Quality Assurance Project Plan

Using Citizen Science to Analyze Underwater Video in the Great Lakes

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	Signature	Date
Mari Nord Project Lead	_____	_____
Molly Wick Technical Contact	_____	_____
John Dorkin Quality Assurance Coordinator	_____	_____
Andy Tschampa Quality Assurance Manager	_____	_____
Chris Korleski Water Division Director	_____	_____

SECTION 1.0, PROJECT OBJECTIVES, ORGANIZATION, AND RESPONSIBILITIES

1.1 The purpose of study

The goal of this project is to assess the feasibility of a web-based citizen science approach in providing habitat and invasive species information from underwater videos collected as part of Office of Water's (OW) National Coastal Condition Assessment (NCCA). Through stakeholder consensus, we will design, test, and deploy a web-based citizen science application to analyze underwater video, and compare results to expert analysis.

1.2 Project objectives

We will address the following question: Can citizen science analysis of underwater video contribute relevant and cost-effective information compared to previously completed expert analysis?

1.3 The secondary data needed

The data to be used in this project includes videos collected as part of the two most recent National Coastal Condition Assessment Surveys conducted in 2010 and 2015. Video were collected at sites throughout the nearshore, defined as <30 m depth and within 5km from shore, based on the NCCA's probabilistic survey design; as well as in the connecting channels of the St. Mary's River and the Huron-Erie Corridor (EPA, 2016).

The video set up used was a GoPro or SeaViewer camera with a light attached to a cable, which was lowered to the bottom to collect at least 2 minutes of video at each site. Field technicians were instructed to hold the camera just above the bottom, but in some cases the camera hit the bottom. Because the camera was just attached to a cable and not a frame, the camera could spin and typically would get a 360 degree view of the entire site. The field of view of the video can vary dramatically depending on the exact height above bottom, the water clarity, angle of view, substrate type, camera angle, and how much the boat drifted during collection. Figure 1 shows an example screenshot from a typical cobble/boulder site.

Figure 1: Example screenshot from an underwater video collected from a hard-bottomed (cobble/boulder) site through the National Coastal Condition Assessment.

1.4 The planned approach for evaluating project objectives (i.e., data analysis)

The objective of this project is to design, test, and deploy a web-based citizen science approach to analyzing underwater video to help inform stakeholders in management decisions regarding benthic habitat and invasive species in the Great Lakes. Based on a stakeholder engagement process from the start, the results will produce estimates of habitat attributes/conditions in the Great Lakes nearshore to meet managers' data needs. The project will test the ability of an end-user designed citizen science project to provide high-quality video interpretation data for management of habitat and invasive species in the Great Lakes for a cost significantly less than expert analysis (e.g. Gardiner, et al., 2012)

Application Development: State and federal resource managers will form a design team. This team will define the habitat and invasive management problem, data needs, how underwater video might address those needs, and how to set up a citizen science video analysis so that results are useful and applicable. Based on their criteria, existing citizen science web platforms will be evaluated, including the Zooniverse.org which is a popular platform for citizen scientists to help with imagery interpretation (e.g. Simpson et al., 2014). A beta-version of an imagery analysis web application will be developed for the selected platform based on the needs defined by the design team.

The analysis developed will generally follow the previous expert analysis developed by MED scientists (see Appendix 1), although it may be more limited in scope and designed to answer specific questions depending on the data needs of stakeholders. The expert analysis

identified substrate type (hard or soft); relative vegetation cover and height; mussel presence and cover; and round goby/fish presence. The design team will utilize the previous expert analysis to build a simplified analysis to be conducted by citizen scientists in response to the specific data needs of the stakeholders.

A consortium of technical experts, including the design team and other state resource managers, along with members of the general public, will beta-test the design. A formal input process will allow testers to provide feedback to optimize the analysis for the data needs defined, and improve instructions and "help" resources. The application will be modified and improved based on testers' input. Following testing and application optimization, the project will be launched publicly and publicized.

Life of Project: Public data collection will continue for approximately 9 months. During that time the project team will monitor and facilitate participants' experiences. This includes answering questions and posting project updates and/or supplementary information on an associated blog and social media outlets. An ongoing, interactive presence on the web application and associated social media has been shown to make online citizen science projects more successful. Project participation metrics will be evaluated and used to direct additional engagement efforts throughout the course of the project.

