Deepwater Horizon Oil Spill (DWHOS)
Water Column Technical Working Group

Image Data Processing Plan: SIPPER

Principal Investigator: Dr. Andrew Remsen

July 26, 2012

Prepared by:
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Period of Performance
June 1, 2012 – December 31, 2012 (6 months)

Objectives and Approach
This plan describes processing of imaging data collected as part of the NRDA cooperative sampling efforts in 2010, under principal investigator (PI) Dr. Andrew Remsen. Imaging data were collected by the Shadowed Image Particle Profiling and Evaluation Recorder (SIPPER) during three cruises in 2010. Other work plans describing analysis of data from the Holocam, Digital Autonomous Video Plankton Recorder (DAVPR), and Video Plankton Recorder (VPRII, PI: C. Davis), In Situ Ichthyoplankton Imaging System (ISIIS, PI: Robert Cowen), and FlowCAM and ZOOSCAN (PI: Malinda Sutor) may involve similar analytical procedures and the processing for these data will be included in separate processing plans.

As part of the NOAA/NRDA Water Column TWG sampling effort, the SIPPER was deployed on three cruises between May and September 2010 (*Weatherbird II* 1, *Gordon Gunter* 1, and *Specialty Diver* 1) (summarized in Table 1). During these cruises, raw images were collected and stored to archival disk drives for subsequent shore-based analyses. These archived data require post-processing to extract sub-images (regions-of-interest, ROIs), classify and measure the objects contained in the sub-images, and compute abundance and size distributions. The end data products will include a database of all extracted SIPPER ROIs and their associated information (location, depth, classification, measurements, etc.), the PICES (plankton image classification and extraction software) system used for querying and viewing all the data within the database, summary tables and figures, and a narrative description of the data.

Table 1. NRDA Cruises conducting SIPPER data collection.

Cruise	Date	Approximate Location
Weatherbird II 1	May 4 – May 14, 2010	Transects ~5 nm from wellhead, and upper water column (<100m) between 50-150nm from wellhead
Gordon Gunter 1	May 27 – June 4, 2010	5 stations to east and west of wellhead, within 60nm
Specialty Diver 1	September 9 – September 17, 2010	18 nm transects in cross shape pattern running SW to NE, and NW to SE around well head
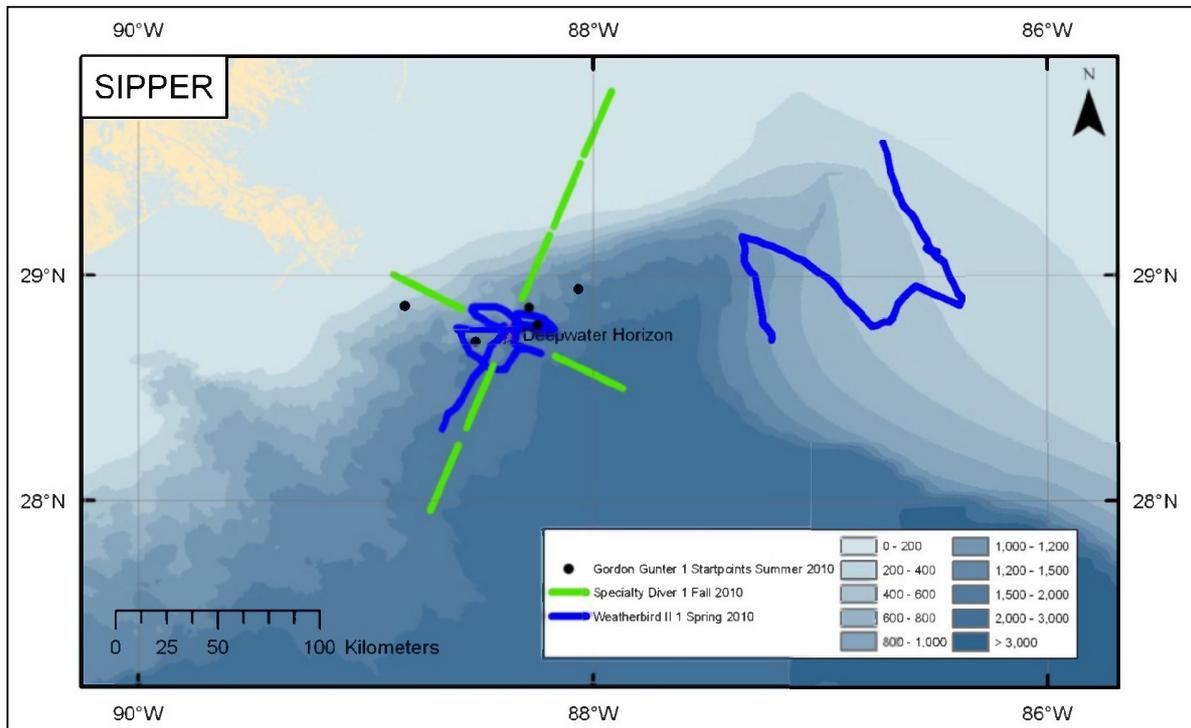
Figure 1. Locations of NRDA SIPPER data collected in the Gulf of Mexico in spring and fall 2010.

