The Power of Seeing: Experiences using video as a deep-sea engagement and education tool

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***Abstract*—This paper describes initiatives underway at Ocean Networks Canada (ONC) in using video data as a tool for public engagement and education: live video streams from cameras on the seafloor, citizen science using video data, audience participation in deep-sea expeditions, and K-12 engagement through the *Ocean Sense* program. Live and archived video attract the majority of user traffic on ONC's website and can be leveraged to direct the viewers to other content and messaging, enhancing their engagement with the deep-sea environment. Public interest in scientific discovery creates a user base for citizen science initiatives, while educational audiences can be connected to both realtime and asynchronous learning materials. The power of live connections is also harnessed during research expeditions, which can be extended from the ship and the seafloor directly into the classroom.**

I. Introduction

Cabled ocean observatories, which supply continuous power and Internet connectivity to subsea instruments from the coast to the deep sea, enable us to extend our reach into unexplored regions of the ocean. Sensors become our eyes and ears in this deep ocean world, allowing scientists and members of the public alike to have a virtual presence in an environment that is otherwise inaccessible for human study. Engaging and educating an online audience can be extremely challenging in today's content-rich digital environment; however, video remains a powerful tool for connecting people to new explorations and knowledge. In this paper, we report on experiences at Ocean Networks Canada (ONC) in using video data as a tool for public engagement and education. We describe four initiatives: live video streams from cameras on the seafloor, citizen science using video data, audience participation in deep-sea expeditions, and K-12 engagement through the *Ocean Sense* program.

In 2014, access to live underwater video streams accounted for over 75% of the visits to ONC's website. Average visit times on live video pages exceeded 1 minute, with some users spending more than 20 minutes per visit. Viewer engagement can result in new discoveries by amateur scientists watching from home. In one instance, a teenager living in the Ukraine recorded ONC's live stream as a female elephant seal consumed a hagfish at a depth of 894 metres. Such predation had never been witnessed by scientists previously. ONC produced a video documenting the discovery, which was shared via social and traditional media channels, eventually reaching an estimated audience of over 40 million people worldwide. The attraction of live video can be leveraged to direct the viewers to other content and messaging, enhancing their engagement with the deep-sea environment.

The public interest in scientific discovery can be further leveraged through citizen science initiatives. The *Digital Fishers* portal provides a platform for members of the public to assist scientists in analyzing and annotating video data [1]. Campaigns, focused on a specific research question, are launched for a limited amount of time during which viewer participation is solicited. Repeat users and a growing user base indicate the potential for this type of tool.

The power of live connections is also harnessed during research expeditions. The idea of at-sea telepresence for public engagement was pioneered over 30 years ago [2]. Since then, technologies have advanced significantly with better two-way video communication tools and improved satellite connections at sea [3]. Streaming live video and audio to a public website allows viewers to take part in off-shore research expeditions. The experience is made more relevant for teachers and students via live connections between the classroom and the ship. Live connections are enhanced through pre-produced video content and daily "at-sea" updates, which give context and add value to the streaming video.

For scientific research on deep-sea biology, cameras provide a platform for conducting non-invasive research on biological diversity and animal behaviour [4]. The *Ocean Sense* program, launched in Fall 2014, introduces middle school and high school students to research methods in biology and oceanography using instrument technology, including cameras. Each lesson is aligned to specific learning objectives in the provincial/territorial curricula of British Columbia, Alberta, and Nunavut, Canada. We anticipate that a network of schools will develop, each sharing their discoveries and collaborating on projects utilizing the data from ocean sensors.

By using a multifaceted approach supported by a combination of live streaming video and video recordings, ONC has been able to reach and retain a broad audience. Due to the continuous nature of cabled observatory data, audience engagement is not limited by at-sea expedition schedules or timezones. Maintaining a continuously updated web-presence with a rich variety of digital video content supports a broad range of engagement from children to scientists around the world.

In the remainder of this paper, we summarize each of these deep-sea video applications and report on their utility as public engagement and education tools.

II. Live Video Streams

A. Camera Locations

Video cameras are an important component of ONC's cabled ocean observatory instrumentation. Streaming video systems have been installed at 10 underwater sites (see Fig. 1), with an additional 3 cameras providing streaming video from shore. The cameras described below are located on the NEPTUNE and VENUS observatories off the west coast of British Columbia, and in Cambridge Bay, Nunavut, in the Canadian Arctic, and on Canada's east coast, at the Bay of Fundy. Underwater cameras offer a unique vantage point for viewing a diverse range of environments including:

- Folger Passage: a daylighted reef ecosystem in a coastal rockfish conservation area
- Saanich Inlet: an hypoxic zone of a coastal fjord
- Strait of Georgia: a busy shipping channel
- Barkley Canyon (Shelf/Slope): a highly productive ecosystem on the continental shelf and slope
- Barkley Canyon (Hydrates): an area with gas hydrate outcrops
- Endeavour: an active hydrothermal venting area with tubeworm colonies
- Cambridge Bay: a shallow water bay beneath seasonal sea ice in the high Arctic
- Bay of Fundy: a bay in Atlantic Canada that experiences the world's greatest tidal ranges

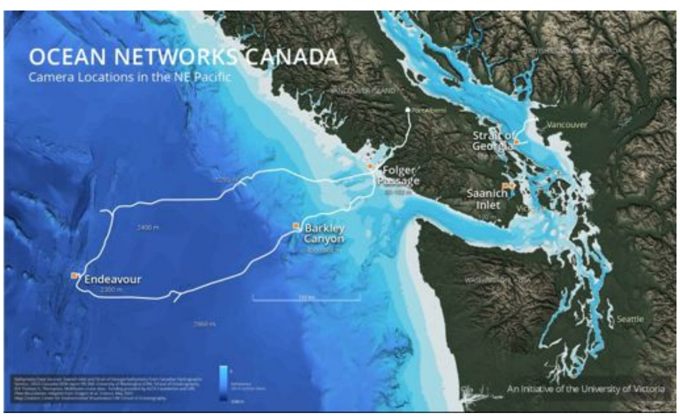

Fig. 1. Map showing locations of past and present Ocean Networks Canada underwater cameras (indicated on the map by orange boxes) on Canada's West Coast, in the northeast Pacific, as of Summer 2015. Additional camera installations in the Arctic and east coast not depicted.