Compile, Synthesize, and Validate Results: Results will be compiled and synthesized. Statistical analyses will be conducted and results will be validated by comparing to the results of expert analysis. More detail on statistics, and data validation is found below in Section 4.0. Results of the science questions defined above will be summarized, and shared with state resource managers and with volunteers and the public online. Results will help guide state habitat and invasive species management actions, as well as GLWQA and NCCA monitoring and assessment work in the Great Lakes.

1.5 Responsibilities of project participants

Two main teams will run this project: The stakeholder design team, and the application development team.

Stakeholder Team:

The stakeholder design team will be a multi-agency team coordinated by Office of Research and Development (ORD) to identify and provide input on the data needs and priorities for the project. That team will also provide feedback on draft/beta versions of the application, and help publicize the application to their respective networks prior and during the application launch.

Project Participant	Organization/Division	Role/Duties
Mari Nord	EPA Region 5	Project lead – Assist in engagement and coordination of stakeholders; assist in marketing web application to Great Lakes networks.
Molly Wick	EPA Office of	Team Lead – Lead stakeholder team to

	Research and Development, Oak Ridge Institute for Science and Education	identify data needs and goals for web application, communicate data needs and web application goals to development team.
Todd Nettesheim	EPA Great Lakes National Program Office	Point of contact – Serve as liaison to GLWQA Science Annex; assist with engaging stakeholders and marketing web application to Great Lakes networks.
Beth Hinchey Malloy	EPA Great Lakes National Program Office	Stakeholder Design Team Member - Serve as liaison to GLWQA Lakewide Management Annex; assist with engaging stakeholders and marketing web application to Great Lakes networks.
Todd Wills, Jay Wesley, Rachel Coale, Matt Preisser	MI DNR, MI DEQ	MI Stakeholder Design Team State Contacts –Provide input on data needs and goals for web application design, help market web application to state networks.
Michele Wheeler, John Masterson, Bob Wakeman, Eva Lewandowski, Paul Skawinski	WDNR	WI Stakeholder Design Team State Contacts - Provide input on data needs and goals for web application design, help market web application to state networks.
Vic Santucci	IL DNR	IL Stakeholder Design Team State Contact
Jim Lehnen	NY DEC	NY Stakeholder Design Team State Contact

Application Development Team:

The application development team will take input from the design team to work through the logistics of design and implementation of the application. This includes hosting the application, launching it, and moderating it. ORD will also coordinate the application development team.

Project Participant	**Organization/Division**	**Role/Duties**
Mari Nord	EPA Region 5	Project lead - Assist in engagement and coordination of development team; assist in marketing web application to Great Lakes networks.
Molly Wick	EPA Office of Research and Development, Oak Ridge Institute for Science and Education	Project Coordinator – lead development team discussion, communicate the data needs and application goals determined by the stakeholder team to the development team and the web programmer.
Carole Braverman	EPA Region 5	Application Development Team - provide technical input on web application

		development; ensure the goals of the web application are feasible and achievable.
David Bolgrien	EPA Office of Research and Development	Application Development Team - provide technical input on web application development; ensure the goals of the web application are feasible and achievable.
Todd Nettesheim	EPA Great Lakes National Program Office	Point of contact- Assist with engaging stakeholders and marketing web application to Great Lakes networks.
Beth Hinchey Malloy	EPA Great Lakes National Program Office	Application Development Team Member Assist with engaging stakeholders and marketing web application to Great Lakes networks.
Sarah Lehmann	EPA Office of Water	Website Manager – Videos will be hosted on EPA's youtube channel.
Hugh Sullivan	EPA Office of Water	Application Development Team Member – Provide input on NCCA priorities and needs for videos, ensure web application is aligned with NCCA program.
Jonathan Launspach	CSRA	Application Development Team Web Programmer – Develop web application based on input from stakeholder team.

The videos will be analyzed by the public during the web application's life. The video analysis procedures will be defined by the data needs identified by the stakeholder design team (e.g. mussel presence), and the methods to address those priorities (e.g. exact questions public will answer about mussels in videos) will be defined by the application development team.

Following the application's life, the results of multiple citizen analysts reviewing the videos will be compiled and reviewed for Quality Assurance by ORD. ORD will complete a report summarizing results which will be distributed to all members of the stakeholder design team, the application development team, as well as individuals who tested the application or participated in analysis through the web application; and will be available online.