Data Processing Prioritization and Schedule

Data sets collected by the SIPPER have been prioritized for processing primarily based on the collection date. The following is a list of the SIPPER data to be processed in order of priority with expected completion dates:

Weatherbird II 1: Completion expected 4 months after start of work
Gordon Gunter 1: Completion expected 4 months after start of work
Specialty Diver 1: Completion expected 6 months after start of work

Methodology
Background
The SIPPER image data were collected in conjunction with data collected from other sampling systems as part of the overall NRDA effort. The image data require post-processing to extract ROIs; and to time match images with conductivity, temperature, depth (CTD) data to determine locations and depths at which images were captured. Attachment 1 contains a detailed description of image extraction and classification. The total number of images captured for a given category (e.g., copepods) per unit time is converted to number of objects per unit volume using the calibrated image volume and sampling rate (volume per unit time). In addition to the number of objects per unit volume, the size of particles will be determined by measuring the image (number of pixels) and then converting to equivalent spherical diameter (ESD; Remsen et al. 2004) which will be used to estimate size distributions. This processing will yield estimates of the array of objects present with respect to size, time, and depth distribution. For a summary of NRDA-collected SIPPER data, see Table 1 in Attachment 1.

The SIPPER data processing consists of both automated classification of the entire image dataset as well as manual review, validation, and processing. ROIs typically contain only one object, but multiple objects can sometimes be found in one ROI. ROIs with more than one object are classified and placed in either the "unknown" category or one of the "multiple objects" categories. Manual review of these categories will result in the appropriate classification of these ROIs.

Several improvements will be made to the PICES software to improve the final data processing. Software improvements and modifications include:
1. Improvements to measuring tools in PICES Commander. These are capabilities for measurements including total length, head length and other biologically meaningful metrics. Presently only areal measurements are available through PICES.
2. Implement dual classification capability to the SIPPER data similar to that used for the VPR data (description of dual classification systems are in Hu and Davis, 2006). In this process two separate classification algorithms are run on each image, and the image is explicitly classified if both classifiers agree on the same image class.
3. Capability for counting plankton associated with other object classes such that the counts are included in the data report.
4. Complete logging of all processing steps.

For a full description of the SIPPER data processing procedure, the data formats, and the feature descriptions, please see attachments 1-3.

Specific work tasks
1) Classification of Objects
The manual classification and counting of objects from ROIs will be performed as follows. First, ROIs from SIPPER deployments from priority cruises will be extracted to a minimum size threshold of 150 pixels total area or ~350μm ESD. These ROIs will then be automatically sorted using recognition data from previous deployments and data from deployments concurrent with the Deepwater Horizon event. Resulting automated classification of objects will be manually corrected using the PICES database software, as described in Attachment 1.

2) Multiple Objects

Classified multiple objects will be manually inspected. As this is time consuming, priority will be given to the *Weatherbird II* in May 2010 and *Gordon Gunter* in May-June, 2010 cruises. Manual assessment will include manual identification and enumeration of ROIs.

3) Plankton

The SIPPER data have already been extracted resulting in a training set of over 10 million individual particle images from the Gulf of Mexico. To adapt this training set to the DWH time period, the following steps will be completed:
1. Development of a training library.
2. Initial run of comprehensive classifier.
3. Assessment of classifier performance, image class reduction, manual validation of rare but important classes in PICES Commander (e.g., fish larvae, euphausiids, etc.) and optimization of classifier.
4. Classification of SIPPER data using optimized classifier.
5. Final error calculations and classifier accuracy using 10-fold cross validation (the standard method of assessing automated classifier accuracy, see Attachment 1, QA/QC section) and manual validation of a random subsample of 5,000-15,000 of the processed images (~1% of the total images per deployment).
6. Generation of SIPPER data reports using PICES commander.

