maintained. *Note: ArcGIS does not recognize dot-dot notation for relative paths. Please use "os.path" functions.*

7.3. License error

Step 1 and 2 of the Marine Coastal KD Toolbox uses the Kernel Density tool. This requires the "Spatial Analyst" extension to be enabled. Users will encounter Error 000824 if this extension has not been enabled (Figure 30). To fix this issue, please enable the Spatial Analyst Extension in the ArcGIS Pro Licensing Options (Figure 31).

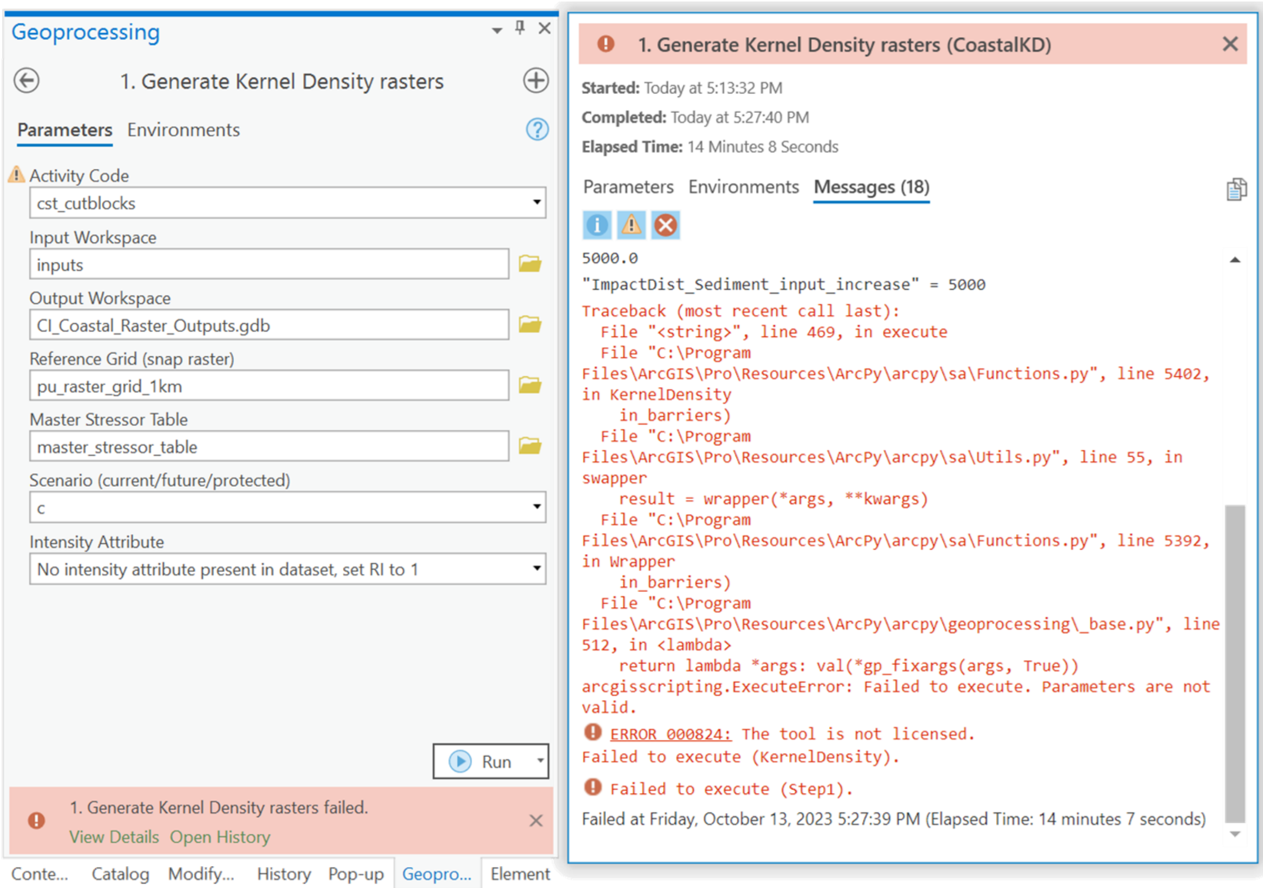

Figure 30. Screenshot of error message for ERROR 000824, shown when the Coastal Kernel Density tools are run when the Spatial Analyst Extension is not enabled.