B. Video Demand

These live video streams provide remote access to the seafloor, not only for researchers conducting experiments, but also for classrooms and the general public.

Live video represents the "800 lb gorilla" for ONC's Internet presence. In 2014, 76% of total web traffic was directed to 10 pages offering live streaming underwater video from ONC's array of seafloor cameras, across all ONC's webpages. Aside from one near-surface camera, all live feeds are intermittent; camera lights illuminate on an automated schedule, revealing the seafloor environment for several minutes at a time at regular intervals. (This video sampling scheme minimizes the impacts of light pollution on deep-sea habitats, which are normally shrouded in darkness.) Despite the preponderance of "dark video" during the remainder of each feed's 24-hour cycle, these pages remain more popular, by far, than any other section of the website (see Fig. 2).

	Ranked percentage of Traffic to Top 15 Web Pages, 2014	Pageviews
1.	Live Video | Ocean Networks Canada	26.59%
2.	Barkley Canyon Axis Camera | Ocean Networks Canada	9.82%
3.	Barkley Upper Slope Camera | Ocean Networks Canada	7.07%
4.	Strait of Georgia Forensics Camera | Ocean Networks Canada	6.99%
5.	Barkley Pod 3 Camera | Ocean Networks Canada	6.76%
6.	Folger Pinnacle ReefCam | Ocean Networks Canada	6.39%
7.	Tempo-mini Vent Camera | Ocean Networks Canada	5.51%
8.	Wally Crawler Cam at Barkley Canyon | Ocean Networks Canada	5.50%
9.	| Ocean Networks Canada	4.89%
10.	Ocean Networks Canada	3.53%
11.	Barkley Canyon Axis, Pod 3, Barkley Upper Slope Lights On | Ocean Networks Canada	0.90%
12.	Images | Ocean Networks Canada	0.83%
13.	Jobs & Opportunities | Ocean Networks Canada	0.61%
14.	About Us | Ocean Networks Canada	0.56%
15.	Tempo-mini Lights On | Ocean Networks Canada	0.50%

Fig. 2. Ranked list of the most visited 15 pages on ONC's public website, with percentages of total pageviews for each page, Jan–Dec 2014. Ten of the top 15 pages (highlighted) offer live streaming underwater video, and accounted for 76% of all pageviews. In contrast, the website home page garnered 8.4% of total traffic. Data collected and analysed using Google Analytics.

C. Enhanced Engagement

In addition to attracting more traffic, video enhances user engagement with the website. In 2014, visitors who viewed videos on the ONC website had 28% longer session durations (5:09 minutes compared to an average of 4:01), viewed 27% more pages (5.62 compared to an average of 4.49), and were less inclined to "bounce" from the website. (A page "bounce" is defined as a site exit from the entrance page with no clicks on that page.) Figure 3 illustrates this engagement, with greater percentages of longer-duration visits attributed to website visitors who watched video during their visit.

D. Audience-Specific Displays

Live video streams are provided in two interfaces, tailored to the needs of different audiences. The majority of access occurs via ONC's public website, where a set of pages allows users to switch between different live feeds, read background information on individual cameras, and check the time when camera lights will next be illuminated (see Fig. 4). An interactive camera-control interface is also provided for researchers. Here, they can control camera pan, zoom and focus, adjust light brightness, and program series of automated camera presets and observation routines (see Fig. 5).

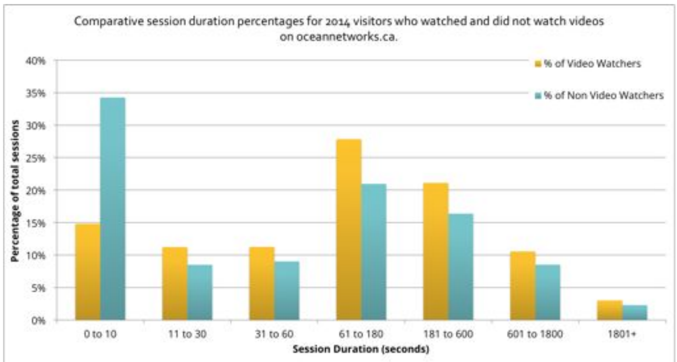

Fig. 3. Comparative percentages of session duration segments for website visitors who watched video (gold) and those who did not (teal), 2014. Among video viewers, percentages were greater for longer duration visits, while a much larger percentage of short visits (0 to 10 seconds) were made by people who did not watch video. Data collected and analysed using Google Analytics.

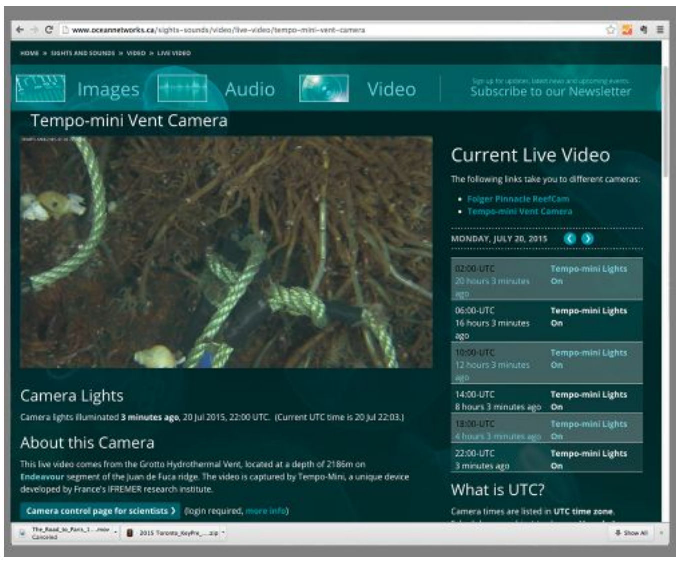

Fig. 4. Live streaming video interface intended for a general audience.

