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Woods Hole Oceanographic Institution

FISH_ROCK: A Tool for Identifying and Counting Benthic Organisms in Bottom Photographs

by

Vicki Lynn Ferrini and Hanumant Singh

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Technical Report

Funding was provided by the National Oceanic and Atmospheric Administration
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Approved for Distribution:

James F. Lynch, Chair
Department of Applied Ocean Physics and Engineering

Table of Contents

List of Figures

1.0 Introduction

Recent advances in underwater robotics and imaging technology now enable the rapid acquisition of large datasets of near-bottom high-resolution digital imagery. These images provide the potential for developing a non-invasive technique for fisheries data acquisition that reveals the organisms in their natural habitat and can be used to identify important habitat characteristics. Using these large datasets effectively, however, requires the development of computer-based techniques that increase the efficiency of data analysis.

FISH_ROCK is a graphical user interface (GUI) that was designed in Matlab as a database building tool for identifying and counting benthic organisms and for categorizing the substrate in bottom photographs collected with the SeaBED Autonomous Underwater Vehicle (AUV; Figure 1). It was initially developed for researchers from the NOAA Pacific Marine Fisheries Division seeking to employ new tools for studying and assessing the population, abundance, and distribution of benthic organisms relevant to fisheries management issues. During a 2-week research cruise aboard the *R/V Thompson* (TN186; Chief Scientist: Elizabeth Clarke) over 30,000 digital images were collected of the seafloor using a pixelfly high dynamic range camera mounted on the SeaBED AUV. FISH_ROCK was created to facilitate the analysis of these images by allowing users to digitally generate a database containing information about organisms and seafloor substrate characteristics within the framework of a geographic coordinate system. This document explains the input format requirements and the GUI functionality, as well as an overview of plans for future development.

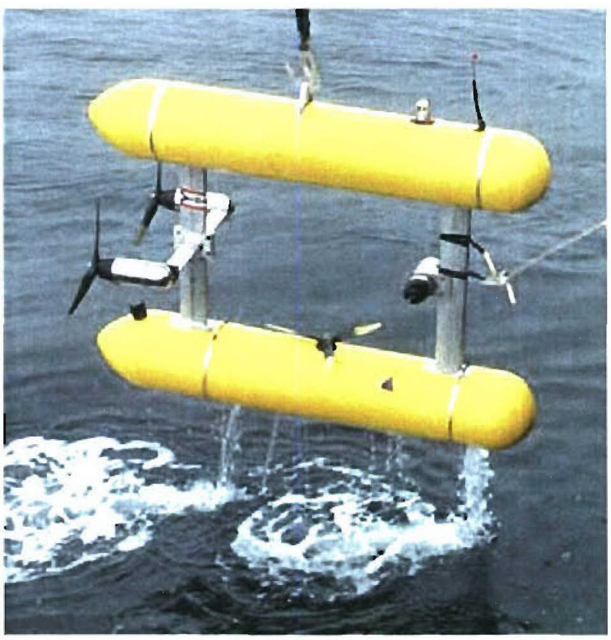


Figure 1: SeaBED AUV

FISH_ROCK is executed through Matlab and requires that three files (FISH_ROCK.m, FISH_ROCK.fig, and HabitatClassification.png) reside within the Matlab path. The output of FISH_ROCK includes a comma delimited text file (*.fct) for each image that contains the navigational information for the image and a list of the organisms identified, as well as comments noted by the user. In addition, upon closing FISH_ROCK, all of the *.fct files contained within the working directory are assembled into a master comma delimited text file that can be loaded directly into a variety of other software packages (i.e. GIS, spreadsheet, statistical software) for further analysis.

Organisms can be identified and counted based on pull-down menus with predefined lists of organisms commonly identified in the study area. There is also an option to input the names of organisms not included in the lists. Measurement tools are included in the GUI to enable the quantification of the dimensions (length and area) of organisms and objects on the seafloor. Note that no corrections have been made for image distortion, and the GUI assigns a centimeter scale to each image based on the assumption of a flat seafloor. Finally, pull-down menus are provided to allow the user to characterize the substrate type following a binary classification scheme that has been used in fish habitat studies (Hixon et al. 1991; Stein et al. 1992);

2.0 Data Input

2.1 Image input

FISH_ROCK is designed to work with images named with a time stamp and image number. The time stamp functions as a unique identifier for each image and is used to extract position and attitude data for each image. The required filename format includes 4 characters at the beginning of the file name followed by date (yyyymmdd), time (hhmmssss), frame number (nnnn), and file extension (*tif, *.jpg, or *.bmp):

```
xxxx.yyyymmdd.hhmmssss.nnnn.jpg
```

Note that in the time portion of the filename, seconds are given as decimal seconds but no decimal point is included (e.g. ssss = decimal seconds: ss.ss). It is recommended that the input data directory contain only the images that will be analyzed and the appropriate navigational file (see section 2.2).

In order to measure lengths and areas of organisms on the seafloor using FISH_ROCK it is critical that the look angles of the camera be accurately known. Since this GUI was designed for a specific pixelfly camera the look angles are hard-coded within the GUI. For the camera used on SeaBED, the look angles are 42.3211° and 34.26°. These angles are used with the number of pixels per image (1280 x 1024) and the altitude of the vehicle to calculate the horizontal and vertical dimensions of the images in centimeters. Using FISH_ROCKwith images collected with a different camera may require that these look angles be modified. This modification can be made on lines 869 and 870 of FISH_ROCK.m (Figure 2).

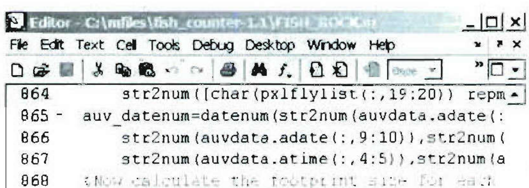


Figure 2: Setting look angles in FISH_ROCK. Lines 869 and 870 of FISH_ROCK.m define the look angles of the pixelfly camera used on the SeaBED AUV. If using this code with data collected with a different camera, these look angles must be correct in order to calculate the scale of the image.

2.2 Navigation data input

2.2.1 Use of the cat_nav.mat file generated for SeaBED

FISH_ROCK seeks a binary matlab data file (*.mat file) called cat_nav.mat as primary navigational input. This file should reside in the same directory as the images that will be analyzed, and is created as a standard output product in the SeaBED AUV data processing pipeline. The first time the code is initialized within a particular data directory, cat_nav.mat is used in conjunction with a listing of all image files in that directory to create a subsampled navigation file that is used by FISH_ROCK to index navigation data to the images. Another mat file called pxlflyNAV.mat is automatically generated based on the time stamps of the images, and is used directly by FISH_ROCK during subsequent use of the code. In addition, a text file, pxlflyNAV.txt (Figure 3), which contains the same information as pxlflyNAV.mat will also be generated, and is provided as a resource to users. The format of this file is:

```
image_name, latitude, longitude, water depth (m), altitude (m), horiz
image dim (m), vert image dim (m), total image area (m^2), local X (m),
local Y (m)
```

