REPORT FOR THE UNIVERSITY OF HAWAIʻI AT HILO
MARINE OPTION PROGRAM

Quantitative and Qualitative Assessment of Underwater Video Annotations

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Abstract

The Office of Ocean Exploration and Research (OER) collects a vast amount of underwater video data (> 600 hours per year) using Remotely Operated Vehicles (ROVs) to understand unexplored deep-sea environments. Efficient use and re-use of these video data depend on the quality of associated video annotations. OER scientists on board the *Okeanos Explorer* collect these annotations in collaboration with volunteer scientists who participate in expeditions remotely through telepresence technology. This project context focused on developing methods to assess and improve the quality of OER's video annotations. Although data sets used during this study were limited to OER's annotations, similar problems what problems? are faced by other NOAA offices that use underwater video as an environmental assessment tool. Using OER's in-house tools to play back video that enabled merging of annotations with video, 43 ROV dives (~ 273 Hours) were analyzed. Quantitative methods were developed to quickly identify where annotations are missing. On average, OER's video annotations occurred every 2.5 minutes. The annotations that surpassed this average threshold were identified and linked directly to the video data for reviewing if further annotations were needed. The accuracy of video annotations can be assessed using the attached hyperlinks to annotations and if necessary, the link and annotation can be sent to the specialist who logged the annotation for verification. The results of this project indicate that the use of dedicated loggers during expeditions can further improve the quality and quantity of annotations. Post expedition assessment is also a necessary step that can be achieved utilizing SeaTube and the methods developed during this project.

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INTRODUCTION

The Office of Ocean Exploration and Research (OER) ship, the *Okeanos Explorer*, is the only federal vessel dedicated to deep-sea exploration. OER conducts telepresence-enabled deep-sea explorations and provides open data that contains unique discoveries data don't contain discoveries,; meeting the needs of many scientists and spurring future scientific research. Data collected in unexplored areas provide insight into deep-sea environments, bettering our understanding of deep-sea processes and natural resources. ~~This~~ These data includes video annotations and oceanographic sensor readings collected from Remotely Operated Vehicles (ROVs), and multibeam sonar seafloor mapping data from the ship. While multibeam and oceanographic data has well developed the data have methods? methods for quality assurance (QA) and quality checking (QC), video annotations collected by OER do not have a standardized post cruise QA/QC process (Malik et al. unpubl. data). This project focused on assessing the different methods of video playback and annotation creation and developing methods to assess the quality of ROV video annotations. Three methods of video playback and annotation creation were compared, methods were developed to assess the completeness and accuracy of the annotations, and finally recommendations were developed to improve quality of video annotations.

Although data sets used for this study were limited to OER's collection, similar problems specify problems are faced by other NOAA offices, such as Marine Fisheries and Sanctuaries, that use video as an environmental assessment tool (Malik et al. unpubl. data). Without quality controlled video annotations, the use and re-use of the video is extremely challenging. The results of this project are expected to improve the quality of video annotations and provide tools that can be used by OER to expedite analysis of video annotations.

Underwater video data sets are massive in size, and difficult to access without proper annotation (Wiener 2017). Several different NOAA offices collect underwater video in various depths ranging from shallow water video (< 500 m) for marine fish stock assessment, to deeper waters (> 3000 m) for recording high density deep-sea coral and sponge colonies and to gain an understanding of deep-sea environments and processes. The deep-sea environment is particularly poorly studied. Although there are no quantitative estimates of the areas in deep sea that have been visually imaged, ~~but~~ it is hypothesized that ~~only~~ < 1 % of deep sea floor deeper than ~~(~~> 500 m~~)~~ has been imaged to date (Copley 2014).

The acoustic tools such as multibeam sonars can map the seafloor efficiently to a depth of 8000 m (https://schmidtocean.org/technology/seafloor-mapping). However, the use of ROV's can being?? extremely expensive to operate and maintain, but the underwater video footage provides information that is not possible to be obtained using only ship mounted acoustic sensors. This information obtained through ROV's include habitat, geological processes, observations of individual organism's morphology and the interaction of different living organisms in their natural environment. Although automatic image analysis techniques are developing rapidly for terrestrial video (Guo and Shi 2010), the underwater video suffers from low lighting, rapid change of background conditions and complex habitats, which make it difficult to use computer vision techniques to identify underwater organisms and environment (Walther, Dirk & Edgington, Duane & Koch, Christof 2004). Therefore, the only viable option for video analysis is currently the human provided annotations of video data sets. Video annotations provide the identification of geological processes and organisms being observed. These are either spoken or logged by scientists during and after the video is collected. The video can also by provide necessary commentary from the expert scientists that assist in locating and extracting information from the video data. However, there are currently no standards in how video data are captured, such as what ancillary information is required and how to assess if annotations from video have been documented accurately and completely. This project developed a framework to assess the quality of video annotations.

METHODS

During this project, the video collected by OER and Global Foundation of Ocean Exploration (GFOE) operated ROV, *Deep Discoverer*, was used to develop a methodology for annotation review. The developed methods are designed to expedite the video annotation review process. Four different expeditions were used? during this project consisting of 43 ROV dives not clear. Each dive consisted? of about 4-6 hours of bottom video. Specific expeditions included EX1307 and three of ORER's 2017 expeditions conducted under the CAPSTONE (Campaign to Address Pacific Monument Science, Technology and Ocean Needs) project.?? What? EX1307, Leg 1 (Dive #5) was chosen as an example before the implementation of new annotations tools in 2017. This dive was conducted in July 2013 in Hydrographer Canyon approximately~ 200 NM offshore from New York. The 2017 expeditions were conducted around in American Samoa, Howland and Baker Island, Kingman Reef and Palmyra Atoll, and Jarvis Island (Figure 1). More details about the different annotation methods (Event log / SeaScribe) are included in Section 2.1. More details about these cruises are available at http://oceanexplorer.noaa.gov/okeanos/explorations/explorations.html left justify

Tables should be black and white in word, for Xeroxing potential

Cruise Number	Date	# of Dives	# of Annotations	Video Length
EX1307	July 13, 2013	1	464	~ 7 hrs
EX1702	02/21/13 - 03/01/13	11	2110	~ 109 hrs
EX1703	03/09/17 – 02/26/17	19	4189	~ 116 hrs

EX1705	04/27/17 – 05/13/13	12	4194	~ 71 hrs

Tables have caption above; figures have caption below Table 1: Number of expeditions used for annotation analysis.
Cruise number refers to NOAA Ship *Okneaos Explorer* cruise numbers used by NOAA OER.