SECTION 2.0, SOURCES OF SECONDARY DATA

The source of data used for this project are videos collected through the National Coastal Condition Assessment. This is a large dataset (over 1000 videos) that is readily available. This dataset was selected because ORD had previously developed methods for analysis of these videos (Lietz et al., 2015). Furthermore, these videos have been analyzed by a team of experts, so we have expert analysis to which we can compare the citizen science analysis results (Wick et al., 2017).

The videos were collected using the standard field protocol described in USEPA, 2009 and USEPA, 2015. The development of reliable, cost-efficient methods to analyze underwater video will benefit the NCCA program and other scientists and programs utilizing underwater video as the technology has become more accessible and affordable. The methods for underwater

video analysis tested here will also apply to other data sources such as underwater video collected by ORD as part of the 2017 Lake Huron Coordinated Science and Monitoring Initiative. All project deliverables will cite the original source of data. The ability to also analyze new video collected by ORD through other programs will reduce workloads of current staff and increasing the ability to share results with public quickly.

SECTION 3.0, QUALITY OF SECONDARY DATA

This pilot project aims to determine appropriate methods for video analysis to address challenges in accuracy, precision, representativeness, completeness, and comparability.

Accuracy of video analysis is challenging to address because in-situ verification of underwater video interpretations is not possible for previously collected video, and is very expensive for future video collections. Instead of addressing accuracy directly, our citizen scientist approach aims to increase precision by having multiple analysts review videos. Agreement among two trained experts on video interpretation is often low, mostly due to discrepancies in interpretation of video quality and confidence in observations (68 – 89%, Wick et al., 2017). By having many (e.g 10) analysts view the videos, we will identify high quality videos when multiple analysts agree on interpretations. Conversely, we will identify poor quality videos when multiple analysts disagree on video interpretation. A minimum number of analysts necessary for confirming precision in a given video will be determined based on previous studies in the literature and the total number of citizen scientists we are able to engage (e.g. Wiggins & Crowston, 2011).

While public analysts have a significantly lower level of training than experts, the analysis will be developed to provide the necessary background information and examples, and will be designed to be simple enough that the general public can successfully perform the analysis. The ability of the public to complete the analysis will be confirmed through beta-testing of the application by the general public. During beta-testing, the application will be modified as necessary based on feedback from testers to ensure that it is understandable and achievable for the general public, and also enjoyable to ensure adequate participation for project success.

Representativeness, completeness, and comparability are addressed by the sampling methods and probabilistic survey design which is described in USEPA, 2009, and USEPA, 2015.

SECTION 4.0, DATA REPORTING, DATA REDUCTION, AND DATA VALIDATION

The video analysis developed to be completed by citizen scientists on the web application will follow methods developed by Lietz et al., 2016 and Wick et al., 2017, with input from the stakeholder design team on data need priorities. The analysis, user interface, training materials, and supporting materials will be designed based on lessons learned by other crowd-sourced imagery and media analysis projects (e.g. Nov et al., 2014; Dickinson et al., 2012; Wiggins & Crowston, 2011; Rotman et al., 2012; Mugar et al., 2014; Raddick et al., 2009; Newman et al., 2012; Reed et al., 2013; Cox et al., 2015; Price et al., 2013; Eveleigh et al., 2014; Luczak-Roesch

et al., 2014; Tinati et al., 2015; Edward et al., 2013; Curtis, 2015; Haythornthwaite, 2009; Crowston & Fagnot, 2008; Kosmala et al., 2016).

Projects typically set targets for number of independent reviews based on the type of media being interpreted, and the type of analysis (e.g. Batalha et al., 2013 required five independent views of each light curve, while Swanson et al., 2016 averaged 26 views of each wildlife image). We evaluate and set a target for minimum number of views for each video. Triggers will be established for additional expert review of individual videos (e.g. Batalha et al., 2013; Wiggins & Crowston, 2011).

The citizen science analysis will ultimately produce a complicated dataset with multiple interpretations for each video. These data will need to be reduced to a single interpretation for each video in order to be summarized. A rich bank of literature has been compiled on data reduction methods and results utilized by citizen science approaches to media analysis, available at https://www.zooniverse.org/about/publications. Methods for data analysis utilized by other citizen science video analysis projects will be reviewed and applied for this project.