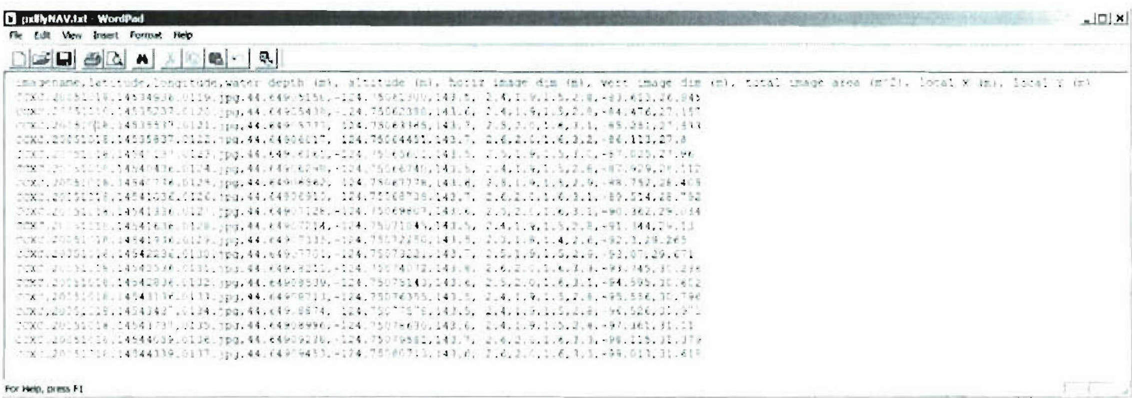


Figure 3: Example pxlflyNAV.txt file that is generated by FISH_ROCK containing navigational information for each image in the directory.

2.2.2 Creating a cat_nav.mat file

If using FISH_ROCK with different input data, a cat_nav.mat file can be created within Matlab, and must contain a data structure called auvdata. This data structure must contain the following fields:

Table 1: Fields that must be included in cat_nav.mat

Field	Size	type	format
adate	N x 10	char	yyyy/mm/dd
atime	N x 11	char	hh:mm:ss.ss
localX	N x 1	double	localX or UTMX (m)
localY	N x 1	double	localY or UTMY (m)
altitude	N x 1	double	altitude of camera (m)
depth2	N x 1	double	total water depth (m)
lat	N x 1	double	decimal degrees (-S)
lon	N x 1	double	decimal degrees (-W)

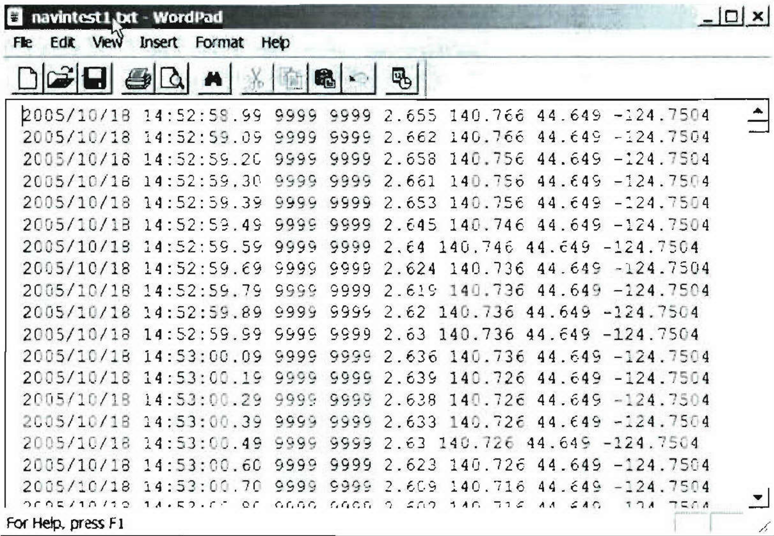
2.2.3 Using a text file for nav input

If neither cat_nav.mat nor pxlflyNAV.mat exist, the user is prompted to select a text file as navigational input. This functionality provides the option of using FISH_ROCK with data not collected with SeaBED. Remember, if using a different camera system with different look angles, they must be declared within FISH_ROCK.m (Figure 2; section 2.1). Once chosen, the text file will be uploaded and used to generate the cat_nav.mat file as well as pxlflyNAV.mat and pxlflyNAV.txt (see section 2.2.1).

This text file must be tab delimited, with no header (Figure 4), following the format:

date time localX localY altitude depth lat lon

The date must be provided with the format yyyy/mm/dd, and time must be hh:mm:ss.ss (Fig. 4). If not working in localXY, any values, including UTM coordinates or a number indicating no data (i.e. 9999) may be used to populate the localX and localY fields. The precision of the latitude and longitude coordinates and attitude data should be determined by the user based on the dataset being analyzed.




```
2005/10/18 14:52:58.99 9999 9999 2.655 140.766 44.649 -124.7504
2005/10/18 14:52:59.09 9999 9999 2.662 140.766 44.649 -124.7504
2005/10/18 14:52:59.20 9999 9999 2.658 140.756 44.649 -124.7504
2005/10/18 14:52:59.30 9999 9999 2.661 140.756 44.649 -124.7504
2005/10/18 14:52:59.39 9999 9999 2.653 140.756 44.649 -124.7504
2005/10/18 14:52:59.49 9999 9999 2.645 140.746 44.649 -124.7504
2005/10/18 14:52:59.59 9999 9999 2.64 140.746 44.649 -124.7504
2005/10/18 14:52:59.69 9999 9999 2.624 140.736 44.649 -124.7504
2005/10/18 14:52:59.79 9999 9999 2.619 140.736 44.649 -124.7504
2005/10/18 14:52:59.89 9999 9999 2.62 140.736 44.649 -124.7504
2005/10/18 14:52:59.99 9999 9999 2.63 140.736 44.649 -124.7504
2005/10/18 14:53:00.09 9999 9999 2.636 140.736 44.649 -124.7504
2005/10/18 14:53:00.19 9999 9999 2.639 140.726 44.649 -124.7504
2005/10/18 14:53:00.29 9999 9999 2.638 140.726 44.649 -124.7504
2005/10/18 14:53:00.39 9999 9999 2.633 140.726 44.649 -124.7504
2005/10/18 14:53:00.49 9999 9999 2.63 140.726 44.649 -124.7504
2005/10/18 14:53:00.60 9999 9999 2.623 140.726 44.649 -124.7504
2005/10/18 14:53:00.70 9999 9999 2.609 140.716 44.649 -124.7504
```

Figure 4: Example of text file used as navigational input.

3.0 Using FISH_ROCK

Before FISH_ROCK can be executed, the three required files (FISH_ROCK.m, FISH_ROCK.fig, and HabitatClassification.png) must be copied to the hard drive. After opening Matlab, the path must be modified to include the folder that contains these files. Once this is done, the GUI is initialized by typing FISH_ROCK in the Matlab command window (Figure 5).