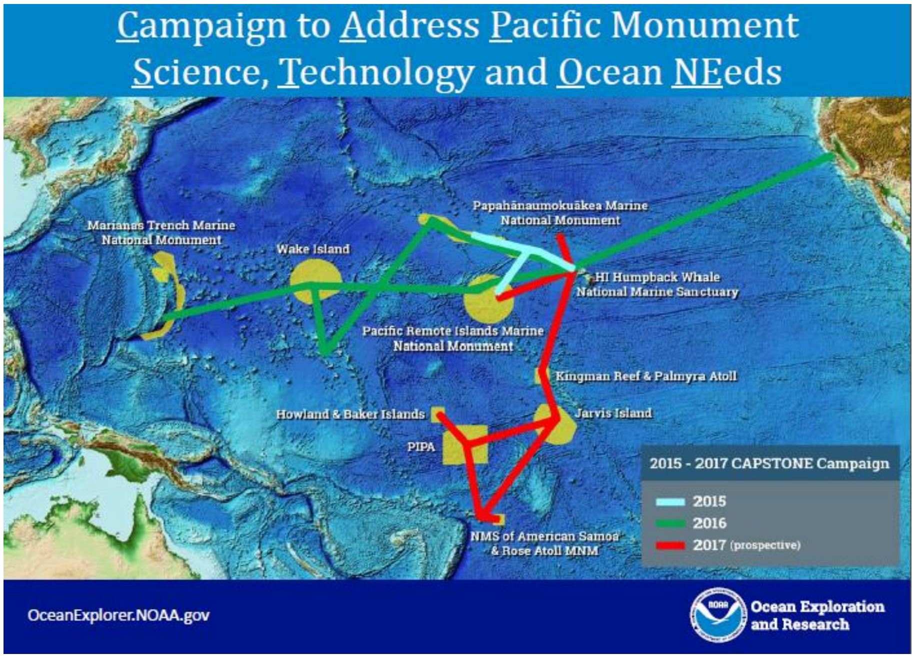
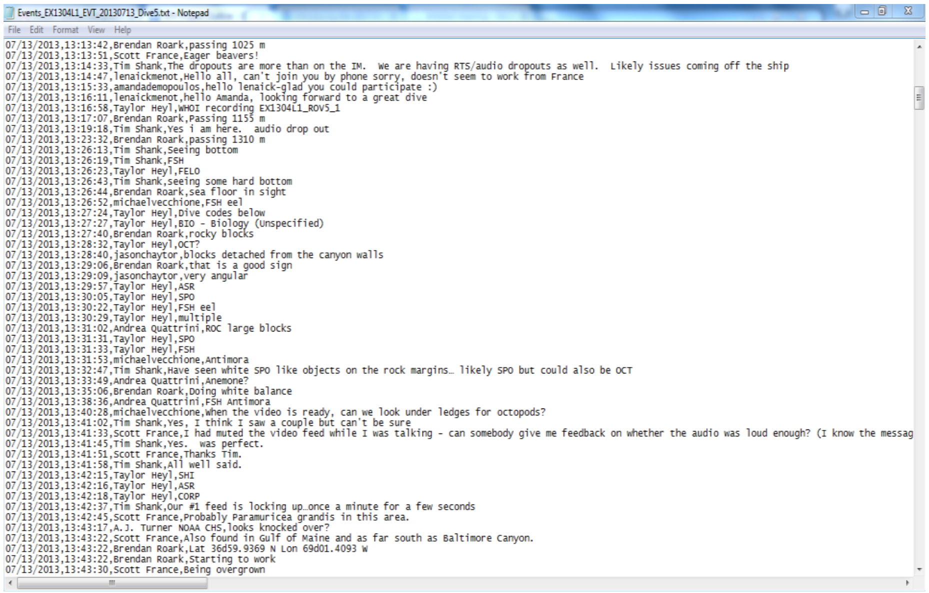


Figure 1: Overview of CAPSTONE efforts led by OER from 2015 -2017.
ROV dives analyzed during this included only the early part of 2017 field season.

Sources ~~Of~~ of Video Annotations

NOAA's ship the *Okeanos Explorer* has been collecting ROV video since 2010. From 2010 to 2016, the video annotations have been obtained in real time through an event log, an online community based chatroom accessible to participating scientists on board the *Okeanos Explorer* and on-shore. In fall of 2016, OER implemented a new way of obtaining video annotations through Ocean Networks Canada (ONC) using SeaScribe/SeaTube. SeaScribe is an online database where participating scientists, on-shore and ship, log annotations during ROV dives. These two annotation formats were used during this study and are described below.

Starting in 2010, the event log was ~~utilized~~used. Never use the word utilize again as long as you live unless you're talking about nutrient uptake. And what do you mean the event log was used? Annotations in the event log contain the following information: date and time of entry, annotator, and the biological and/or geological description. The depth and latitude and longitude, and the chat room dialog from the scientists mixed? throughout the annotation entries. The event log (Figure 2) was used exclusively as the primary annotation tool for all expeditions until 2016.



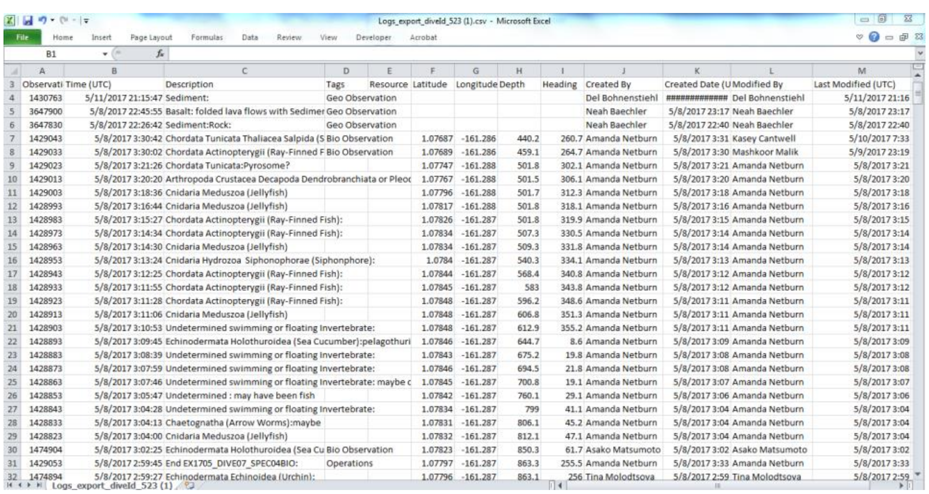
Events_EX1304L1_EVT_20130713_Dive5.txt - Notepad