Thresholds can be set for determining video quality based on the minimum level of agreement or disagreement of multiple viewers (Newman et al., 2012). The sensitivity of the analysis results to those thresholds will be evaluated. A consensus algorithm can be applied to determine the result for each video (e.g. Swanson et al., 2015; Matsunaga et al., 2016). Consensus algorithms used in other studies are often available as open source resources (Swanson et al., 2015).

Statistical analysis methods will be selected by the application development team, following the methods done for other citizen science video analysis projects. Swanson et al., 2016 used the following metrics: level of agreement among classifications, fraction of classifications supporting the aggregated answer, and fractions of classifiers who reported “nothing here” for an image that was ultimately classified as containing an animal. These statistics will provide information on the uncertainty and difficulty of interpreting videos.

The results of the citizen scientists’ analysis will be compared to the results of previously-collected expert interpretations of the same videos to evaluate the citizen science analysis. While the entire video dataset has been analyzed by at least a single expert, a subset (56 videos) has been analyzed by multiple experts allowing a more in-depth validation effort for a subset of the dataset. Citizen scientists results that disagree with expert analysis will be flagged for further review, and if necessary be reviewed by multiple experts. Because no ground truth data are available, determining the actual accuracy of experts or volunteers is not possible. Results that disagree with single/multiple expert analysis indicate marginal video quality and will be eliminated from final results.

The deliverable products that will be prepared for this project include a final report and a peer- reviewed journal article. Results and data will be shared with state and local stakeholders.

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Appendix 1

Underwater Video Analysis Protocol

Overview:

Underwater videos (UVID) were collected in from 2009 - 2016 for the National Coastal Condition Assessment throughout each Great Lake and in the Huron-Erie Corridor (Detroit River, Lake St. Clair, and St. Clair River), and St. Marys River. These videos can be used to supplement traditional grab sampling techniques to characterize benthic habitat, and identify the presence, and possibly relative density, of invasive species such as Dreissenids. The contractor is responsible for analyzing these videos using the protocol developed by EPA and described below.

Conducting Underwater Video Analysis

A database, which is set up with relevant site information, fields, and UIDs needing analysis, will be provided by the EPA along with the underwater videos. The database will include filenames/links to each underwater video needing analysis. A single analyst should be responsible for analyzing all videos to produce consistent results.

Overview of steps in analysis:

1. Analysts will view each video *at least twice in its entirety* and portions of videos that are unclear or questionable will need to be viewed additional times slowly.
2. After viewing the videos, the Underwater Video Analysis will be completed by filling out the required fields in the database based on the observations of the video, and the criteria described below and in the attached supporting materials.
3. Review the video again following completion of the analysis to verify results.

The database guide (see below) provides detailed instructions for filling out each field. All fields in the database that include dropdown options must be completed for each video. Every effort should be made to use the options available, however if necessary new options could be added. Comment fields are also included. Be as descriptive as possible in the comment fields. A VIDcomment should be included for every video. VidFishID, VidFishComment, VidVegComment, and VidMusselComment should be included for each video that includes fish, vegetation, and mussels, respectively.

Training Tools

The following tools have been developed to train analysts to conduct the underwater video analysis:

- UVID Database Guide.xlsx: This explains what each field in the database means and instructions for how to fill it out.
- VideoQualityClarityFlowChart.pdf: Flow chart for assigning videos a quality and clarity rating (From Lietz et al., 2015).
- UVID Analysis Example Screenshots.pdf: Document with examples of screenshots from videos of the UVID analysis for various fields.
- UVIDTrainingDatasetFinal.accdb: Database with results of UVID analysis for 44 training videos completed by EPA analyst, along with a blank sheet for contractor to practice UVID analysis.
- 44 Training Videos from 2015 and 2010 NCCA Sites

Quality Assurance: QA set

A subset of the 2009 - 2016 videos in the analysis will be analyzed for quality assurance (QA) by EPA once training is complete and the contractor has begun analyzing the dataset. This Initial QA set will consist of the first 30 videos analyzed by the contractor. This initial QA set will "test" the reproducibility of the analysis and help identify any discrepancies between Contractor and EPA analysts. The contractor will adapt the implementation of the methodology based on the results of this preliminary QA analysis, and discussion with EPA analysts.