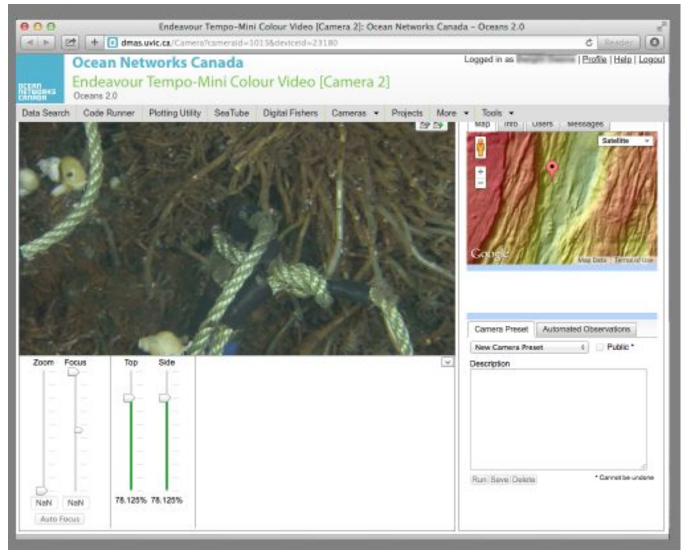

Fig. 5. Interactive camera control interface available to authorized researchers.

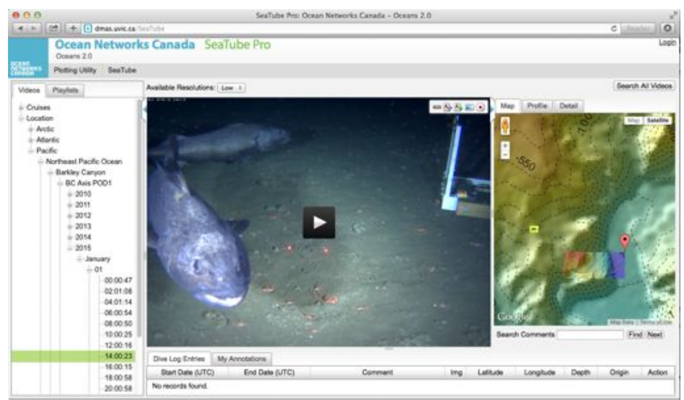

Fig. 6. ONC's *SeaTube Pro* user interface in action. This tool provides play-on-demand video access to ONC's archives of video recordings from both fixed cameras (shown in this example) and remotely operated vehicle footage.

E. *Video Archives*

All of ONC's live video streams are also recorded, transcoded and saved to a large, ever-expanding video archive, which provides free, on-demand streaming access to view and download any recorded segment from any camera. As of July 2015, the archive contained 77 TB of video data.

ONC's scientific video viewer, called *SeaTube Pro*, allows users to browse the full library of clips recorded by fixed cameras at the seafloor as well as full-length recordings from remotely operated vehicle dives performed during installation and maintenance expeditions (see Fig. 6).

F. *Time-lapse Movies*

Twenty-four-hour time-lapse movies are generated automatically every day from two of ONC's shore-based video cameras, located in Cambridge Bay, Nunavut and the Bay of Fundy. These condensed snapshots of the previous day are provided as play-on-demand clips in the public website, and are used both for outreach and research purposes. Time-lapse clips from the high Arctic camera, in particular, have helped scientists study the timing of the ice freeze/thaw cycle, in the context of interactions with other measured seawater properties (see Fig. 7).

III. Citizen Science Using Video Data

ONC has recorded thousands of hours of video, both during installation dives and from underwater cameras installed across the subsea network. This video needs to be catalogued, but software has not yet become sophisticated enough to automatically detect and identify a wide variety of pelagic and benthic fauna and features of the substrate. The video needs to be reviewed by human eyes, but a considerable time investment is required for scientists to review and annotate so much footage. In order to process this large volume of recorded

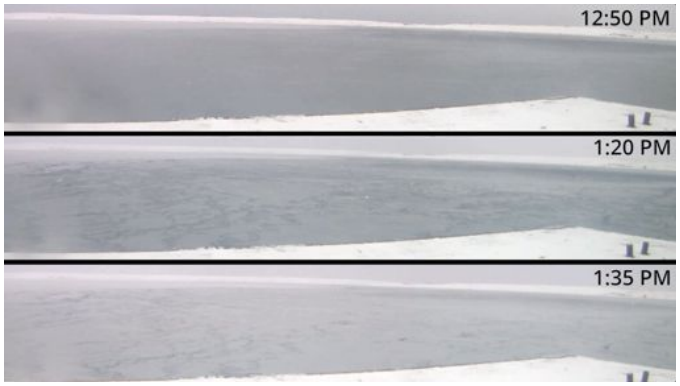

Fig. 7. Still frames from time-lapse video taken at Cambridge Bay, Nunavut on 18 October 2012. The sequence illustrates the rate at which surface sea-ice freezes in the bay, and helps scientists compare changes in seafloor water properties with transformations at the sea surface.

video, ONC is leveraging its community of non-specialists or "citizen scientists" to assist with the analysis of these data.

A. Digital Fishers: Citizen Science in Action

Digital Fishers is an online crowd-sourcing ocean science observation game (see Fig. 8), which asks volunteers to help analyze deep-sea videos—60 seconds at a time. By participating in this gamified website, citizens help researchers gather data from the video clips, and unveil the mechanisms shaping the faunal communities inhabiting the deep.

As an example of one outcome from this application, *Digital Fishers* data from a region-specific citizen science campaign has been proposed for use to help manage the Endeavour Hydrothermal Vents Marine Protected Area. Previous campaigns have focused on gathering ground truth data for automated detection methods for identifying crabs and counting fish, among other scientific questions.