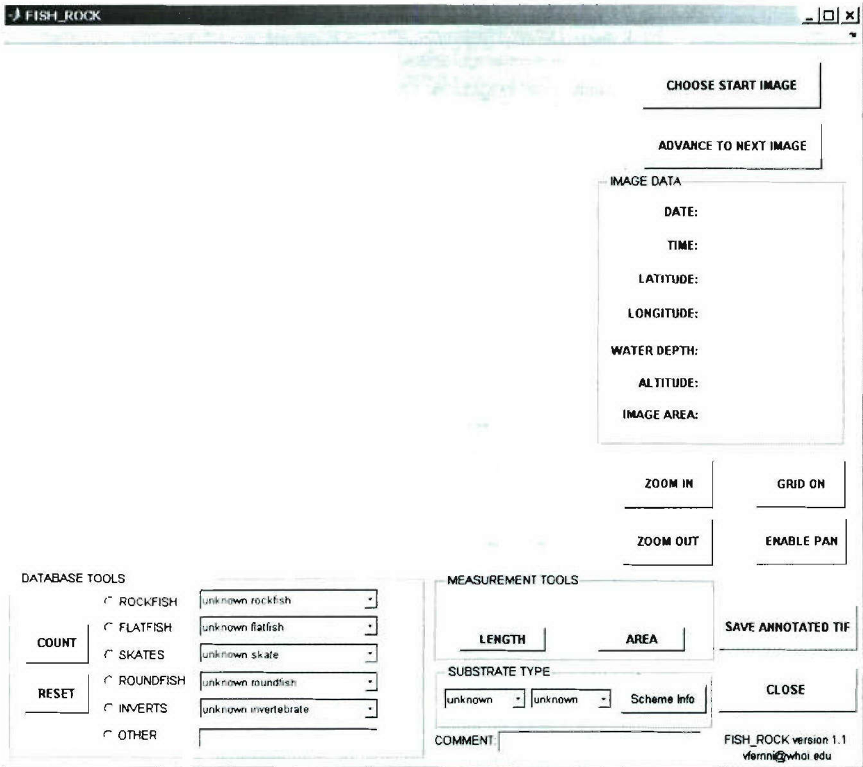


Figure 5: FISH_ROCK Graphical User Interface (GUI) as it appears on startup.

3.1 Choose Start Image

To begin using FISH_ROCK, first select an image to start with by pressing the *Choose Start Image* button located in the upper right corner of the GUI (Figure 5). The user will then be prompted to browse through their computer to select an image (Figure 6). Once an image has been selected, the program will gather the necessary navigational information from the navigation file (see section 2) which must reside in the same directory as the images. The selected image and its corresponding navigational information will then be displayed in the GUI, and the *Choose Start Image* button will no longer be visible (Figure 7).

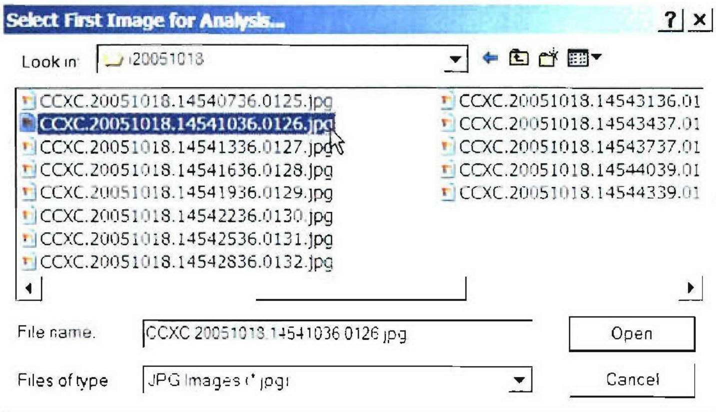


Figure 6: *Choose Start Image* browsing tool.

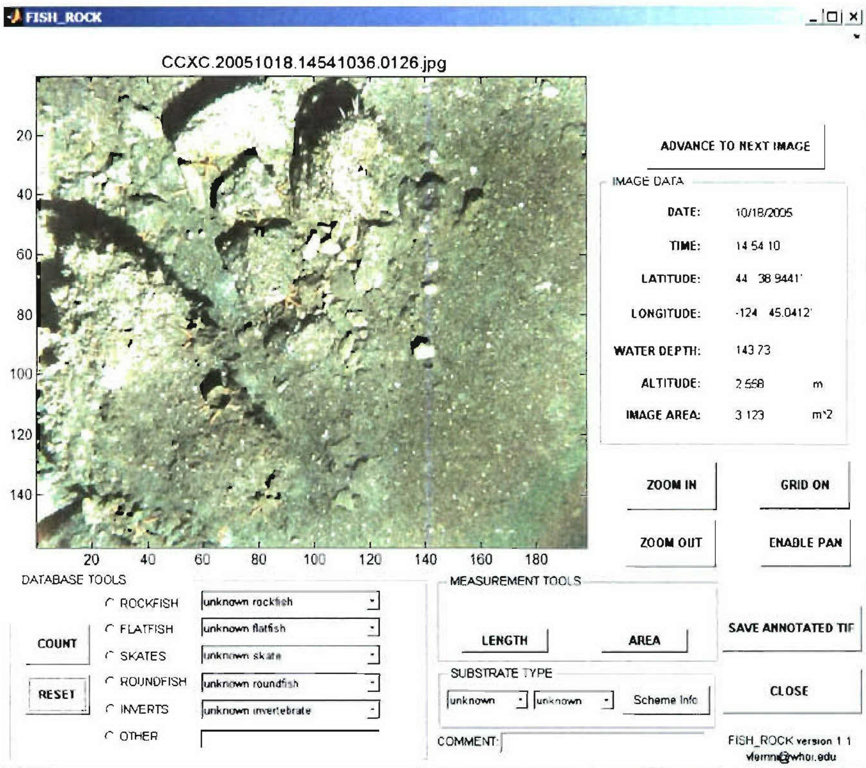


Figure 7: FISH_ROCK as it appears after choosing the first image to be analyzed. Note that the *Choose Start Image* button is no longer visible.

3.2 Nav Display – Image Data

Upon loading an image, its navigational data is displayed on the right side of the GUI window to help orient the user within the geographic framework of the dataset (Figure 7). The navigation information that is displayed includes date, time, lat, long, water depth, altitude, and image area (assuming a flat seafloor) and is all derived from the navigation file (see section 2). The image name, which also contains date and time, is displayed in the GUI, above the image itself (Figure 7).

3.3 Navigating Through a Dataset

After selecting the first image, the user can navigate through the images in the folder using the *Advance to Next Image* button (Figure 7). After advancing to the second image, a *Previous Image* button will appear in the upper right corner of the GUI to allow the user to step back to the previous image (Figure 8).

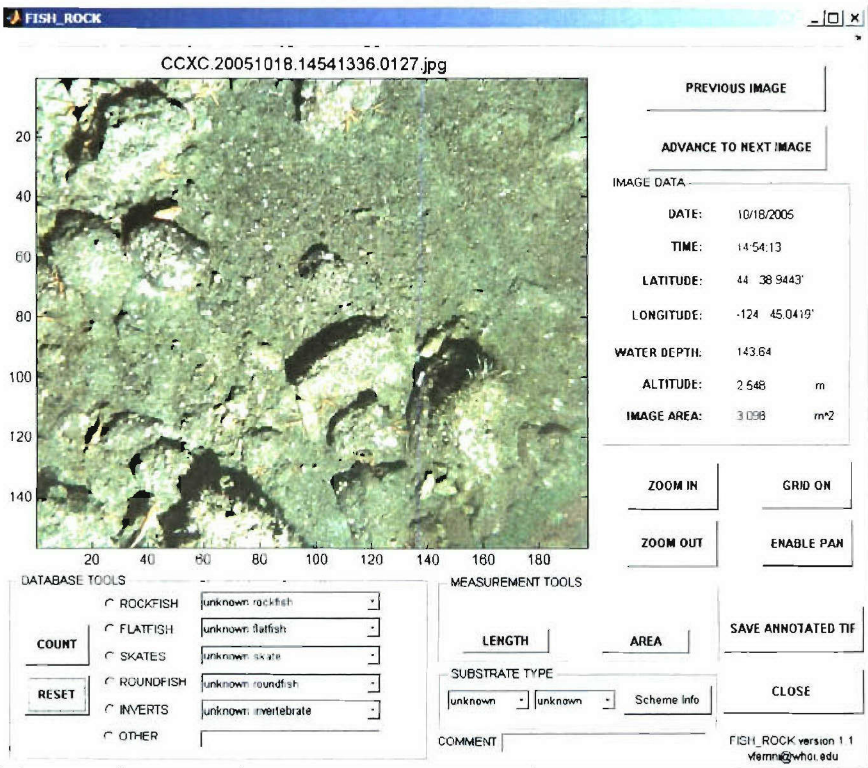


Figure 8: FISH_ROCK as it appears after advancing to the second image in the dataset. The *Previous Image* button, now visible in the upper right corner of the GUI, can be used to step back to the previous image, and the *Advance to Next Image* button can be used to step forward.