File Edit Format View Help

```
07/13/2013,13:13:42,Brendan Roark,passing 1025 m
07/13/2013,13:13:51,Scott France,Eager beavers!
07/13/2013,13:14:33,Tim Shank,The dropouts are more than on the IM.  We are having RTS/audio dropouts as well.  Likely issues coming off the ship
07/13/2013,13:14:47,lenaickmenot,Hello all, can't join you by phone sorry, doesn't seem to work from France
07/13/2013,13:15:33,amandademopoulos,hello lenaick-glad you could participate :)
07/13/2013,13:16:11,lenaickmenot,hello Amanda, looking forward to a great dive
07/13/2013,13:16:58,Taylor Heyl,WHOI recording EX1304L1_ROV5_1
07/13/2013,13:17:07,Brendan Roark,Passing 1155 m
07/13/2013,13:19:18,Tim Shank,Yes i am here.  audio drop out
07/13/2013,13:23:32,Brendan Roark,passing 1310 m
07/13/2013,13:26:13,Tim Shank,Seeing bottom
07/13/2013,13:26:19,Tim Shank,FSH
07/13/2013,13:26:23,Taylor Heyl,FELO
07/13/2013,13:26:43,Tim Shank,seeing some hard bottom
07/13/2013,13:26:44,Brendan Roark,sea floor in sight
07/13/2013,13:26:52,michaelvecchione,FSH eel
07/13/2013,13:27:24,Taylor Heyl,Dive codes below
07/13/2013,13:27:27,Taylor Heyl,BIO - Biology (Unspecified)
07/13/2013,13:27:40,Brendan Roark,rocky blocks
07/13/2013,13:28:32,Taylor Heyl,OCT?
07/13/2013,13:28:40,jasonchaytor,blocks detached from the canyon walls
07/13/2013,13:29:06,Brendan Roark,that is a good sign
07/13/2013,13:29:09,jasonchaytor,very angular
07/13/2013,13:29:57,Taylor Heyl,ASR
07/13/2013,13:30:05,Taylor Heyl,SPO
07/13/2013,13:30:22,Taylor Heyl,FSH eel
07/13/2013,13:30:29,Taylor Heyl,multiple
07/13/2013,13:31:02,Andrea Quattrini,ROC large blocks
07/13/2013,13:31:31,Taylor Heyl,SPO
07/13/2013,13:31:33,Taylor Heyl,FSH
07/13/2013,13:31:53,michaelvecchione,Antimora
07/13/2013,13:32:47,Tim Shank,Have seen white SPO like objects on the rock margins… likely SPO but could also be OCT
07/13/2013,13:33:49,Andrea Quattrini,Anemone?
07/13/2013,13:35:06,Brendan Roark,Doing white balance
07/13/2013,13:38:36,Andrea Quattrini,FSH Antimora
07/13/2013,13:40:28,michaelvecchione,When the video is ready, can we look under ledges for octopods?
07/13/2013,13:41:02,Tim Shank,Yes, I think I saw a couple but can't be sure
07/13/2013,13:41:33,Scott France,I had muted the video feed while I was talking - can somebody give me feedback on whether the audio was loud enough? (I know the messag
07/13/2013,13:41:45,Tim Shank,Yes.  was perfect.
07/13/2013,13:41:51,Scott France,Thanks Tim.
07/13/2013,13:41:58,Tim Shank,All well said.
07/13/2013,13:42:15,Taylor Heyl,SHI
07/13/2013,13:42:16,Taylor Heyl,ASR
07/13/2013,13:42:18,Taylor Heyl,CORP
07/13/2013,13:42:37,Tim Shank,Our #1 feed is locking up…once a minute for a few seconds
07/13/2013,13:42:45,Scott France,Probably Paramuricea grandis in this area.
07/13/2013,13:43:17,A.J. Turner NOAA CHS,looks knocked over?
07/13/2013,13:43:22,Scott France,Also found in Gulf of Maine and as far south as Baltimore Canyon.
07/13/2013,13:43:22,Brendan Roark,Lat 36d59.9369 N Lon 69d01.4093 W
07/13/2013,13:43:22,Brendan Roark,Starting to work
07/13/2013,13:43:30,Scott France,Being overgrown
```

Figure 2: Example of 30 minutes of the Event log entries

From 2016 to present, SeaScribe was ~~utilized~~ used by participating scientists, on-shore and ship, to log annotations during ROV dives. Each entry contains the following information: observation ID, date and time (UTC) entered, description, tags (biological or geological observation), latitude and longitude, depth, heading, annotator, if/who modified the annotation and date and time (UTC) of modification. Sea Scribe allows the annotations to be accessed in real-time and can be modified immediately to ensure the accuracy of annotations. SeaScribe annotations are automatically populated into SeaTube ~~(~~, an online annotation-aware video browsing tool~~)~~, and is accessible in real-time by any interested parties. Since inception of SeaScribe (Figure 3), a separate chat room has been created for scientist to access during dives to communicate and discuss about their observations.