Quality Assurance and Control

Quality assurance of data products will be achieved via a phased QA/QC process to be implemented across the NRDA plankton/particle imaging PI's (Andrew Remsen (SIPPER), Cabell Davis (Holocam, DAVPR, VPRII), Robert Cowen (ISIIS), and Malinda Sutor (FlowCAM, ZOOSCAN)). The first phase of QA/QC will involve the sharing of computerized classification methods among the PIs working with digital image analyses of plankton and other classification categories. This activity will assess the degree to which the PIs are classifying imaged objects to a similar level (e.g., suspended particulate matter (SPM) and major taxa of plankton such as copepods, etc.). If needed, taxonomic resolution will be adjusted to achieve the best possible agreement between image classification systems, while recognizing the differences in size classes evaluated and discrimination capabilities such that identification is to the lowest possible taxon for each instrument. It is envisioned, but not required, that the initial discussion between the PIs will occur at an in-person meeting. Following this initial cross-coordination, communication is expected to occur on an as-needed basis, as decided by the PIs and the Trustees. A report will be compiled and provided to all parties to this agreement which will document the common classification schemes and provide the basis for integration across the listed imaging systems. The report will also provide a comparison of the level of taxonomic resolution between the instruments/systems used. If any major updates or changes are made to the classification systems as the data processing progresses, an amended report will be developed and distributed.

A second phase of QA/QC will be performed at the software level. This includes identification of training images, the creation of training image sets, and conducting routine manual checks of image processing software. These 3 tasks will be carried out by Andrew Remsen during the

processing of each data set (see descriptions in Attachments 1-3). Dr. Remsen will perform the manual identifications, and another plankton/particle imaging PI (Davis, Cowen, Sutor, or Benfield) will check his work by identifying a randomly selected subset of at least 5% of the images. For the SIPPER ROIs, detection and false positive rates will be determined via confusion matrices generated when building the automatic classifiers from sets of training images (Hu and Davis, 2006). A confusion matrix compares the classifications made by a human expert (columns) to those made by the computer (rows). The accuracy, precision and comparability of the identifications varies with taxonomic group. By using equal numbers of images from the training set for each category classified, classification accuracy is quantified by the confusion matrices (i.e., the confusion matrices show the proportion of false positives, true positives, false negatives, and true negatives). Abundances (e.g., number of organisms per liter) are corrected using the information from the confusion matrix. Abundances generated by this automated method are similar to those based on human sorted images (Hu and Davis, 2006). Confusion matrices and associated abundance corrections (Hu and Davis, 2006) will be shared among PI's to ensure the different software systems are performing similarly, and will be included in the official data record released to the Trustees and BP. For identifications that require manual identification (e.g. multiple objects in a single ROI), the classifications will also be subject to a 5% check of the images by another PI.

A third phase of QA/QC will involve an independent cross-check between the principal investigators working with imaging systems (Davis, Remsen, Cowen, and Sutor). At least 50 images will be randomly selected from each taxonomic group and sent to at least one other PI for their independent identification by manual inspection. This will serve as a quality control check for the SIPPER data and will be part of an integrated system of QA/QC checks across the plankton program. The listed PIs will independently review and identify images and will confer with each other about classifications. As necessary, Dr. Remsen will also make adjustments to software as possible to ensure maximum agreement among investigators.

The final phase of QA/QC will be to determine that the data are reported in geographically correct locations, as compared to field-recorded vessel and station locations for the imagery collections. This task will be performed by the NOAA NRDA Data Management Team after the lab data for a priority level are received, and before the data are released to the Trustees and BP. Since the whole process is based on electronic data, transcription from paper data sheets to electronic media is not anticipated. However if transcription does occur, a cross-check of 100% of all transcriptions will be conducted by someone other than the person who completed the original transcription.

Distribution of Results
Upon completion of the data processing and inter-PI QA/QC procedures (QA/QC phases (1) – (3) as identified above) at each priority level, the principal investigator (Dr. Andrew Remsen) will deliver all products generated as part of this work plan (e.g., processed data sets) to the NOAA NRDA Data Management Team. Once the Data Management Team has completed their QA/QC review of the station metadata for that priority level (the final phase above), the data and metadata for that priority level will be made available to the parties of this agreement by means appropriate to the data type as determined by the NOAA NRDA Data Management Team. NOAA and the Louisiana Oil Spill Coordinator's Office (LOSCO) on behalf of the State of

Louisiana and BP (or Cardno ENTRIX on behalf of BP) will be alerted when these data become available.