If FISH_ROCK has been used during a prior iteration to identify organisms or substrate or to track comments, this information will be automatically displayed in the GUI when navigating through the dataset. Substrate Type and Comments can be directly modified within FISH_ROCK. To change organisms that have already been identified, however, the user must either modify the *fct file or use the *Reset* button to reset all data for the image to the default values (see section 3.4.1).

If organisms have been identified and counted, substrate has been identified, or a comment has been entered for a particular image, or if a data is uploaded from an existing *fct file, pressing *Advance to Next Image* or *Previous Image* button will prompt the user to declare whether the information gathered on the current image should be saved (Figure 9). Saying yes will create an *fct file for this image containing the information that appears in the GUI, and will overwrite any existing *fct file for this image (see section 4).

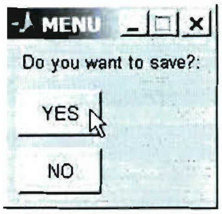


Figure 9: Menu window that appears to confirm whether data should be saved in an * fct file.

3.4 Database Tools

3.4.1 Selecting Organism Type/Name

Organisms may be counted and identified by using the Database Tools, located in the lower left corner of the GUI (Figure 10). The radio buttons can be used to select the organism category (e.g. rockfish, flatfish, skates, roundfish, inverts) and more specific identifications can be made using the pull-down menus (to species on some cases). The *Other* category can be used to identify organisms that are not included in the predefined lists or to log additional data that may be important to include in the database. For example, if anthropogenic material (fishing nets, lobster pots, miscellaneous debris, etc) is visible in a particular image, the other option provides a means for logging this information within the database.

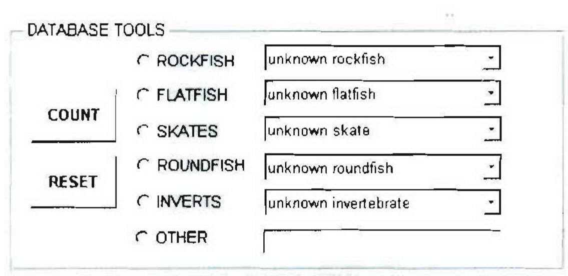


Figure 10: Database Tools portion of FISH_ROCK GUI.

3.4.2 Counting Organisms

Pressing *COUNT* after selecting a radio button or pull-down menu item enables the counting function and allows the user to left click on organisms in the image to identify them. Note that left-clicking when the count function is engaged indicates that additional organisms of this type will be identified at this time. Right-clicking, however, will disengage the counting function after identifying a single organism. For example, if there are three unknown rockfish in the image, the user should first select the *ROCKFISH* radio button, and then press *COUNT*. The first two organisms should then be identified using the left mouse button, and the third organism should be selected with the right mouse button. If only one rockfish is to be identified, the user must select *COUNT* and then use the right mouse button to identify that organism.

3.4.1 Annotation of Identified Organisms

When identifying organisms, a yellow and black cross-hair symbol is displayed on the image to mark the organism's location. In addition, a symbol indicating the fish type and index will be displayed beside the cross-hair symbol referring to the broad category chosen (Rockfish: RO#; Flatfish: FL#; Skates: SK#; Roundfish: RN#; Inverts: IN#; Other: OT#), and the cumulative index of organisms in this category (Figure 11). For example, if 3 rockfish are chosen, there will be 3 symbols (RO1, RO2, and R03) displayed on the image (Figure 11).

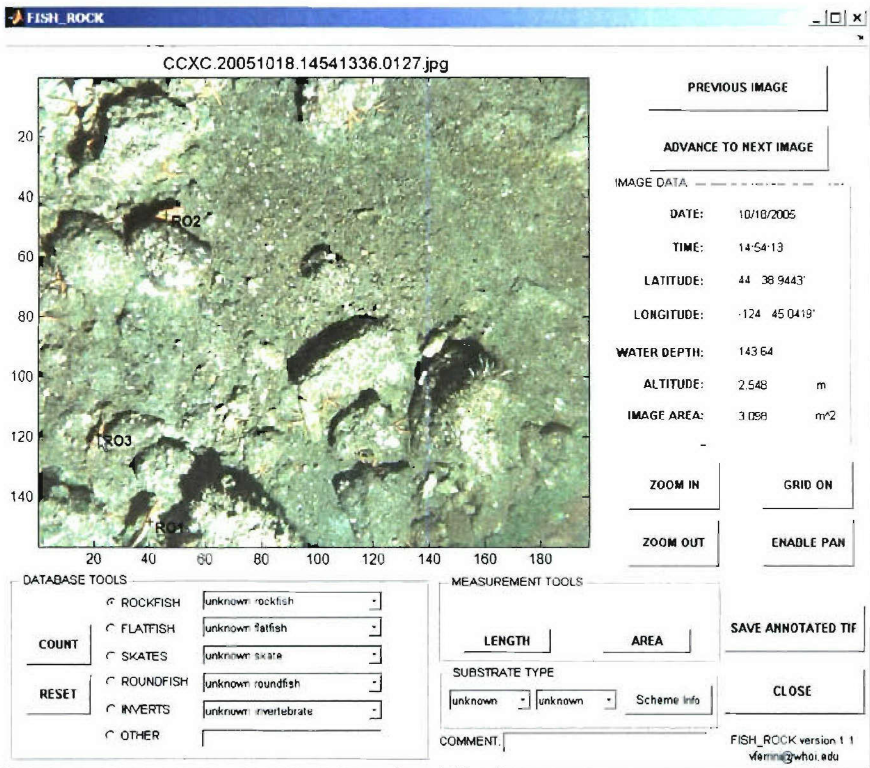


Figure 11: FISH_ROCK with three rockfish identified and marked with cross-hairs.

3.4.1 Resetting data

The *RESET* button included in the DATABASE TOOLS portion of the GUI (Figure 10) can be used to purge all information for the current image. This includes not only organisms, but also substrate type, comments, and measurements. If an output data file (*.fct) was created for this image during previous usage of the GUI, the *.fct file will be deleted upon resetting the database information.