Logs_export_diveId_523 (1).csv - Microsoft Excel

	A	B	C	D	E	F	G	H	I	J	K	L	M
3	Observati	Time (UTC)	Description	Tags	Resource	Latitude	Longitude	Depth	Heading	Created By	Created Date (U	Modified By	Last Modified (UTC)
4	1430763	5/11/2017 21:15:47	Sediment:	Geo Observation						Del Bohnenstiehl	#############	Del Bohnenstiehl	5/11/2017 21:16
5	3647900	5/8/2017 22:45:55	Basalt: folded lava flows with Sedimer	Geo Observation						Neah Baechler	5/8/2017 23:17	Neah Baechler	5/8/2017 23:17
6	3647830	5/8/2017 22:26:42	Sediment:Rock:	Geo Observation						Neah Baechler	5/8/2017 22:40	Neah Baechler	5/8/2017 22:40
7	1429043	5/8/2017 3:30:42	Chordata Tunicata Thaliacea Salpida (S	Bio Observation		1.07687	-161.286	440.2	260.7	Amanda Netburn	5/8/2017 3:31	Kasey Cantwell	5/10/2017 7:33
8	1429033	5/8/2017 3:30:02	Chordata Actinopterygii (Ray-Finned F	Bio Observation		1.07689	-161.286	459.1	264.7	Amanda Netburn	5/8/2017 3:30	Mashkoor Malik	5/9/2017 23:19
9	1429023	5/8/2017 3:21:26	Chordata Tunicata:Pyrosome?			1.07747	-161.288	501.8	302.1	Amanda Netburn	5/8/2017 3:21	Amanda Netburn	5/8/2017 3:21
10	1429013	5/8/2017 3:20:20	Arthropoda Crustacea Decapoda Dendrobranchiata or Pleoc			1.07767	-161.288	501.5	306.1	Amanda Netburn	5/8/2017 3:20	Amanda Netburn	5/8/2017 3:20
11	1429003	5/8/2017 3:18:36	Cnidaria Meduszoa (Jellyfish)			1.07796	-161.288	501.7	312.3	Amanda Netburn	5/8/2017 3:18	Amanda Netburn	5/8/2017 3:18
12	1428993	5/8/2017 3:16:44	Cnidaria Meduszoa (Jellyfish)			1.07817	-161.288	501.8	318.1	Amanda Netburn	5/8/2017 3:16	Amanda Netburn	5/8/2017 3:16
13	1428983	5/8/2017 3:15:27	Chordata Actinopterygii (Ray-Finned Fish):			1.07826	-161.287	501.8	319.9	Amanda Netburn	5/8/2017 3:15	Amanda Netburn	5/8/2017 3:15
14	1428973	5/8/2017 3:14:34	Chordata Actinopterygii (Ray-Finned Fish):			1.07834	-161.287	507.3	330.5	Amanda Netburn	5/8/2017 3:14	Amanda Netburn	5/8/2017 3:14
15	1428963	5/8/2017 3:14:30	Cnidaria Meduszoa (Jellyfish)			1.07834	-161.287	509.3	331.8	Amanda Netburn	5/8/2017 3:14	Amanda Netburn	5/8/2017 3:14
16	1428953	5/8/2017 3:13:24	Cnidaria Hydrozoa Siphonophorae (Siphonophore):			1.0784	-161.287	540.3	334.1	Amanda Netburn	5/8/2017 3:13	Amanda Netburn	5/8/2017 3:13
17	1428943	5/8/2017 3:12:25	Chordata Actinopterygii (Ray-Finned Fish):			1.07844	-161.287	568.4	340.8	Amanda Netburn	5/8/2017 3:12	Amanda Netburn	5/8/2017 3:12
18	1428933	5/8/2017 3:11:55	Chordata Actinopterygii (Ray-Finned Fish):			1.07845	-161.287	583	343.8	Amanda Netburn	5/8/2017 3:12	Amanda Netburn	5/8/2017 3:12
19	1428923	5/8/2017 3:11:28	Chordata Actinopterygii (Ray-Finned Fish):			1.07848	-161.287	596.2	348.6	Amanda Netburn	5/8/2017 3:11	Amanda Netburn	5/8/2017 3:11
20	1428913	5/8/2017 3:11:06	Cnidaria Meduszoa (Jellyfish)			1.07848	-161.287	606.8	351.3	Amanda Netburn	5/8/2017 3:11	Amanda Netburn	5/8/2017 3:11
21	1428903	5/8/2017 3:10:53	Undetermined swimming or floating invertebrate:			1.07848	-161.287	612.9	355.2	Amanda Netburn	5/8/2017 3:11	Amanda Netburn	5/8/2017 3:11
22	1428893	5/8/2017 3:09:45	Echinodermata Holothuroidea (Sea Cucumber):pelagothuri			1.07846	-161.287	644.7	8.6	Amanda Netburn	5/8/2017 3:09	Amanda Netburn	5/8/2017 3:09
23	1428883	5/8/2017 3:08:39	Undetermined swimming or floating invertebrate:			1.07843	-161.287	675.2	19.8	Amanda Netburn	5/8/2017 3:08	Amanda Netburn	5/8/2017 3:08
24	1428873	5/8/2017 3:07:59	Undetermined swimming or floating invertebrate:			1.07846	-161.287	694.5	21.8	Amanda Netburn	5/8/2017 3:08	Amanda Netburn	5/8/2017 3:08
25	1428863	5/8/2017 3:07:46	Undetermined swimming or floating invertebrate: maybe c			1.07845	-161.287	700.8	19.1	Amanda Netburn	5/8/2017 3:07	Amanda Netburn	5/8/2017 3:07
26	1428853	5/8/2017 3:05:47	Undetermined : may have been fish			1.07842	-161.287	760.1	29.1	Amanda Netburn	5/8/2017 3:06	Amanda Netburn	5/8/2017 3:06
27	1428843	5/8/2017 3:04:28	Undetermined swimming or floating invertebrate:			1.0784	-161.287	799	41.1	Amanda Netburn	5/8/2017 3:04	Amanda Netburn	5/8/2017 3:04
28	1428833	5/8/2017 3:04:13	Chaetognatha (Arrow Worms):maybe			1.07831	-161.287	806.1	45.2	Amanda Netburn	5/8/2017 3:04	Amanda Netburn	5/8/2017 3:04
29	1428823	5/8/2017 3:04:00	Cnidaria Meduszoa (Jellyfish)			1.07832	-161.287	812.1	47.1	Amanda Netburn	5/8/2017 3:04	Amanda Netburn	5/8/2017 3:04
30	1474904	5/8/2017 3:02:25	Echinodermata Holothuroidea (Sea Cu	Bio Observation		1.07823	-161.287	850.3	61.7	Asako Matsumoto	5/8/2017 3:02	Asako Matsumoto	5/8/2017 3:02
31	1429053	5/8/2017 2:59:45	End EX1705_DIVE07_SPEC04BIO:	Operations		1.07797	-161.287	863.3	255.5	Amanda Netburn	5/8/2017 3:33	Amanda Netburn	5/8/2017 3:33
32	1474894	5/8/2017 2:59:27	Echinodermata Echinoidea (Urchin):			1.07796	-161.287	863.1	256	Tina Molodtsova	5/8/2017 2:59	Tina Molodtsova	5/8/2017 2:59

Logs_export_diveId_523 (1)

Figure 3: Example of one hour of SeaScribe annotations

In addition to the annotation logs, the participating scientists also offer audio commentary,~~ (~~via conference line~~)~~ during the live dives, that is recorded alongside the video. The video's audio can be used to clarify the annotations. This audio is not transcribed by OER and there is no means available to search through audio for specific words. However, the video available at SeaTube has audio recording encoded,~~;~~ giving access to the conversations between ROV engineering team, onboard scientists and shore scientists.

Video Replay

To assess the quality of video annotations, the primary requirement is to be able to play back the video and allow easy access to the video annotations. The original method of using video players with manual access to the annotations ~~(~~,text or audio files~~) –~~, is very time consuming. To assess the time requirements for the three video replay methods, the manual video replay methods were first assessed. Two separate methods of video annotation creation, as described above, were used for the purposes of this report. Once the video replay methods were described, the requirements to assess the completion and accuracy of the annotations were evaluated.