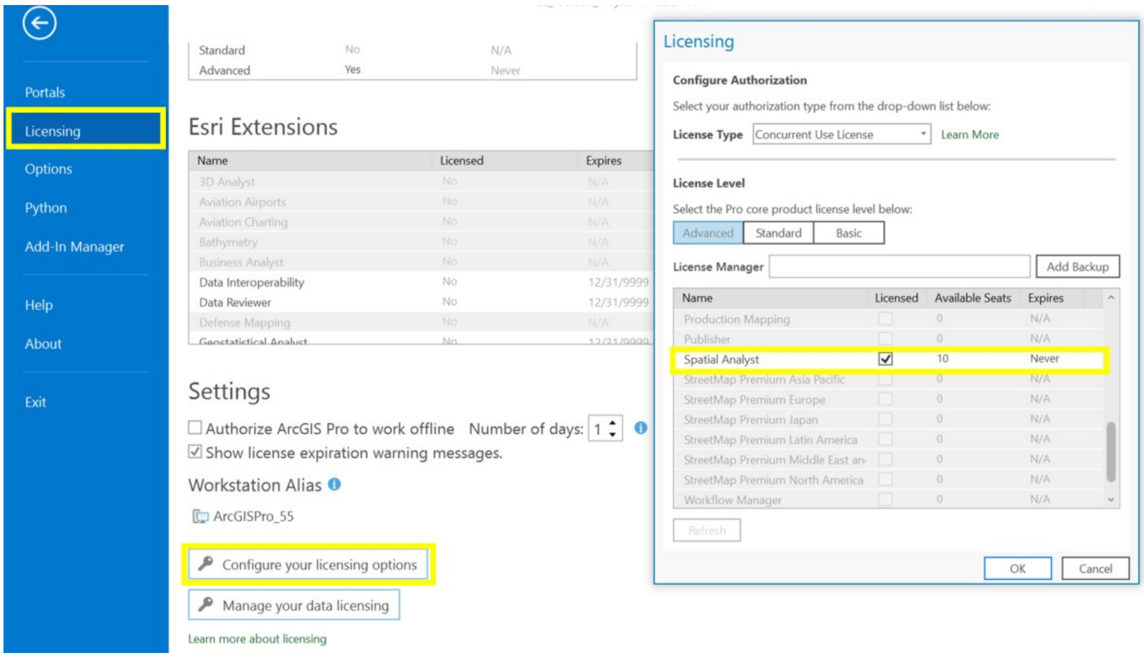

Figure 31. Screenshot of the Licensing configuration options to enable the Spatial Analyst Extension.

8. Abbreviations and codes

The Cumulative Impact Toolboxes utilize a series of codes representing different activities, scenarios, habitats and other things. The sections below outline the meaning of each abbreviation and where they are likely to be found.

8.1. Habitats

Table 9. Code descriptions for habitat feature classes in the habitats feature dataset.

Habitat feature class	Description
bh	Benthic habitats
dp	Deep pelagic (>30m)
eg	Eelgrass
kp	Kelp
sp	Shallow pelagic / surface waters (<30m)
sr	Sponge reefs

Table 10. Code descriptions for HabitatCODE field in habitat feature classes.

Habitat type	Habitat feature class	HabitatCODE	Description
Biogenic habitats	eg	SEAG	Eelgrass
	kp	KELP	Kelp
	sr	SPONGE	Sponge Reefs
Benthic habitats	bh	SITDL	Soft intertidal
		MITDL	Mixed Intertidal
		HITDL	Hard intertidal
		UITDL	Undefined intertidal
		SSHLW	Soft Shallow
		MSHLW	Mixed Shallow
		HSHLW	Hard Shallow
		USHLW	Undefined Shallow
		SSHLF	Soft Shelf
		MSHLF	Mixed Shelf
		HSHLF	Hard Shelf
		USHLF	Undefined Shelf
		SCANYON	Soft Canyons
		MCANYON	Mixed Canyons
		HCANYON	Hard Canyons
		UCANYON	Undefined Canyons
		SSLOPE	Soft Slope
		MSLOPE	Mixed Slope
		HSLOPE	Hard Slope
		USLOPE	Undefined Slope
		SDEEP	Soft Deep
		MDEEP	Mixed Deep
		HDEEP	Hard Deep
		UDEEP	Undefined Deep
		SHILL	Soft Hill
		MHILL	Mixed Hill
		HHILL	Hard Hill
		UHILL	Undefined Hill
		SKNOLL	Soft Knoll
		MKNOLL	Mixed Knoll

Habitat type	Habitat feature class	HabitatCODE	Description
		HKNOLL	Hard Knoll
		UKNOLL	Undefined Knoll
		SSEAMT	Soft Seamount
		MSEAMT	Mixed Seamount
		HSEAMT	Hard Seamount
		USEAMT	Undefined Seamount
Pelagic habitats	sp	SPELAGIC	Shallow Pelagic
	dp	DPELAGIC	Deep Pelagic

8.2. Activities

Table 11. Descriptions for code segments used in activity feature classes and datasets.

Activity code segments	Description
_cf_	Commercial fisheries (footprint)
sportf	Sport fisheries (footprint)
clim	Climate change variable (footprint)
mar	Marine activity (footprint)
cst	Coastal activity (point-source, marine/on land)
lnd	Inland activity (point-source from estuary)

8.3. Scenarios

Table 12. Descriptions for scenario prefix codes.

Scenario prefix	Description
c_	Current
f_	Future
p_	Protected

8.4. Other Miscellaneous Codes

Table 13. Descriptions of miscellaneous code segments used in names of geodatabases, feature classes, datasets, and fields.

Code segment	Description
pu_	Planning Unit
CI_	Cumulative Impacts
DFO	Department of Fisheries and Oceans
KD	Kernel Density
LI	Land Index
MF	Marine Footprint
HabAREA	Habitat Area
WT	Weight

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