3.5 Measurement Tools

The measurement tools provided in FISH_ROCK assume a flat seafloor and that the organisms/objects being measured are on the seafloor. The distance of the seafloor from the camera lens is assumed to be equal to the vehicle altitude. Both length and area measurements are displayed in the GUI directly above the buttons used to enable the measurement tools. Measurements can also be assigned to a particular organism/object that has been counted. If a measurement has been assigned to an organism, the cross-hair symbol identifying the location of the organism will change to indicate which measurement has been assigned (see sections 3.5.1 and 3.5.2).

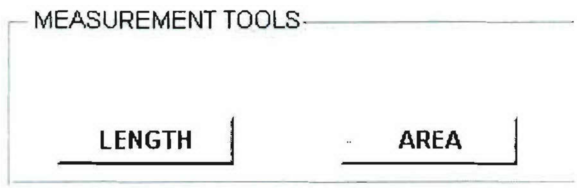


Figure 12: Measurement Tools portion of FISH_ROCK GUI.

3.5.1 Length Measurement

To measure the length of an organism or object, press on *LENGTH*, and left-click on a point in the image to begin the line. This point will be annotated with red cross-hair symbol, and a rubber-band tool with a thick blue line will be enabled to visually aid the user in identifying the position and orientation of the line being drawn (Figure 13). To end the line, the user must right-click on the last point of the line. This function can also be used to measure a polyline, by left-clicking on all points except for the last one, which must be identified by right-clicking to disengage the measurement tool.

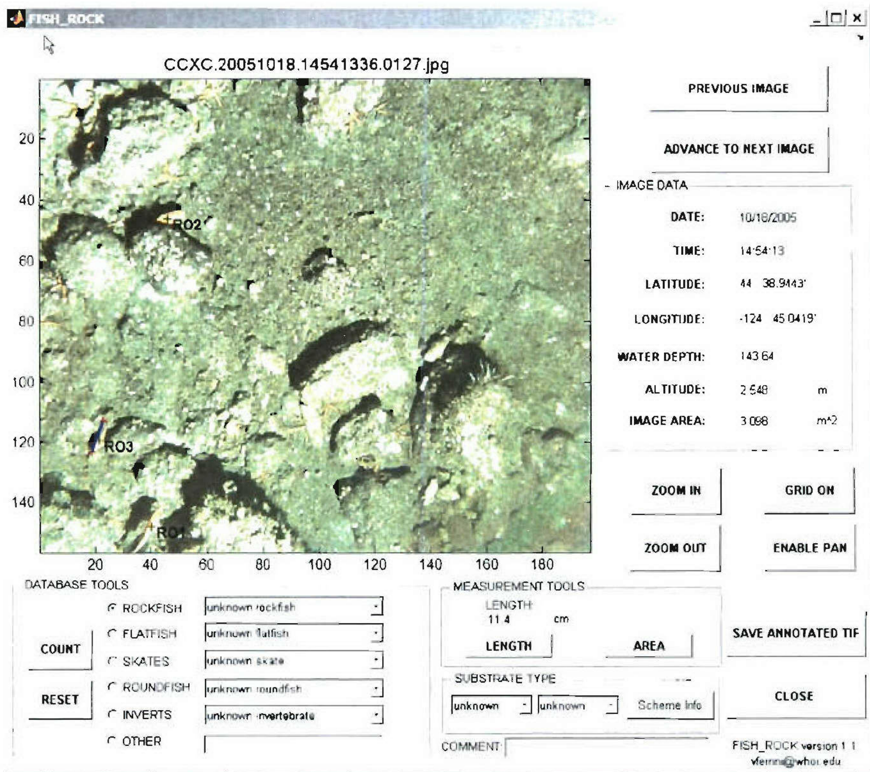


Figure 13: Example of use of *Length* measurement tool of FISH_ROCK GUI with the rubber-band tool displayed on the portion of the image that is measured. In this example, the fish being measured has already been identified as RO3.

Once the line is completed, and the measuring tool is disengaged, the length is displayed above the *Length* tool button (Figure 13). In addition, the user is prompted to declare whether or not the measurement should be assigned to an organism that has been identified (Figure 14a). To avoid over-populating the image with lines and symbols, the blue line and red cross-hair symbols are removed from the image after this choice is made. If *Yes* is selected, a second menu will appear displaying a list of all organisms currently identified in the image (Figure 14b). This menu is used to select the organism to which the measurement should be assigned. If a length measurement is assigned to an organism that was identified through the GUI, the cross-hair symbol associated with that organism will be surrounded by a yellow square (Figure 15).

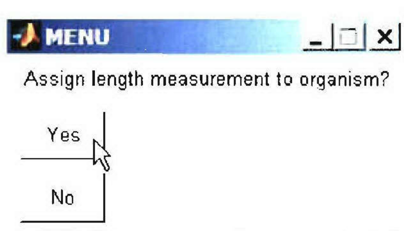


Figure 14a: Assign length to organisms menu

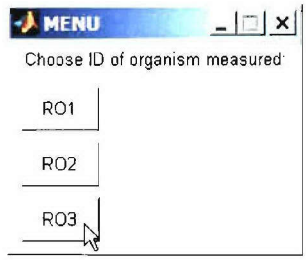


Figure 14b: List of organisms that have been identified in the image used to assign measurement to an organism.

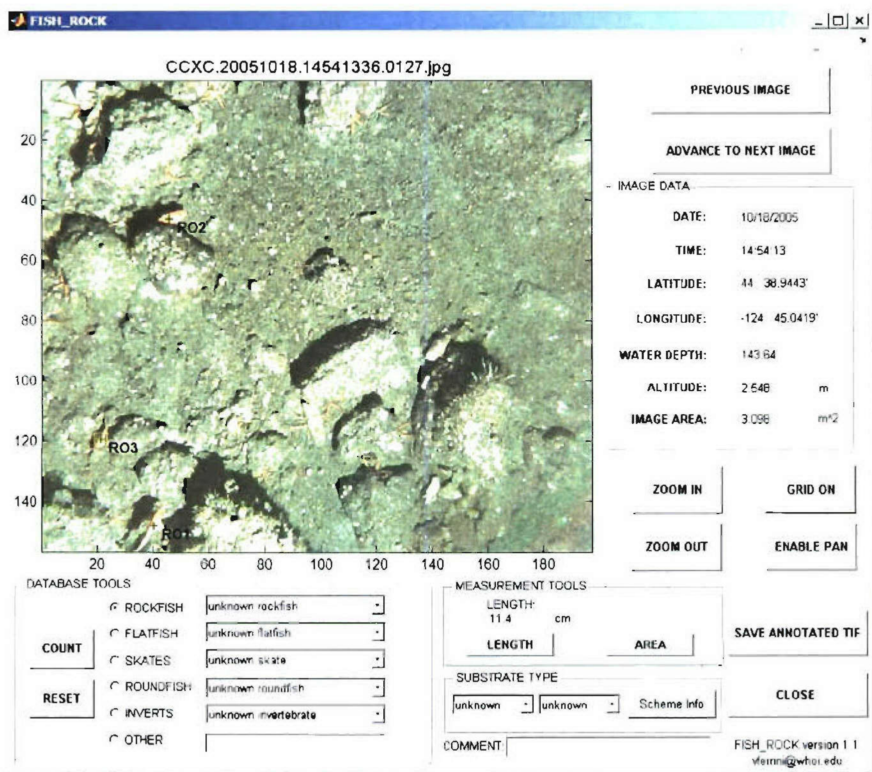


Figure 15: FISH_ROCK after assigning a length measurement (11.4 cm) to an organism (RO3). The yellow square surrounding the cross-hair symbol indicates that a length measurement has been assigned to this organism.