Assessment Of Video Replay Methods

Three separate video playback methods were used for the purposes of assessing annotation quality. These methods include~~:~~ ~~Manual~~ manual video playback, a semi-automated video playback tool developed by OER that uses annotation entry times (UTC) for video playback and a cloud based video playback program (SeaTube) with the ability to browse the video using annotation times.

Manual Replaying Of Video

The first method used to assess annotation quality was the manual playback process. The manual playback was performed by using the 'Event log' and ROV dive video. The selected ROV dive was conducted in 2013, 90 miles off the Northeast of the United States, in ~~the~~ Hydrographer Canyon. ~~As stated earlier,~~ T~~t~~he Event logs include chatroom dialog and annotations logged by the participating scientists. To conduct the review of the annotations, every entry in the event log had to be reviewed and the biological and/or geological annotations were extracted.

The time recorded in Event logs referred to UTC time of the dive itself. However, the video time displayed in the video player is referred to the start time of video, not the UTC time recorded for the annotations. The entry time (referenced to start time of video) of the annotation had to be calculated and searched on the ROV video using the video player. The video review started thirty seconds before each annotation, with audio, to verify the entry time was correct and check for missing annotations. If the entry time was off, the time difference was calculated and recorded in the log. If there were missing annotations, the time was calculated, and the annotation was recorded in the log.

Figure 4: VLC video player (manual checking process), Hydrographer Canyon

Semi-Automated Video Replaying

The second method reviewed was the ROV video analyzer tool developed by OER. This tool is a ~~python~~ Python based utility that enables playing of video at a specific UTC time, thus reducing the effort of manually browsing the video. The tool merges three data sets: the selected dive's event log (a text file), ROV track log (a text file), and ROV video (in mpg format). Each entry was reviewed to extract the biological and geological annotations and the edited event log file (after selecting only the observations) was exported into a spreadsheet. The time (UTC) of the annotation was entered in the ROV video analyzer, which launches the video in a video player to the location of the annotation. The annotation review consisted of listening to the science audio and reviewing the video from the time the ROV landed on and left the sea floor. Each entry was reviewed using the video analyzer, verifying if the entry time was correct, the annotation accurate, and reviewing for missing annotations. The annotation was noted in the spreadsheet as verified, modified or corrected then entered in the video analyzer, which creates a new text file with the reviewed annotations.

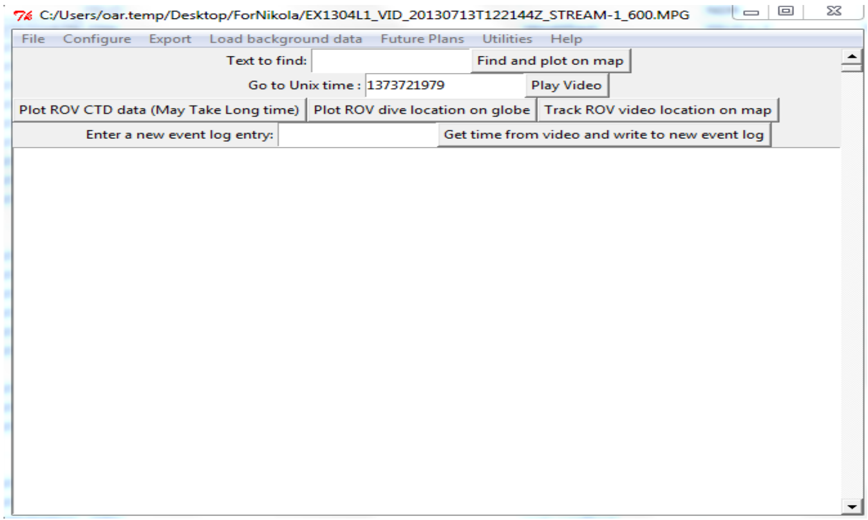


Figure 5: Event Log Search (ROV video analyzer) tool developed by OER.

Video Browsing Based On Annotations

The third method reviewed was the online cloud based video playback program, SeaTube. This method was assessed by accessing SeaTube through ONC's website. In SeaTube, each expedition's video is stored, and the annotations are directly linked to the video, enabling a quick access to video frames of interest.

To conduct the assessment of SeaTube, the .csv files for the annotations were downloaded from SeaScribe, a program within ONC's website, into a spreadsheet. SeaScribe is was? used to create and edit annotations during ROV dives. In addition to the annotations, the time and distance intervals, and hyperlinks were added to the spreadsheet.

The time interval for each annotation was calculated by finding the time difference between the annotations. The distance interval was calculated by converting the longitude and latitude (degrees) for each annotation into Universal Transverse Mercator (UTM, given in meters). To convert the longitude and latitude into UTM, a UTM batch converter was used (https://www.uwgb.edu/dutchs/UsefulData/UTMConversions1.xls), which converts the longitude and latitude (degrees) into UTM coordinates ~~(m).~~in meters. The distance intervals of the annotations were then calculated by using a distance formula. Hyperlinks for each annotation's specific video frame were added by linking the webpage to the annotations specific time (UTC), date, and dive number. These hyperlinks were used to assess to the video annotations at frames where time intervals crossed a chosen threshold. Additionally, hyperlinks to the specific annotations in the video can also be used to send to specialist to assist in accuracy verification.