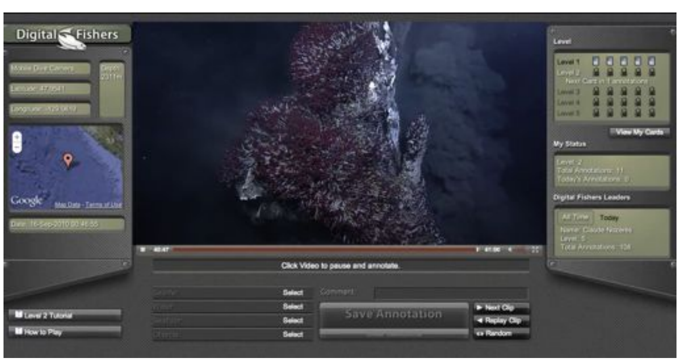

Fig. 8. *Digital Fishers.* A crowd-sourcing citizen science observation game.

B. Citizen Observations

In addition to using the *Digital Fishers* tool, viewers of the live cameras through the website also contribute scientifically relevant observations. When an event of interest is spotted by a citizen scientist watching the ONC live cameras, it can be quickly shared with ONC staff scientists through a comment field on the page. On occasion, these events lead to discoveries that inform the research being conducted at these study sites. These events are also turned into educational videos and shared on the ONC YouTube channel to encourage more members of the public to participate in the project. Observations by citizen scientists enhance the power of cabled observatories to crowdsource the review of vast amounts of video data in order to reveal previously unknown or suspected habits of deep-sea fauna.

1) Citizen Science Around the Globe: On 12 January 2013, 14-year-old citizen scientist Kirill Dudko was watching the live ONC video feed from this home in Donetsk, Ukraine. He was watching the Pod 4 camera in Barkley Canyon, at a depth of 894 metres, and noticed a hagfish moving around on the sediment below the camera. Suddenly, from the top of the video frame, the snout of a marine mammal appeared, and quickly ingested the hagfish. Dudko recognized that this creature was a mammal because of its nose and whiskers, but contacted ONC's scientists to confirm his suspicions.

Dudko recorded the clip and posted it on his YouTube channel, then sent ONC a message asking if they could help identify the creature that caught the hagfish. Through consultations with marine mammal experts in Canada and the US, the animal was identified to be a female northern elephant seal. This is ONC's first sighting of an elephant seal in seafloor footage, recorded by a camera situated 894 metres below the surface.

In order to share this story with the scientific community and the public, ONC produced a YouTube video [5], sharing the discovery and commending Dudko on his contribution to the scientific community. This video garnered over 900,000 views and the story was circulated internationally by numerous news agencies.

2) Crab Migration Caught on Camera: On 12 February 2015 one of ONC's seafloor observatory video cameras captured a natural phenomenon at the Barkley Canyon POD 1 platform: hundreds of crabs crawling over the seabed amid strong currents, almost 1,000 metres below the surface (see Fig. 9).

One of ONC's citizen scientists witnessed this crab migration as it unfolded, in front of the live camera. Michael, a post-office worker from Minnesota, alerted ONC's science team via email and asked what might have caused this abundance of crabs.

Much of our knowledge of tanner crab movements and behaviours comes from analysis of crabs caught in trap and trawl surveys at different depths and at different times of year. Direct observations of these crabs and other deep-sea species are rare. Recent scientific papers published by the ONC research community (such as [4]) describe periods in Barkley Canyon when crabs are more abundant, and even dominate the rest of the fauna. However, ONC scientists had never previously witnessed such extremely high numbers of one particular species: the grooved tanner crab, or *Chionoecetes tanneri*.

Engaging the citizen scientist community with long-term video monitoring from the ONC cabled observatories provides ocean scientists with a powerful new tool to study the movements of species as they migrate through submarine canyons. Such information can inform biodiversity conservation and the sustainable management of deep-sea fisheries.

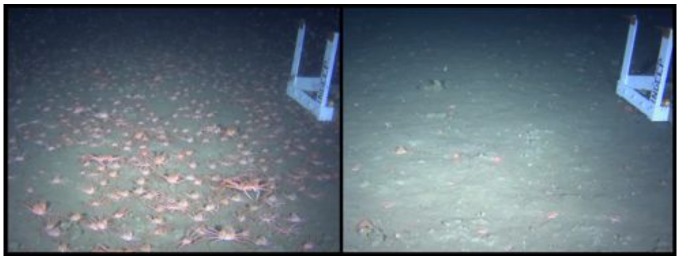

Fig. 9. ONC's Barkley Canyon observatory site, POD 1 platform, on 12 February 2015, 18:00:19 UTC, during the height of the crab migration (left) and, under more typical conditions on 10 February 2015 (right).

IV. Audience Participation in Deep-Sea Expeditions

In order to maintain and expand the observatories and instrumentation (including camera systems), ONC conducts at-sea maintenance expeditions each year. During these expeditions, instruments are recovered and deployed, samples are taken, deep-sea surveys are conducted, and ship-based sensor data are collected. The allure of participating in exploration and discovery is fascinating for kids and adults alike. The idea of seeing something that no human has ever seen before or of finding life in unexpected places excites our imagination. Ocean exploration, like space exploration, is challenging, dangerous (especially historically), requires specialized skill and equipment, and is very expensive. It is not uncommon for a modern research expedition to cost on the order of $100,000 per day, when crew, remotely operated vehicle costs, and fuel are factored in.

For these reasons, both now and in the past, the privilege of participating in ship-based exploration has been limited to "the few," rather than "the many." Changes in exploration vessels themselves have enabled increased participation in scientific discovery. Although scientists ("naturalists") were often aboard 18th century missions, it was not until the 19th century that laboratory space was incorporated on vessels, giving rise to at-sea oceanographic research methods [6]. Now, most commonly, data are collected at sea but analysed on shore, both during and after the expedition. Broadband satellite Internet connectivity has now become instrumental in allowing onshore participation in at-sea operations. Advances in communication technology have enabled scientists, educators, and members of the public on shore to go from being recipients of news from the "elite" on board to being active participants in realtime discovery and exploration. Furthermore, participation is not geographically or economically limited—we are now in an era where anyone with an Internet connection can take part. Live video is critical to supporting this participation.