3.5.2 Area Measurement

The area measurement tool is operationally similar to the length measurement tool. To measure the area of an organism or object, first press on *AREA*, then left-click to identify each of the points in the polygon except the last point which must be right-clicked. Each point of the polygon will be marked by red cross-hair symbols connected by a blue line. As with the length measurement tool, a rubber-band tool is displayed with a blue line to help identify the correct placement of points of the polygon on the image

(Figure 16). After closing the polygon, the area measurement is displayed above the *AREA* tool button (Figure 16). As with the length measurement tool, the user will then be prompted to declare whether or not to assign the measured area to an organism that has been counted (Figure 14). If an area measurement is assigned to an organism that was identified through the GUI, the cross-hair symbol associated with that organism will be surrounded by a black circle (Figure 17). Note that if both length and area measurements are assigned to a single organism, the cross-hair symbol that identifies it will be surrounded by both a yellow square (Figure 15) and a black circle (Figure 17).

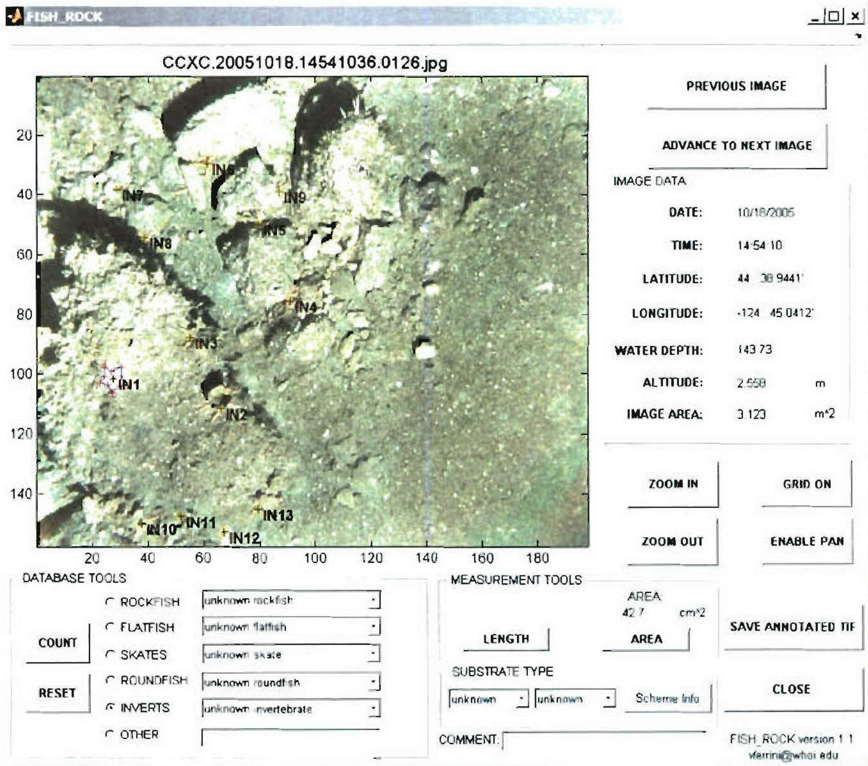


Figure 16: Use of area measurement tool to measure the area of an invertebrate (IN1). Once the last point of the polygon has been selected with the right mouse button, the measurement is displayed above the AREA button, and the user is prompted to declare whether or not this measurement should be assigned to an organism (Figure 17).

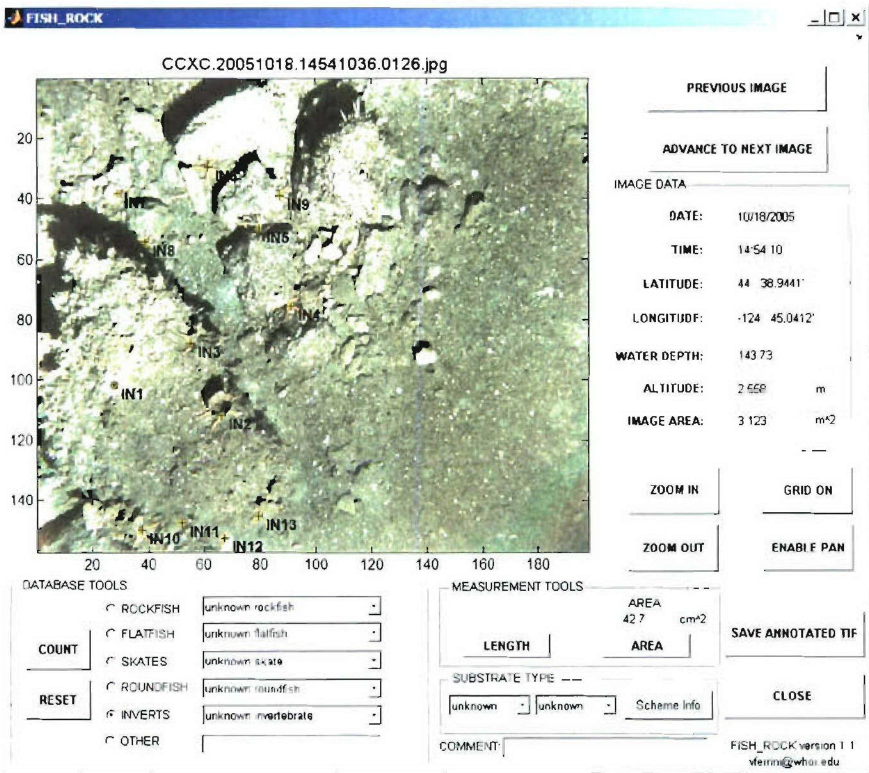


Figure 17: After assigning the area measurement (42.7 cm2) to an organism (IN1) the measurement polygon is removed from the image and the cross hair symbol that identifies the location of the organism is surrounded by a black circle.

3.6 Substrate Type

Substrate type is defined by using the two pull-down menus under *Substrate Type* near the bottom of the GUI (Figure 18). A figure explaining the binary habitat classification scheme (Figure 19) can be viewed by pressing the *Scheme Info* button located within the *Substrate Type* portion of the GUI display (Figure 18). The binary classification scheme requires that two substrate types (primary and secondary) be selected with the pull-down menus in the GUI (Hixon et al., 1991; Stein et al., 1992).

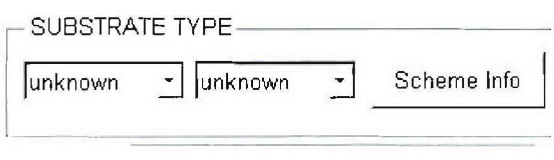


Figure 18: Substrate Type tool.