The table below describes the measures that will be used to evaluate the contractor's analysis for quality assurance. Percent Agreement refers to the percent of videos where the Contractor's result for the field of interest exactly matches the EPA's result for the field of interest. While all fields will be reviewed (with a target for 90% agreement for non-comment fields), the Priority QA fields are the fields that EPA will use to evaluate success for the contractor.

Measures for evaluating Contractor/EPA Quality Assurance Videos			
Fields In Database	**QA Measure**	**Criteria**	**Priority QA Fields**
UID	Completion	Completed	
VidTime	Completion	Completed	
CameraType	Completion	Completed	
Analyst	Completion	Completed	
VidBottom1	Percent Agreement	90%	Yes
VidBottom2	Percent Agreement	90%	Yes
VidBottomDom	Percent Agreement	90%	
VidBottom3	Percent Agreement	90%	
VidFish	Percent Agreement	90%	Yes
VidFishID	Completion	Completed	
VidFishComment	Comments Present if fish observed by EPA	TRUE	
VidGobyRating	Percent Agreement	90%	
VidVeg	Percent Agreement	90%	Yes
VidVegCover	Percent Agreement	90%	
VegHeight	Percent Agreement	90%	
VegTypeDom	Percent Agreement	90%	
VegTypeSubDom	Percent Agreement	90%	
VidVegComment	Comments Present	TRUE	
VidMussels	Percent Agreement	90%	Yes
VidMusselDensity	Percent Agreement	90%	
VidMusselRating	Percent Agreement	90%	Yes
VidMusselComment	Comments Present	TRUE	
VidRating	Percent Agreement	90%	Yes
VidH2OClarityRating	Percent Agreement	90%	Yes
Controllable?	Percent Agreement	90%	
ControllableID	Percent Agreement	90%	
Uncontrollable	Percent Agreement	90%	
UncontrollableID	Percent Agreement	90%	
VidComment	Comments Present	TRUE	
Priority QA Fields	Percent Agreement	90%	Yes
All Fields	Percent Agreement	90%	

NCCA Underwater Video Analysis Database Guide			
Field	**Description**	**Possible Entries/Options**	**Instructions**
UID	What is the video's Unique ID?	UID	The UID will be given for each video in the database provided.
CameraType	Which type of Camera was used?	SeaViewer, GoPro	Choose what type of camera was used for the video. SeaViewer files are .avi files and have a SeaViewer logo on the bottom of the video. GoPro videos are .mp4 files.
Analyst	Who completed the analysis?	Analyst	Indicate Name of Analyst.
VidBottom1	What is the dominant substrate at site?	Soft (silt/clay/sand); Hard (gravel/cobble/boulder/rock/bedrock); Unknown; Unknown/veg	*Choose NA for VidBottom2 if the site only has one sediment type. *If two substrate types are present in equal proportions, check yes for VidBottomCodominance. *In some cases, the substrate is completely obscured by vegetation beds (indicated with a VidVegCover = Dense below). In those cases, the substrate should be marked as unknown/veg. In other cases, the site may be dominated by a veg bed, but the camera does get glimpses of the substrate and it can be identified. In those cases the dominant substrate should be chosen. If the substrate is not able to be identified for any other reason (e.g. camera movement, distance, turbidity, light issues, etc), then "unknown" should be chosen.
VidBottom2	What is the secondary substrate at the site?	Soft (silt/clay/sand); Hard (gravel/cobble/boulder/rock/bedrock); Unknown; Unknown/veg; NA	
VidBottomCodominance	Are VidBottom1 and VidBottom2 codominant?	Check box	
VidBottomComment	Include any comments about substrate type.	Text as needed	Note any observations/comments about substrate type. If you are confident in a more refined substrate determination (e.g. sand or boulder or gravel), you can add that here, or if there are any additional observations of the bottom including wood or foreign objects. Include confidence in substrate claims.