A. Innovations in Vessel Communication

Modern at-sea telepresence emerged in the mid-1980's when submersible technology began to support reliable realtime video links with the deep-sea. The eerie video of the RMS *Titanic* discovery engaged kids and adults around the world [2]. Robert Ballard's early innovations in telepresence technology, notably the vision for the Argo submersible which enabled deep-sea video to be seen live on ship and the establishment of the JASON Foundation for Education, which brought deep-sea discoveries to students, were instrumental in establishing new standards for participatory ocean exploration [7]. In the mid-2000's, the National Oceanic and Atmospheric Administration's (NOAA's) acquisition and retrofit of the R/V *Okeanos Explorer* as a dedicated satellite-based education and public outreach platform represented a further acknowledgement of the impact of realtime connection to ocean exploration. Not only does the technology enable onshore outreach and education initiatives to take place, but furthermore, with video and data streaming to shore, the scientific aspects themselves can be managed virtually by scientists working from command centers on land [8], [9]. The R/V *Nautilus* [3] and the R/V *Falkor* [10] are two other examples of active research and exploration vessels using this model.

ONC does not own and operate a dedicated research vessel, but rather, expeditions are conducted with multiple different suitable vessels and remotely operated vehicle (ROV) platforms. In order to support an ongoing at-sea telepresence program, ONC has acquired a broadband satellite antenna, a transferable intercom system for audio connection, and a video transmission studio. ONC has also developed an in-house logging system, *SeaScribe* [11], which permits realtime observations to be logged simultaneously onboard and ashore.

B. Wiring the Abyss Web Portal

Live video and updates, including photos, video highlights, and blog posts, are made publicly available through the *Wiring the Abyss* web portal during expeditions. The audience for the website includes teachers and students, members of the public, and scientists. Live video from all remotely operated vehicle dives is broadcast from the ship to the website along with dive logs, dive plans, and ROV telemetry and data. This live connection supports participation and monitoring of operations by scientists on shore. Live connections are enhanced through pre-produced video content and daily "at-sea" updates from the chief scientist and other crew, which give context and add value to the streaming video. Social media engagement complements the web content by providing two-way interactions with viewers. Since the launch of *Wiring the Abyss* in 2012, visitors from over 100 countries have tuned in to live at-sea expeditions.

C. Ship2Shore Program

Launched in the 2012 field season, the *Ship2Shore* program connects educators and classrooms with at-sea operations. The program includes onboard participation of educators in research expeditions, live video conferencing with classrooms and follow-up activities and opportunities on shore.

When vessel logistics permit, ONC offers the opportunity for "Marine Educators" to participate in at-sea expeditions, either as day passengers for near-shore operations, or for several weeks in off-shore operations. The educator's primary responsibility is for communicating with audiences on shore via video updates, blog posts, photos, and live presentations (Skype or video conferencing) in classrooms and museums (see Fig. 10). In addition, educators are also encouraged to "get their hands wet" by participating in technology deployments, logging ROV operations, and collecting scientific data. Taking part in an expedition is a hands-on opportunity which provides the educator with experience and knowledge which can be incorporated into classroom lessons after the expedition, thus reaching a large number of students beyond the duration of the expedition.

Fig. 10. Marine Educator Scott Doehler (Brentwood College School, Mill Bay, BC) communicates with shore from the R/V *Thompson* using portable video-conferencing technology.

D. *Beyond the Field Season: Follow-up*

Due to weather conditions in the Northeast Pacific, the field season for ONC is limited to the warm season for offshore expeditions. The connection of at-sea work to other means of engagement throughout the year is therefore essential. The excitement of live participation and live-video links is extended through the other opportunities for video engagement described in this paper. An at-sea expedition, while exciting during its duration, cannot alone provide the continuous, on-going connection to the deep-sea environment that cabled observatory technology enables.

V. K-12 Engagement through the Ocean Sense Program

A. *Canadians as a Coastal People*

Canada boasts the longest coastline of any country in the world (202,080 km, [12]), but one of the lowest population densities: an average of 3.3 people per square kilometre [13]. Between 1986-2001, Canada's total population grew at a rate of 1.24%/year while its coastal populations—defined as people living within 20 km of a coastline of the Atlantic, Arctic, or Pacific oceans, or the Great Lakes—grew at a rate of 1.32%/year [14]. By 2001, 38.3% of the Canadian population (11.5 million people) lived within 20 km of a coastline, with the growth rate of these coastal populations predicted to increase to 2.24%/year by 2015 [14].

With a recognition of the importance of water's critical role in Canada's environment and economy (e.g., [15], [16], [17]), the increasing use of and impacts to the ocean from growing global and coastal populations [18]–[22], and the increasing volume and ease of public access to data (e.g., [23], [1]) and news on ocean health and marine science research (e.g., [24], [25], [26]), comes a need for "ocean literate" [27] citizens.

B. *The Ocean Literacy Imperative*

Studies of citizens in the United States [28], [29], Europe [30], [31], New Zealand [32], and Canada [33] indicate a significant knowledge gap with respect to marine science and ocean health. Experiences of educators, such as those recounted by Yerrick et al. [34], who have encountered students who live close to the ocean but have never visited it, are not uncommon. Education programs that encourage students to reflect on their own attitudes, values, and needs as ocean literate citizens can not only help close this knowledge gap but also translate learning into the behavioural changes necessary for engaged ocean stewards [35]–[37].

C. *The Role of Video in Ocean Literacy*

As portable web-connected devices increase in capability and ubiquity, today's students—termed "digital natives" by [38], [39]—and many educators inhabit a world increasingly saturated with digital images and video [40], [41]. Recognizing the ability of video to elicit powerful emotional and cognitive responses [42] and communicate complex ideas [40], educators have been making use of film in classrooms for many years. However, digital video offers the additional advantages of being readily accessible, editable, streamable, and sharable, and may be created on personal computers and mobile devices, often with free or inexpensive software, providing each student unparalleled opportunities for creativity and self-directed learning and exploration [43]–[45].