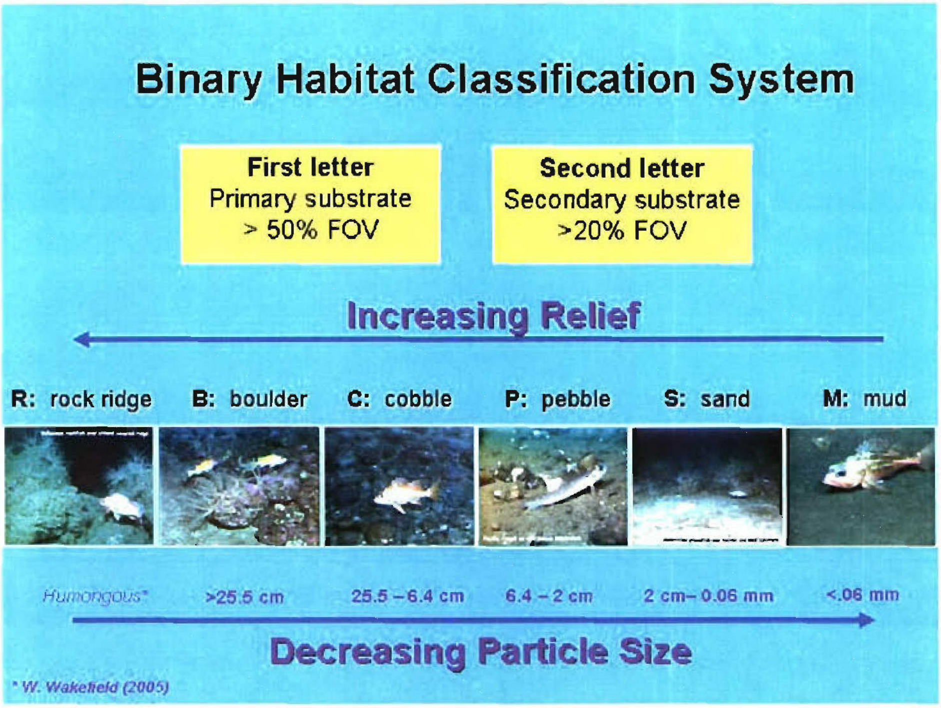


Figure 19: Benthic Habitat Binary Classification Scheme

3.7 Other Tools

3.7.1 Grid On/Off

The *Grid On* button is located on the right side of the GUI, just below the navigational information display (Figure 17) and is used to overlay a grid on the current image. The grid is based on the calculated footprint of the image (assuming flat seafloor) based on the vehicle altitude and the field of view of the camera (section 2.1). This button toggles to *Grid Off* after it is enabled (Figure 20), and can be pressed to remove the displayed grid from the view.

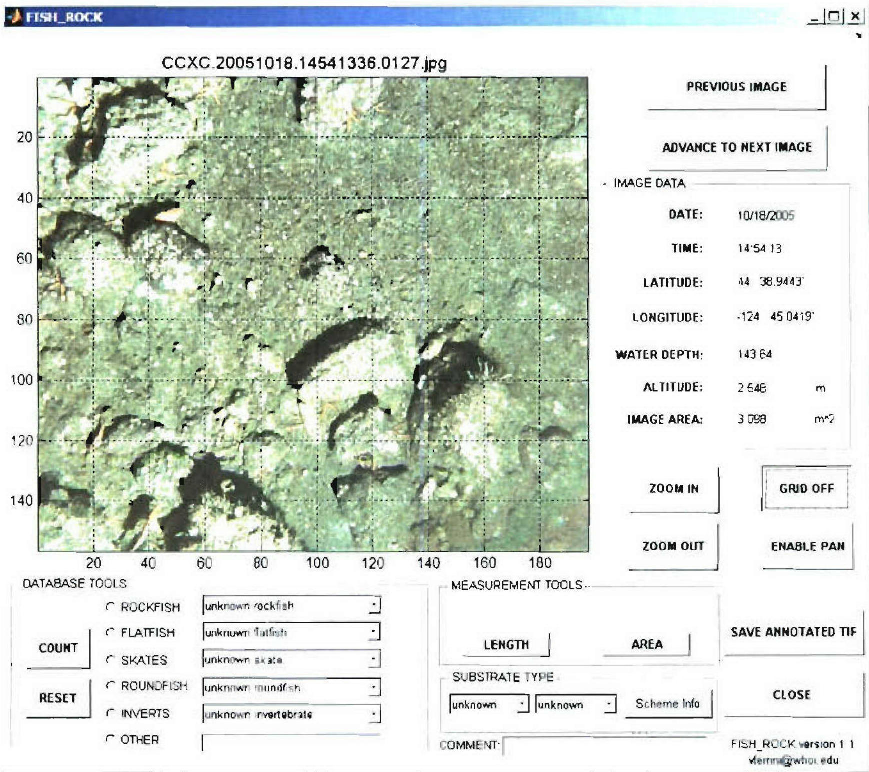


Figure 20: When *Grid On* is pressed, a grid is displayed on the image, and the *Grid On* button toggles to *Grid Off*.

3.7.1 Zoom In/Out

The *Zoom* buttons are located on the right side of the GUI, just below the navigational information display (Figure 20) and are used to zoom the view in or out. Note that if grid lines are displayed, they will scale when the zoom buttons are used.

3.7.2 Enable/Disable Pan

The *Enable Pan* button is located on the right side of the GUI, just below the navigational information display (Figure 20), and can be used to change the current view within the image. Clicking on it will toggle the button to *Disable Pan*, which should be pressed when finished navigating around the image. To Pan, click on the *Enable Pan* button, then left-click on the image, hold, and drag the image to the desired view.

3.7.4 Save Annotated Tif

The *Save Annotated Tif* button is used to generate a full-resolution tiff file of the current image with the displayed annotation and a centimeter scale along each axis (Figure 21). If a grid is overlain on the image when *Save Annotated Tif* is pressed, the resulting tiff image will include those grid lines (Figure 21b). If the current view is zoomed, however, it is important to note that the output tiff file will be saved with the full view rather than the zoomed view. The output image has the same root name as the input image, and has cm scales added to both X and Y axes.

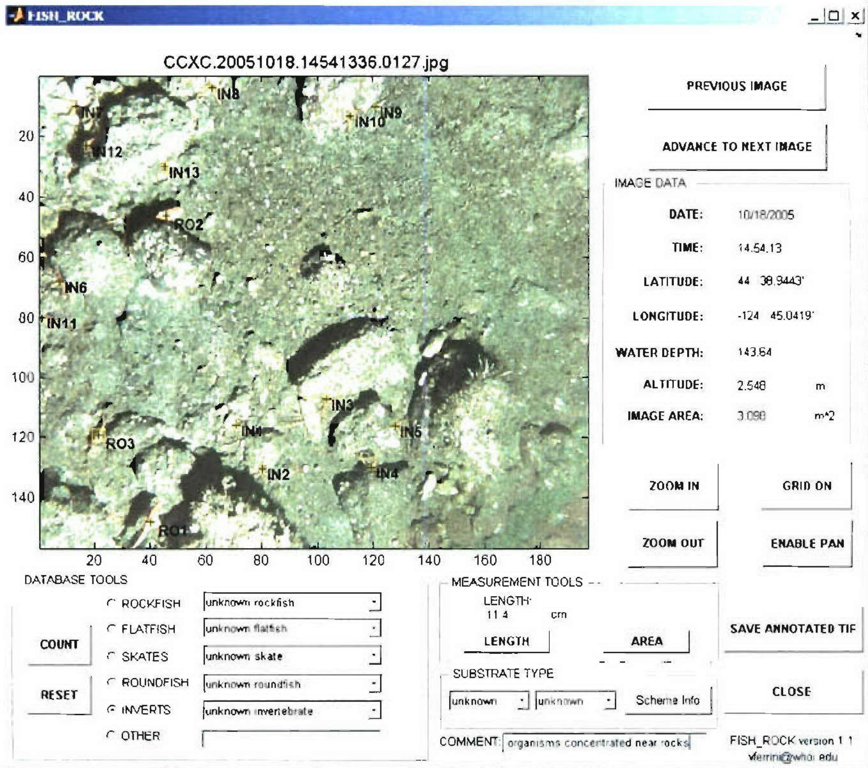


Figure 21a: Example of annotated image in FISH_ROCK.