In the interest of maintaining one consistent data set for use by all parties, only the verified and validated data set made available to the parties by the NOAA NRDA Data Management Team shall be considered the consensus data set. In order to ensure reliability of the consensus data and full review by the parties, no party shall publish consensus data until 14 days after such data have been made available to the parties. Any questions raised about the consensus data set, as it was made available to the parties by the NOAA NRDA Data Management Team, shall be handled consistent with the procedures in Section 7.2 of the Deepwater Horizon NRDA Analytical Quality Assurance Plan.

- The trustees and BP shall each designate an individual responsible for raising questions, if any, on the consensus data set.
- If questions are raised, the two designated individuals will meet to determine the source of the difference and resolve.
- The questions raised and their resolution shall be distributed to all parties.
- No changes to the consensus data set will be made if the differences are considered immaterial by both designated individuals, acting on behalf of the parties.
- If the parties agree that changes to the dataset should be made, the dataset will be updated in accordance with the resolution and reposted with a notation that the dataset has been revised.
- If the designated individuals do not agree on how to resolve the difference concerning the consensus data set, the designated individuals shall request assistance from the Assessment Managers for the trustees and BP.

Retention of Materials

All imagery will be retained, along with any changes in processing software or results. All of this information will be maintained during all review steps in the process and stored in secure locations under Trustee control and will be provided to all parties as part of the data release process.

All materials associated with the collection or analysis of samples under these protocols or pursuant to any approved work plan, including any remains of samples and, including remains of extracts created during or remaining after analytical testing, must be preserved and disposed of in accordance with the preservation and disposal requirements set forth in Pretrial Orders ("PTOs") # 1, # 30, #35, # 37, #39 and #43 and any other applicable Court Orders governing tangible items that are or may be issued in MDL No. 2179 IN RE: Oil Spill by the Oil Rig "DEEPWATER HORIZON" (E.D. LA 2010). Destructive analytical testing of oil, dispersant or sediment samples may only be conducted in accordance with PTO # 37, paragraph 11, and PTO # 39, paragraph 11. Circumstances and procedures governing preservation and disposal of sample materials by the trustees must be set forth in a written protocol that is approved by the state or federal agency whose employees or contractors are in possession or control of such materials and must comply with the provisions of PTOs # 1, # 30, # 35, 37, #39 and #43.

Budgeting

The Parties acknowledge that this budget is an estimate, and that actual costs may prove to be higher due to a number of potential factors. The costs indicated in Budget Chart # 1 below and any additional reasonable costs within the scope of this workplan that may arise shall be reimbursed by BP upon receipt of written invoices submitted by the Trustees. The Trustees will make a good faith effort to notify BP in advance of any such increased costs.

Budget Chart #1.

Analysis Costs	Total
NOAA Contractor Labor:	
Andrew Remsen, PI	███████
Kurt Kramer (technician)	███████
Travel	$3,000
Supplies	$1,000
Total Budget	███████

References

Hu, Q. and C. S. Davis. 2006. Accurate automatic quantification of taxa-specific plankton abundance using dual classification with correction. *Mar. Ecol. Prog. Ser.*, 306, 51-61.

Remsen, A., Samson, S., Hopkins, T., 2004. What you see is not what you catch: a comparison of concurrently collected net, Optical Plankton Counter, and Shadowed Image Particle Profiling Evaluation Recorder data from the northeast Gulf of Mexico. *Deep Sea Research I*, 51 (1), 129-151.

Attachments
Attachment 1 – SIPPER Data Processing Procedure
Attachment 2 – SIPPER Feature Descriptions
Attachment 3 – SIPPER Raw Data Layout
Attachment 4 – Sensor Calibration Sheets

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Approvals

Approval of this work plan is for the purposes of processing imaging data for the Natural Resource Damage Assessment. Parties each reserve its right to produce its own independent interpretation and analysis of any data processed pursuant to this work plan.

BP Approval   _Joyce Miley_   _[signature]_   10/8/12
                   Printed Name   Signature   Date

Federal Trustee Approval   _[illegible]_   _[signature]_
                   Printed Name   Signature   Date

Louisiana Approval   _KAROLIGH DEBUSSCHER_   _[signature]_   11/2/12
                   Printed Name   Signature   Date