The ocean still holds many mysteries, even for those who have dedicated their careers to studying life and processes in the pelagic and benthic realms. For scientific research in the deep sea, underwater cameras provide a platform for conducting non-invasive research on biological diversity and animal behaviour [4], acting as our "eyes" in an environment we could not otherwise experience. By accessing deep-sea video, students leave "one world of experiences for another" [46], p. 260, experiencing a sense of anticipation and a memorable visual impression that simulates, inspires, and helps foster deeper learning [42].

D. Ocean Networks Canada's Use of Video to Educate

Launched in Fall 2014, *Ocean Sense: Local Observations, Global Connections* is an ONC educational program which introduces middle school and high school students to research methods in biology and oceanography using instrument technology, including cameras, installed on coastal "community observatories" in British Columbia and the Canadian Arctic. Each lesson is aligned to specific learning objectives in the provincial/territorial curricula of British Columbia, Alberta, and Nunavut, Canada.

Each lesson in the program incorporates data collected by a particular observatory sensor—e.g., chlorophyll-*a* concentration measured by a fluorometer—and introduces the students to a particular oceanographic concept: primary productivity, in this example. Data from other sensors—e.g., temperature, oxygen, solar radiation—are then used to deepen the students' understanding of the concept while encouraging them to explain how physical, chemical, and biological parameters are related in the ocean and how these relationships differ over time and by location.

In addition to visually augmenting each of the lessons, some lessons emphasize the use of underwater video footage. For instance, watching a time lapse of seasonal ice formation and breakup in the Arctic is an emotive and memorable complement to plotting ice profiler data for the same time period.

In one example, students view video from ONC observatory cameras at different depths and locations and report their observations with respect to environmental conditions (water clarity, substrate type), species diversity, and animal behaviour (see Fig. 11). Estimates can then be made of species richness and abundance, with the students developing hypotheses to explain why these metrics may change over time (diel, seasonal) and space (depth, latitude). Data on physical and chemical parameters from other co-located observatory sensors can then be used to help modify and strengthen student hypotheses as they work to understand connections between biotic and abiotic factors and develop their knowledge of ocean processes.

A version of this lesson was used at ONC's annual Ocean Science Symposium to introduce educators and grade 8–10 students from British Columbia and Nunavut to the applications of Ocean Networks Canada video in the classroom. Student feedback was very positive, including comments such as the following:

> "I really enjoyed seeing the bottom of the ocean and the creatures."
>
> "I enjoyed the camera [lesson] because I'm very interested in deep sea observation. We got to look at recordings from the deep sea cameras to identify species and ask science questions."
>
> "I enjoyed guessing what happened according to the video."
>
> "Hands-on and exciting."

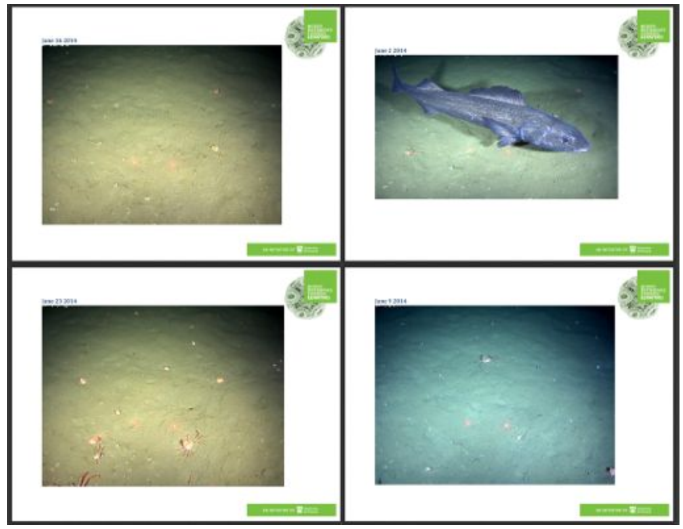

Fig. 11. Supplementary handout, containing example camera views from a seafloor camera used in the video-based lesson plan, "I see what you did there" (http://www.oceannetworks.ca/camera-lesson-i-see-what-you-did-there), tailored for secondary school general science audiences.

As we continue to develop the *Ocean Sense* program with input from educators, we hope to foster a growing network of schools, from British Columbia to the Arctic and beyond, each sharing their discoveries and collaborating on projects utilizing data from coastal and deep-sea sensors and cameras. As noted by Yerrick et al. [34], providing educators and students the tools and opportunities to explore, share, and build conversations around their video observations makes for a more meaningful learning experience than that afforded by reading a textbook.

ONC observatory video footage is being used in a similar way to teach classes in oceanography, marine biology and ecology, and environmental technology in universities and colleges across Canada and the United States. In one student project, biology students at the University of North Carolina at Wilmington used observatory video footage to investigate differences in the composition of communities colonizing wood falls and whale falls in the deep sea. In another, students investigated the effects of water temperature on sablefish swimming speed.

ONC also created *Ocean Alive!*, a magazine-style television project conceived as another tool to help close the ocean literacy gap. It features deep-sea video from the ONC cabled observatory network and interviews with oceanographers, marine biologists, and engineers.

In the pilot episode, researchers introduce the viewer to exotic black smokers rising from a mid-ocean ridge 300 kilometres off the British Columbia coast and 2,600 metres deep, describe how earthquakes and tsunamis impact Canada's western coastline, and explain how human-caused noise can affect many ocean animals—especially whales.

This mix of content presented by scientists of different genders, ages, and disciplines, helps students "see themselves in science" [47], an approach shown to enrich both the learning of science content [48], [49] and students' understanding of what a scientist is and science as a career pathway [49].

Footage shot for *Ocean Alive!* has also been incorporated into *Shouting Whales*, an online resource for educators of grades 6–8, developed jointly by ONC and Open School BC (see Fig. 12). The instructor's package, which includes a teaching guide, lesson plans, video interviews, and acoustical data, allows educators to easily deliver an introductory inquiry unit in marine science, specifically in the fields of marine biology and acoustics.

Fig. 12. Landing screen for the *Shouting Whales* online resource (http://openschool.bc.ca/shouting_whales/).