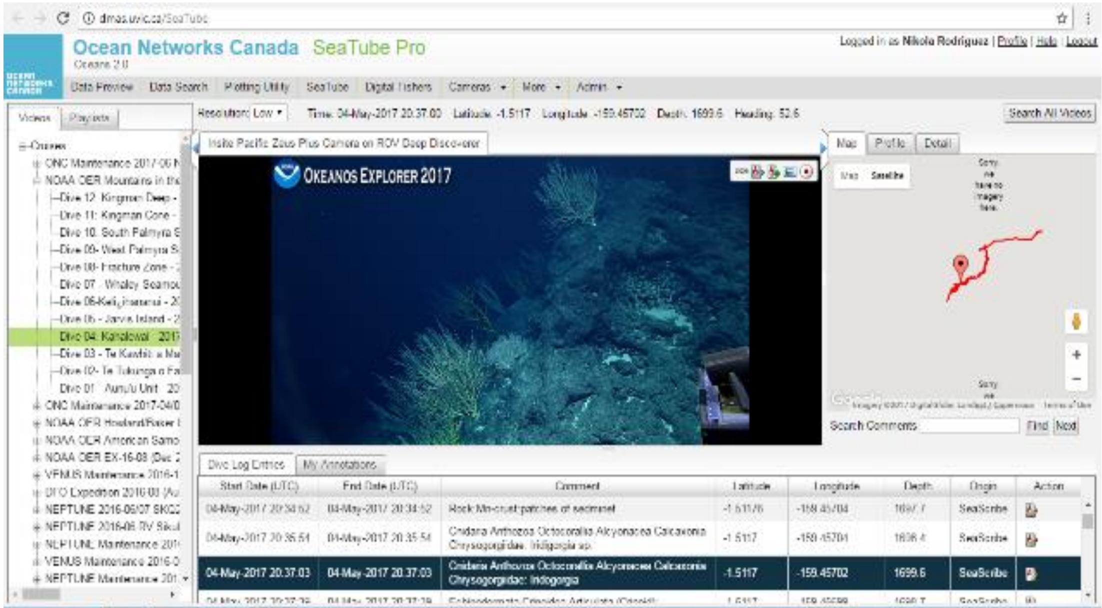


Figure 6: SeaTube annotation video review

Qualitative Assessment

The qualitative assessment of annotations was conducted by reviewing the annotations and associated video to verify the time and accuracy of annotations. Annotation review of the full video started one minute before the time that the ROV saw the ocean floor and ended when the ROV left the ocean floor. The review was started one minute before the ROV saw bottom to ensure the time of the first annotation was recorded accurately; therefore, the start of the annotations would then begin at the correct time. Each annotation was checked by viewing the video 30 seconds before and after each annotation to assure the whole video was reviewed. While the video was being reviewed any missing annotations were recorded. If/when an annotation was verified the time was recorded or modified in a new event log. The review of video qualitatively proved to be prohibitively long for manual video replay and extremely laborious process even with access to SeaTube (See results section). To improve the quality assessment of annotations, quantitative methods were developed to quickly identify places of the video where additional annotation review maybe required. As a solution to reviewing the entire video and expediting the review process, a spot checking method (every 1, 2.5, 5 minutes) was incorporated.

Quantitative Assessment

The time and distance intervals between annotations may vary depending on the terrain and density of organisms. For example, observing an organism while zoomed in will create a large annotation time interval, though the distance interval between annotations will be extremely small. Therefore, combination of time and distance interval between annotations can be effective proxies to describe the completeness of annotations. The time and distance intervals also expedite the review of the video annotations by quickly identifying where no annotations exist in the video. After the addition of new annotations in the places with time and distance gaps, the process can be repeated to check completeness and identify the times of video where further annotations may be needed to reduce time and distance intervals between annotations. The time interval between the annotations was found by calculating the differences between annotations. The distance interval ~~(m)~~, in meters, between annotations was calculated by using the longitude and latitude of each annotation. The longitude and latitude were converted into Universal Transverse Mercator (UTM), which converts the degrees of longitude and latitude into meters. Examples of time interval plots are shown in Figures 2 and 3.

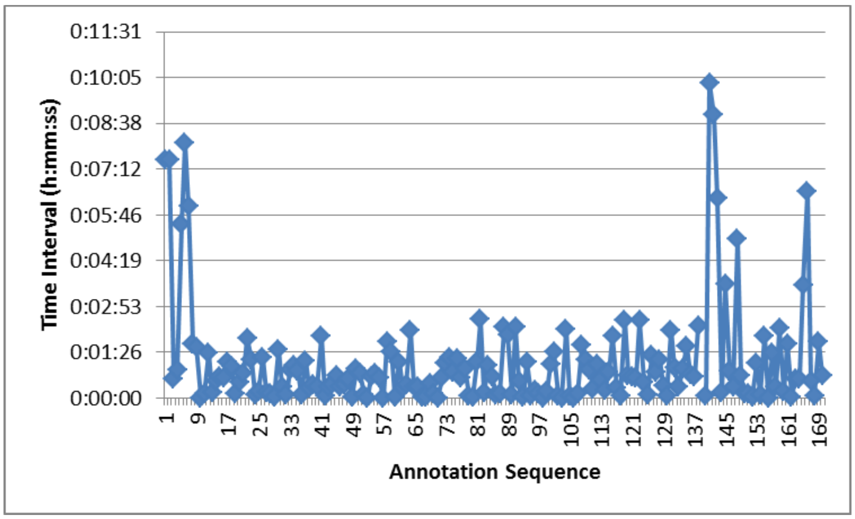


Table 2: Plot of time interval between logged annotations. Mean: 1.4

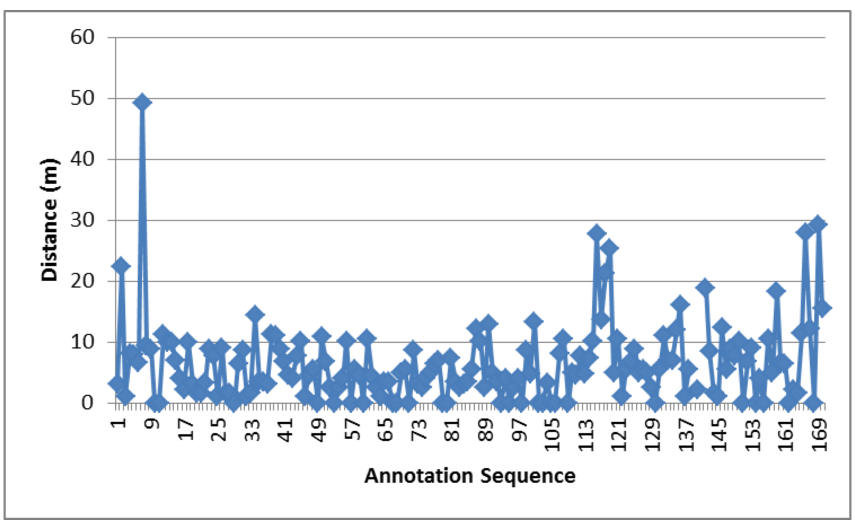


Table 3: Distance intervals of annotations, Median: 2.5, St. Dev: 3.3, Mean: 3.2

Although there is no minimum time interval that can be selected for ROV video annotations, three different time interval thresholds were selected for the purposes of this project: 1 minute, 2.5 minutes and 5 minutes. For post-cruise video access and discovery, a minimum of one annotation every 5 minutes is required. This requirement is based on the current OER practice of archiving video segments on OER video portal (https://www.nodc.noaa.gov/oer/video/) in 5 minutes chunks. If there is no associated annotation to each of archived video segment, the users will not be able to find the wanted video segments. For each threshold, the percentage of the dive that had no annotation within the selected threshold was calculated and graphed. The analysis of the time intervals can assist in expediting the completion assessment of annotations for each dive and the whole cruise. Depending on the need for completeness, one can use a specific interval threshold based on the goal of the dive and/or area surveyed. An example of assessing the completeness of annotations using the three thresholds (1, 2.5 and 5 minutes) is shown in Figure 4 for the twelve dives from the Mountains in The Deep (EX1705) expedition. The diversity of time intervals between annotations is revealing and helped summarize the status of annotation completeness.