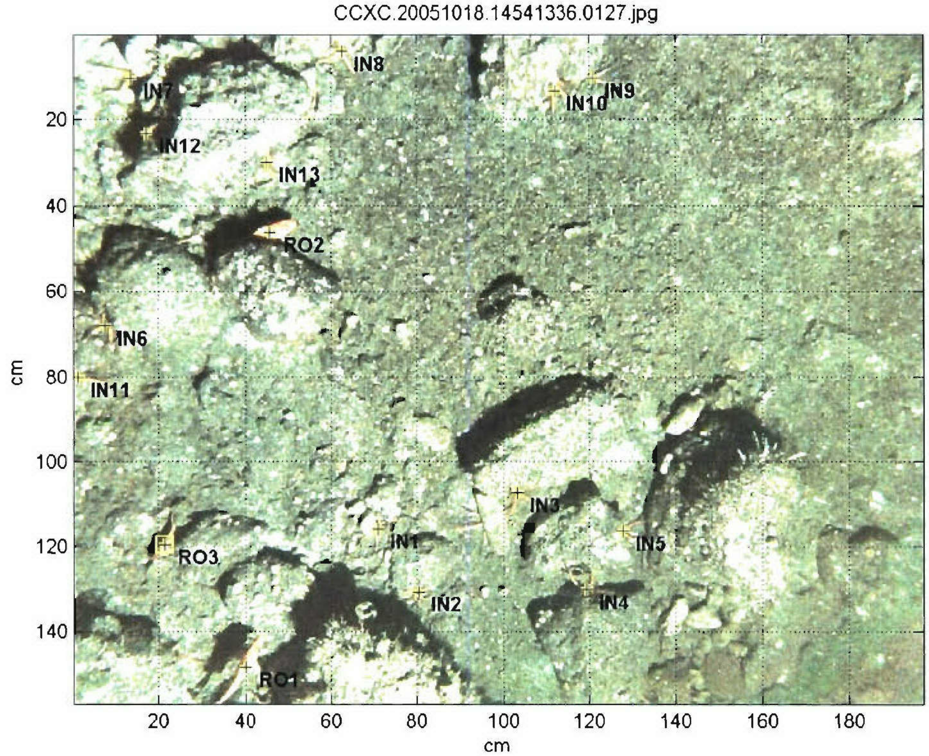


Figure 21b: Example of annotated tif image created from image displayed in FISH_ROCK in Figure 21a (CCXC.20051018.14541336.0127_annotated.tif). Note that this image was created with a grid overlain on the display.

3.9 Closing the GUI

Upon exiting the GUI with the Close button, a COMBINED_FCT.fct file is created by concatenating all information in the {image_name}.fct files (see section 4). The COMBINED_FCT.fct file is a self-updating text file that includes data assembled from all *.fct files in the working directory.

When the user reaches the last image in the directory that is associated with navigational data, it will display a message indicating that there are no more files. It will then automatically perform the actions that occur when CLOSE is pressed.

4.0 Database Output – FCT Philosophy

For each image file, an *.fct (Fish CounT) file is created with the same root as the input image. For example, for image CCXC.20051018.14541036.0126.jpg, a text file will be created called CCXC.20051018.14541036.0126.fct. If data have been assembled for a particular image, the user is prompted to declare whether or not to save the data (see section 3.3). Saying yes will overwrite any existing *.fct file for that image. Note that if an *fct file exists for an image that is being displayed in the GUI, the information contained within it will be displayed when advancing through the images (see section 3.3).

Each *.fct file contains a comma delimited list of each of the organisms that were counted/identified as well as navigation and image information. In order to make FISH_ROCK a versatile tool that can be used to address a suite of scientific questions, each line in the text file contains navigational data, fish identifications and measurements, as well as substrate type and comments. In addition, the location of each organism within the image is provided, which after further software development, can be used to address questions associated with spatial distribution on a fine scale.

FCT file format:

```
lat,long,water depth,image name,date,time,image area,image
width,image height,substrate,fish type,fish
subtype,index,posX,posY,organism length,organism
area,comment
```

FCT default values:

substrate type: not classified
organism length: Nan
organism area: Nan
comment: no comment
fish type: Nan
fish subtype: Nan

Upon closing the GUI, the COMBINED_FCT.fct file is created using information in all of the individual *.fct files. Since this file is regenerated each time the GUI is closed with the *Close* button, it is self-updating based on the *.fct files in the directory. This file can be loaded directly into a GIS package, a spreadsheet, or statistical software for additional analysis.

5.0 Conclusions and Plans for Future Development

FISH_ROCK is a tool intended to create digital databases for the analysis of information contained within bottom photographs. The development of FISH_ROCK is an important step toward efficiently utilizing large datasets of digital photographs to address a range of oceanographic problems. Data files created with FISH_ROCK are text files that can be directly uploaded into statistical software, a spreadsheet, or a GIS package. Although the current version is specific to benthic organisms common off the west coast of the U.S., it can be modified for use in a variety of environments including the deep sea. The pull-down menus can be customized so the GUI could be used to assess not only benthic organism abundance and distribution, but also geologic features, and the distribution of archeological artifacts.

Creating additional modules that can be used in conjunction with FISH_ROCK will facilitate more advanced analysis. For example, using the information already contained within the *.fct files, a module can be written to quantitatively analyze the distribution of organisms/objects at a variety of spatial scales. In addition, by utilizing image feature matching algorithms already developed at WHOI/DSL for photo-mosaicking applications (Pizarro and Singh, 2003; Figure 22) in conjunction with data in the *.fct files an additional module can be created to automate the removal of redundant data from transects of images, automatically providing accurate estimates of abundance and diversity per unit area. The feature matching algorithm can also be used to measure organisms/objects that are in the water column between the camera and the seafloor as long as the object is imaged in subsequent photos. Finally, future work will also include the application of distortion corrections to improve the accuracy of length and area measurements.

Figure 22: Photo-mosaic of the three adjacent images presented in this report. The feature-matching algorithm used for this mosaic is a robust tool that can be used to enhance the analytical functionality of FISH_ROCK in future versions of the code.

6.0 References

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16. Abstract (Limit: 200 words)

Recent advances in underwater robotics and imaging technology now enable the rapid acquisition of large datasets of near-bottom high-resolution digital imagery. These images provide the potential for developing a non-invasive technique for fisheries data acquisition that reveals the organisms in their natural habitat and can be used to identify important habitat characteristics. Using these large datasets effectively, however, requires the development of computer-based techniques that increase the efficiency of data analysis. This document describes one such tool, FISH_ROCK, which was developed for a group of fisheries researchers using the SeaBED AUV during a research cruise in October 2005. FISH_ROCK is a graphical user interface (GUI) that is executed within Matlab, and allows users digitally generate a database that includes organism identification, quantity, size and distribution as well as details about their habitat. Further development of this GUI will enable its use in different oceanographic environments including the deep sea, and will include modules that perform data analysis.

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