Through this unit, students investigate the science of sound as well as acoustical data collected by hydrophones on ONC's underwater observatories. Using these data and additional evidence, students are asked to think critically about how whales experience the marine soundscape. The unit focuses on various human-made sounds in the marine environment and asks students to hypothesize how marine mammals (specifically orcas) may function in this changing soundscape. The unit culminates with a student-led project in which participants are challenged to come up with an action plan to inform, elicit action, or inspire legislation about noise in the marine environment.

VI. Looking to the Future

Future science and observatory maintenance expeditions—such as the Fall 2015 voyage to the Endeavour Hydrothermal Vents Marine Protected Area—will continue to provide unique and rewarding educational and outreach opportunities for educators and students, via the *Ship2Shore* program, and for the public via the *Wiring the Abyss* web portal.

More digital underwater cameras will come online as ONC installs additional community observatories along the BC coast in 2015–2016, with an additional Arctic installation proposed for Churchill, MB. Providing insight to species abundance and distribution, animal behaviour, and other visual phenomena in the ocean, these cameras will enable new citizen science opportunities through *Digital Fishers* campaigns as well as an expansion of the *Ocean Sense* program.

Finally, as the archive of ONC observatory video footage continues to grow and a network of schools develops using the *Ocean Sense* program, we hope that educators will continue to find creative ways to incorporate digital video in their classrooms.

The ease of access to deep-sea footage and to software that allows for editing and reimagining video content opens up opportunities for students and teachers to annotate videos with their own observations, incorporate existing footage into new lessons and projects (such as class or student vlogs), and re-edit the footage to create their own science videos to share with, and "viducate" [50], peers in other schools.

Reimagining and creating video content, particularly if it includes footage of local relevance and connects science to everyday experiences, is a powerful approach to engage students in learning science [51], [52], while sharing content with other schools provides valuable opportunities to connect students from different cultural and linguistic backgrounds and oceanographic environments [34].

Video provides both a means to engage viewers and participants around the world in deep-sea exploration today, and holds promise for tomorrow as a powerful tool to encourage and excite the next generation of ocean scientists and explorers. While challenges remain, operating the world's largest regional-scale cabled observatory continues to provide ONC with valuable opportunities to explore different forms of deep-sea engagement and education through video.

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References

[1] "Data & Tools," 2015. [Online]. Available: http://www.oceannetworks.ca/information

[2] R. D. Ballard, "A Long Last Look at Titanic," *National Geographic*, pp. 698–727, 1986.

[3] K. Bell, "New Frontiers in Ocean Exploration: The E/V Nautilus 2014 Gulf of Mexico and Caribbean Field Season," *Oceanography*, vol. 28, no. 1, pp. 1–60, Mar. 2015.

[4] C. Doya, J. Aguzzi, M. Pardo, M. Matabos, J. B. Company, C. Costa, S. Mihaly, and M. Canals, "Diel behavioral rhythms in sablefish (Anoplopoma fimbria) and other benthic species, as recorded by the Deep-sea cabled observatories in Barkley canyon (NEPTUNE-Canada)," *Journal of Marine Systems*, vol. 130, pp. 69–78, Feb. 2014.

[5] "Teen Spots Hagfish-Slurping Elephant Seal," 2013. [Online]. Available: https://www.youtube.com/watch?v=nzMB8jqioV0

[6] A. Adler, "The Ship as Laboratory: Making Space for Field Science at Sea," *Journal of the History of Biology*, vol. 47, no. 3, pp. 333–362, Aug. 2014.

[7] "Robert Ballard," 2015. [Online]. Available: http://www.britannica.com/biography/Robert-Ballard-American-oceanographer