NCCA Underwater Video Analysis Database Guide			
Field	**Description**	**Possible Entries/Options**	**Instructions**
VidFish	Were fish observed in the video?	Yes, No, Unknown	Indicate if any fish were observed in the video. Choose yes if fish were observed. Choose no if no fish were observed. Choose unknown if fish may be present but you are not confident, or if video quality, video clarity, etc prevents observation of fish.
VidFishID	If fish were observed, what species were identified?	Species names and quantity, or any notes about type of fish, or unknown.	If fish are present in the video, the VidFishID field should be filled out with what species can be identified. If species cannot be identified, enter unknown and any additional information available (juvenile, approximate quantitiy, etc). Indicate uncertainty/confidence as necessary. Round gobies are a species of interest, so try to identify any fish that may be round gobies if possible, and note confidence.
VidFishComment	Include any comments about fish in the video.	Text as needed	Include any comments about fish observed, along with times in the video when fish are observed (if not present throughout video), and confidence in identification.
VidFilamentousVeg	Are filamentous forms of vegetation observed in the video?	Yes, No, Unknown	This field asks whether filamentous forms of vegetation are observed or not. This aims to identify sites that have algae present. Use unknown if you are not confident in your claim that there is or isn't filamentous vegetation, or if video quality, video clarity, etc prevents observation of the bed/vegetation at all. If you are confident there is filamentous vegetation present, even if it is at very small quantities, choose yes.
VidVegOther	Are other types of vegetation besides filamentous vegetation observed in the	Yes, No, Unknown	Indicate if the video shows the site has any vegetation other than filamentous vegetation types. Use unknown if you are not confident in your claim that there is or isn't vegetation other than filamentous vegetation, or if video quality, video clarity, etc prevents observation of the bed/vegetation at all. Make sure to say yes even if

NCCA Underwater Video Analysis Database Guide			
Field	**Description**	**Possible Entries/Options**	**Instructions**
	video?		there is only a few stems.
VidVegCover	What is approximate cover of all types (filamentous and other) of vegetation?	Absent (No vegetation) Sparse - individual/isolated plants (<10% cover). Medium - Patchy vegetation cover. Dense - site is completely vegetated (>90% cover) Unknown	Mentally integrate the entire video to estimate the cover of all vegetation types over the entire site represented by the video, using the bins described here.
VegHeight	What is the general/dominant height ofall types (filamentous and other) of vegetation?	Absent (No vegetation) Low (< 0.3 m) High (>0.3 m) Unknown	Indicate the general stature of dominant vegetation at the site: low or high. Canopy forming vegetation is always high. Choose Unknown if video clarity, video quality, etc. prevents an estimate from being made.
VidVegComment	Include any comments about the vegetation in the video.	Text as needed	Include any additional observations of vegetation. If it can be identified, include types of vegetation (finely branched, leafy, ribbon leaved, emergent/floating, filamentous, etc) and/or species you can easily identify with little effort, and any notes on structure, type, variability, etc. Mention confidence in veg claims.
VidMussels	Are live dreissenids present at the site?	Yes, No, Unknown	In order to indicate that mussels are present, live mussels must be observed. If only shells are observed or no mussels or shells are observed, choose No. If you think that mussels may be present but are not confident, or if the video quality or clarity prevent a determination, choose unknown.
VidMusselDensity	What is the density of live mussels at the	Absent (no live mussels) Sparse (< 10% cover - a few isolated spots)	Mentally integrate the entire video to estimate the density of live mussels over the entire site represented by the video, using the bins described here. If it is

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Field	**Description**	**Possible Entries/Options**	**Instructions**
	site?	Medium (10 - 90% cover - consistently present in a patchy manner) Dense (>90% cover - most surfaces covered) Unknown	difficult to estimate density, err on the conservative side. For example, if the video is blurry or fast-moving and you only see one shot of a small area where you can confidently identify mussels, but there may be many other areas that are just too blurry to confidently identify them, estimate density only based on the ones that you can confidently identify (e.g. Sparse). Indicate Unknown if vegetation, video clarity, video quality, etc. prevents an estimate from being made.
VidMusselComment	Include any comments about the mussels observed in the video.	Text as needed	Include comments on mussels. Include notes on variability, density, attachment to surfaces, confidence in claim, etc. Include timestamp for any "fleeting glimpse" mussels sightings if they are not present throughout the entire video.
VidQualityComment	Comment on video quality.	Text as needed	Comment on video quality, including if there were technical issues, or other issues with the video. E.g. video never gets close enough to bottom/rocks/mussels, camera stirs up bottom, improper lighting, improper camera angle/view, turbidity/dark color, blurry images, fish don't present themselves, vegetation is too thick, bouncy image, spinning camera, only small area is viewable, or just can't make things out. Discuss confidence of individual claims in VidMusselComment, VidVegComment, VidFishComment, and VidBottomComment.