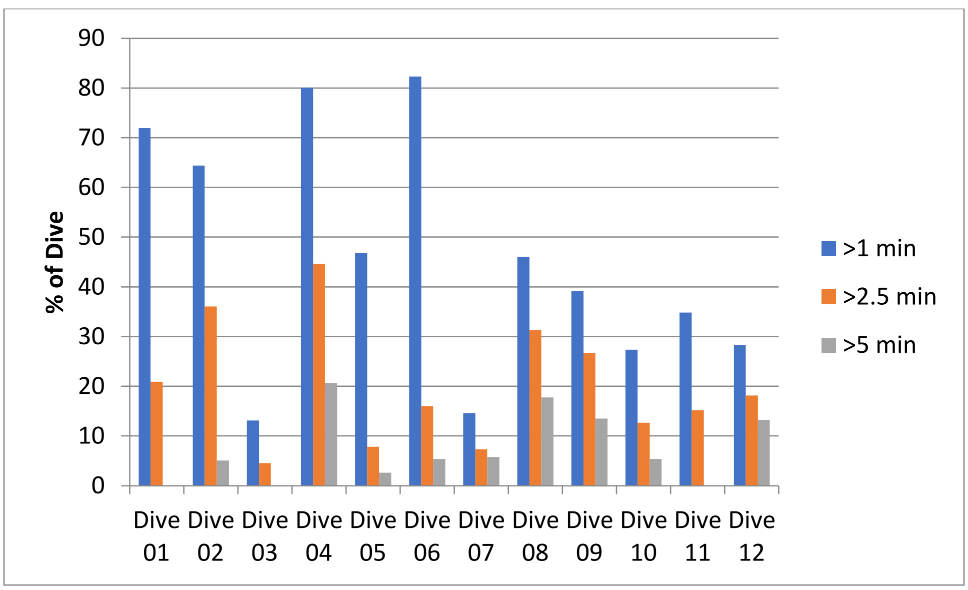


Table 4: Plot of dive percentage there are no annotations for time intervals

RESULTS

Video Play Back Assessment

The manual playback method for assessing annotation completeness and accuracy took about 5 hours to assess 1 hour of video. The time is inclusive of the sorting and editing of the event log annotations from chatroom dialog. A total of 192 annotations were retrieved from the event log–. The manual replaying of the video was only conducted for 2 hours of video from the EX 1307 dive. Analysis of the ROV video using the video analyzer program was conducted for 7 hours of video for the EX1307 dive. Reviewing 7 hours of ROV video (464 annotations) entailed about 22 hours of analysis. The time was also spent sorting the chat room dialog and from the biological and geological annotations. Video review using SeaTube took two to three hours to review one hour of video. This time is not inclusive of sorting chatroom dialog from annotations. SeaTube only stores annotations linked to the exact time in the video it was logged.

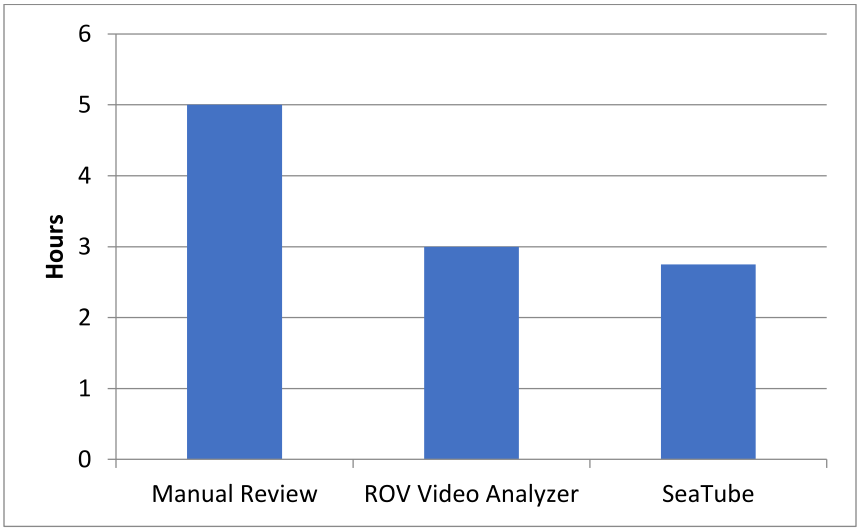


Table 5: Comparison of review time of one hours of video using one hours of video

Accuracy ~~Of~~ of Annotations

Assessing the accuracy of the annotations was done at a genus level. Organisms were reviewed by listening to the video audio. Any annotations that needed to be confirmed by experts were listed as not confirmed and hyperlinks were attached so experts could be reached for confirmation.

DISCUSSION

Summary ~~Of~~ of Video Play Back Assessment

The review of the three video playback methods highlighted the challenges of working with large ROV data sets and allowed the areas that need more work to be discovered. The manual playback method was the most labor intensive due to the multiple files that needed to be accessed. The removing of the chatroom dialog from the event log, where only 192 entries (out of 791 total entries) were found to be actual annotations, was labor intensive. Contributing to the man-hours needed to complete the review ~~was~~ were the manual calculations of the annotation time (referenced to the video start time), and the manual search of the ROV video.

While the ROV video analyzer, designed by OER, made locating the annotations in the video easier, it was still labor intensive due to the event log needing to be cleaned of the chat dialog and it also needed multiple files to be accessed individually to conduct the review.

Lastly, ONC's online program SeaTube was the most efficient of the playback methods. SeaTube's annotations only contain only biological and geological annotations and they are linked directly to the ROV video through ONC's SeaScribe. SeaScribe and SeaTube eliminate the need for more than one file to complete the review, which shortens the time needed to find annotation in the video. When reviewing annotations through SeaTube, the video launches to the time stamp of that entry. This feature also contributes to the annotation review being conducted more efficiently. One problem with SeaTube's annotations being time stamped is that it makes the review of missing annotations difficult. SeaTube video is logged in 5-minute segments and the reviewer has no way of seeing the whole video without segments.

The ability to review video annotations quickly and efficiently has become more important with the continued increase of video data that is collected by OER and other NOAA offices. The *Okeanos Explorer* is equipped with telepresence technology that links scientists around the globe together for deep-sea exploration. OER's ROV video data can be easily accessed by the public and interested scientists through SeaTube. Many NOAA offices use video data for assessing and documenting critical habitats and assessing fish stocks. The use of online annotation programs such as SeaTube, organize ROV videos and link the videos to the key environmental data for the area that they were recorded. The review of annotations was expedited by the ability directly view the annotation in question. For the purposes of assessing quality of video annotations, improvements to SeaTube's video playback methods are needed to further expedite the review.

Development ~~Of~~ of Methodology To Assess Annotation Quality

The complete review of a whole video's annotations is prohibitively laborious, but it may be necessary if lacking initial logged annotations. OER prides itself in making the data collected during ROV dives easy to access and open to scientists~~'~~ post cruise, m~~. M~~aking annotations logged during expeditions extremely valuable for future scientific research. However, it is fully expected that this data is a baseline data set and not all the organisms will have been annotated. The data is a sufficient starting point for future scientific research. Additionally, if appropriate experts are not available during the ROV dives, field identifications will be annotated to the genus level. In this scenario, it is important for OER to set a baseline standard for the quality of annotations that are produced. On one spectrum of annotation quality, it can be argued that annotations need to be 100 % complete (i.e. all organisms observed have associated annotation by the respective experts). The achievement of this goal is not realistic for real-time annotations. Therefore, it is suggested that OER supplements real-time annotations with additional post-cruise annotation quality checks. Post-cruise annotation review can be achieved efficiently if initial annotations are logged at correct times (i.e. video observations and annotation time match). It is beneficial for annotation review if annotations are created at consistent spatially and temporally, and the organisms are described to at least genus level accuracy.

The creation of time intervals for annotations allow the video review to be focused on areas where there's larger time intervals (> 1, 2.5 or 5 minute). Larger time intervals can imply missed annotations and show where in the video annotation review is needed. For confirming a complete and accurate data set of annotations, one could conduct a spot check using time intervals and choosing a specific threshold period (1, 2.5 or 5-minute threshold). For this project, time intervals of the annotations and a plot of the time intervals were used as a guide for checking the completeness of the annotations. A time interval plot provides a visual guide to the times of the video that there may be missing annotations. When using the time intervals to direct a spot check of the completeness of the annotations, the hyperlinks attached to the annotations help expedite the review.

Accuracy ~~Of~~ of Annotations

The participating scientists have a wide range of expertise and participate from all over the world through telepresence technology. This dynamic group of scientists create a diverse and complex data set, making the accuracy virtually impossible to check for someone without the scientist's expertise. The process of checking the accuracy of annotations for deep-sea exploration ROV video data is possible, but only with the assistance of the scientists who participated in the dive in review or other specialists of deep-sea organisms. Without these specialists, annotation accuracy can be checked to the genus level at best.

To assess the accuracy of annotations, all annotations from EX1702 EX1703, and EX1705 were reviewed in SeaTube. The hyperlinks created for each annotation provide a quick way to reach out to the respective experts to solicit their input for annotations that need verification. These links can simply be copy and pasted and sent to the expert. Creating a quick simple way of confirming annotations.

Recommendations For OER To Improve The Quality Of Video Annotations

The need to improve video annotations for future scientific research is extremely important. Complete and accurate annotations provide valuable data to scientists for future research. The recommendations below are based on using the current program SeaScribe while being on the *Okeanos Explorer* during EX 1706.

For more complete and accurate annotations, the use of a designated shore or on-board annotation logger would improve the completeness of the online data. The logger should be a marine science or biology major and/or intern with interests in deep-sea organisms and exploration. To help ensure the logger can efficiently and accurately log annotations, calibrating them on the known species in the area would be beneficial. A base-line knowledge of deep-sea organisms and/or geology of the area of interest is beneficial, but not necessary if the logger is calibrated before each cruise. The designated logger that is in the control room or online, can listen to the science leads and view SeaScribe to observe what annotations need to be added during the dives. After the dive, the logger can then contact the science leads for any verifaication that may be needed, which helps to ensure annotations are complete and accurate.

Post-dive annotation review would be more efficient if the time of the entry on SeaScribe could be modified directly from SeaTube while analyzing. Currently, SeaTube allows modifications to the annotation description only. SeaTube also is split into 5 minute video increments, which makes the video review time consuming and confusing. Navigation of the video in review would be easier if the video was not segmented and still had the time stamps for each annotation in the video.

CONCLUSION

This project contributed to what? in two ways. The assessment of the video annotation review process showed video replay is a tedious task that takes a lot of man hours to complete. Additional tools, such as SeaTube, are needed to expedite annotation review. To manually review video annotations from the start to end takes about five times longer than the length of the video itself, but can be reduced to about three times as long by using tools like SeaTube. Having quality assurance and quality checking methods for video annotations is important for the use and reuse of this data in future environmental assessments and scientific research. The need to create an accurate database for video annotations is growing as deep-sea exploration using underwater cameras becomes more prevalent in our constantly changing environment. ROV facilitated exploration provides valuable ecological information for unknown deep-sea areas. During OER's ROV dives, telepresence has enabled scientists around the world to collaborate in real time to annotate biological and geological features that are being revealed for the first time. Without telepresence, OER would not have been able to execute the past deep-sea explorations as effectively. Annotations that document the marine life and natural resources in areas are the synthesis of new information gleaned from these ROV dives.

The growing deep-sea ROV video footage and telepresence capability has created a backlog of data that has become difficult to access and interpret. Without proper review and management of the data it can become lost and invaluable to scientists with minimum funding due to amount of man hours needed to conduct a review. The post-dive review of ROV footage and annotations is laborious and on average takes three times as longer than the length of the video to review accurately. With programs like ONC's SeaScribe and SeaTube, metadata collected during telepresence enabled ROV dives in unexplored areas can be efficiently recorded and stored for post-dive review.

Post-dive review is a crucial element to ensure future research can be developed from the initial data. In this project, three methods of video annotation review were analyzed, and methods of annotation review were developed. The method of spot checking video annotation, which was conducted by looking at large time intervals, proved to be the most time efficient and effective in ensuring the completeness of annotations for each dive. It was not possible during the project to check the accuracy of annotations without the assistance of the scientist who made the annotation or person with the same specialty. However, methods such as the hyperlinks were developed to make it as easy as clicking on a link to enable scientist to view a specific video frame and edit annotations. SeaScribe and SeaTube proved to be a key component to facilitate OER's goal of providing an initial baseline data set about chosen unexplored areas in the Pacific. The data collected by OER will help the efforts of multiple NOAA offices that are focused on protection and conservation of these invaluable natural resources.

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