[8] C. Martinez and P. Keener-Chavis, "NOAA Ship Okeanos Explorer: Telepresence in the Service of Science, Education and Outreach," in *OCEANS 2006*. IEEE, Sep. 2006, pp. 1–5.
[9] J. Clarke, "Telepresence Technology Increases Accessibility of Deep-Sea Research," *Sea Technology*, vol. 53, no. 10, p. 81, 2012.
[10] V. Zykov, "Collaborative Oceanographic Research Opportunities with Schmidt Ocean Institute," in *American Geophysical Union, Fall Meeting 2014*. San Francisco: American Geophysical Union, 2014.
[11] R. Jenkyns, F. Gervais, and B. Pirenne, "SeaScribe : An Annotation Software for Remotely Operated Vehicle Dive Operations," in *Oceans - San Diego, 2013*, San Diego, CA, USA, 2013.
[12] Central Intelligence Agency, "Coastline: Country Comparison to the World," 2014. [Online]. Available: https://www.cia.gov/library/publications/the-world-factbook/fields/2060.html
[13] P. H. McMurry, M. F. Shepherd, and J. S. Vickery, *Particulate Matter Science for Policy Makers: A NARSTO Assessment*. Cambridge: Cambridge University Press, 2004.
[14] G. K. Manson, "On the coastal populations of Canada and the world," in *Proceedings of the 12th Canadian Coastal Conference*. Dartmouth, Nova Scotia: Natural Resources Canada, 2005.
[15] G. Ng and M. Felder, "Water and the Future of the Canadian Economy," The Involve Group, Toronto, Tech. Rep., 2010.
[16] S. J. Wilson, "Natural capital in BC's lower mainland: Valuing the benefits from nature," Pacific Parklands Foundation / David Suzuki Foundation, Vancouver, Tech. Rep.
[17] D. Henderson and N. Parker, "The Blue Economy: Risks and Opportunities in Addressing the Global Water Crisis," Blue Economy Initiative, Tech. Rep., 2012.
[18] M. Ateweberhan, D. A. Feary, S. Keshavmurthy, A. Chen, M. H. Schleyer, and C. R. C. Sheppard, "Climate change impacts on coral reefs: synergies with local effects, possibilities for acclimation, and management implications." *Marine pollution bulletin*, vol. 74, no. 2, pp. 526–39, Sep. 2013.
[19] J. Bijma, H.-O. Pörtner, C. Yesson, and A. D. Rogers, "Climate change and the oceans–what does the future hold?" *Marine pollution bulletin*, vol. 74, no. 2, pp. 495–505, Sep. 2013.
[20] K. M. Gjerde, D. Currie, K. Wowk, and K. Sack, "Ocean in peril: Reforming the management of global ocean living resources in areas beyond national jurisdiction," *Marine Pollution Bulletin*, vol. 74, no. 2, pp. 540–551, Sep. 2013.
[21] T. H. Hutchinson, B. P. Lyons, J. E. Thain, and R. J. Law, "Evaluating legacy contaminants and emerging chemicals in marine environments using adverse outcome pathways and biological effects-directed analysis." *Marine pollution bulletin*, vol. 74, no. 2, pp. 517–25, Sep. 2013.
[22] T. J. Pitcher and W. W. L. Cheung, "Fisheries: hope or despair?" *Marine pollution bulletin*, vol. 74, no. 2, pp. 506–16, Sep. 2013.
[23] "National Estuarine Research Reserve System," 2015. [Online]. Available: http://cdmo.baruch.sc.edu
[24] American Association for the Advancement of Science, "Marine Science Portal," 2015. [Online]. Available: http://www.eurekalert.org/marinescience/
[25] "Marine and aquatic sciences," 2015. [Online]. Available: http://www.plosone.org/browse/marine_and_aquatic_sciences
[26] "Oceanography News," 2015. [Online]. Available: http://www.sciencedaily.com/news/earth_climate/oceanography/
[27] "Ocean and Climate Literacy: Essential Principles and Fundamental Concepts," 2013. [Online]. Available: http://oceanservice.noaa.gov/education/literacy.html
[28] V. N. Spruill, "US public attitudes toward marine environmental issues," *Oceanography*, vol. 10, pp. 149–52, 1997.
[29] B. S. Steel, C. Smith, L. Opsommer, S. Curiel, and R. Warner-Steel, "Public ocean literacy in the United States," *Ocean & Coastal Management*, vol. 48, no. 2, pp. 97–114, Jan. 2005.
[30] J. Seys, N. Fockedey, E. Copejans, T. Hoeberigs, and J. Mees, "What do people want to know about the sea? Exploratory analysis into the information needs of the public at large with regard to knowledge of the sea and coast," Flanders Marine Institute (VLIZ), Ostend, Belgium, Tech. Rep., 2008.
[31] S. Fletcher, J. S. Potts, C. Heeps, and K. Pike, "Public awareness of marine environmental issues in the UK," *Marine Policy*, vol. 33, no. 2, pp. 370–375, Mar. 2009.
[32] T. D. Eddy, "One hundred-fold difference between perceived and actual levels of marine protection in New Zealand," *Marine Policy*, vol. 46, pp. 61–67, May 2014.
[33] H. Guest, H. K. Lotze, and D. Wallace, "Youth and the sea: Ocean literacy in Nova Scotia, Canada," *Marine Policy*, vol. 58, pp. 98–107, Aug. 2015.
[34] R. Yerrick, D. Ross, and P. Molebash, "Promoting Equity with Digital Video. In the Curriculum: Science," *Learning & Leading with Technology*, vol. 31, no. 4, pp. 16–19, 2004.
[35] M. Hawthorne and T. Alabaster, "Citizen 2000: development of a model of environmental citizenship," *Global Environmental Change*, vol. 9, no. 1, pp. 25–43, Apr. 1999.
[36] S. Fletcher and J. Potts, "Ocean Citizenship: An Emergent Geographical Concept," *Coastal Management*, vol. 35, no. 4, pp. 511–524, Sep. 2007.
[37] E. McKinley and S. Fletcher, "Individual responsibility for the oceans? An evaluation of marine citizenship by UK marine practitioners," *Ocean & Coastal Management*, vol. 53, no. 7, pp. 379–384, Jul. 2010.
[38] M. Prensky, "Digital Natives, Digital Immigrants Part 2: Do They Really Think Differently?" *On the Horizon*, vol. 9, no. 6, pp. 1–6, Nov. 2001.
[39] ——, *Don't bother me mom—I'm learning*. Minnesota, USA: Paragon House, 2006.
[40] M. Pasquali, "Video in science. Protocol videos: the implications for research and society," *EMBO reports*, vol. 8, no. 8, pp. 712–716, Aug. 2007.
[41] L. Gannes, "YouTube changes everything: The online video revolution," in *Television goes digital*, D. Gerbarag, Ed. New York, NY, USA: Springer, 2009.
[42] R. Berk, "Multimedia teaching with video clips: TV, movies, YouTube, and mtvU in the college classroom," *International Journal of Technology in Teaching and Learning*, vol. 5, no. 1, pp. 1–21, 2009.
[43] R. Cobcroft, S. Towers, J. Smith, and A. Bruns, "Mobile learning in review: Opportunities and challenges for learners, teachers, and institutions," in *Online Learning and Teaching (OLT) Conference 2006*. Brisbane: Queensland University of Technology, 2006.
[44] L. Bell and G. Bull, "Digital Video and Teaching," *Contemporary Issues in Technology and Teacher Education*, vol. 10, no. 1, pp. 1–6, 2010.
[45] S. Y. Ekanayake and J. Wishart, "Mobile phone images and video in science teaching and learning," *Learning, Media and Technology*, vol. 39, no. 2, pp. 229–249, Apr. 2014.
[46] C. Jewitt, "Multimodality and Literacy in School Classrooms," *Review of Research in Education*, vol. 32, no. 1, pp. 241–267, Feb. 2008.
[47] G. Aikenhead, G. Orpwood, and P. Fensham, "Scientific literacy for a knowledge society," in *Exploring the landscape of scientific literacy*, C. Linder, D. Ostman, P. Roberts, O. Wickman, G. Erickson, and A. MacKinnon, Eds. New York, NY, USA: Routledge, 2011, pp. 28–44.
[48] B. France and J. L. Bay, "Questions Students Ask: Bridging the gap between scientists and students in a research institute classroom," *International Journal of Science Education*, vol. 32, no. 2, pp. 173–194, Jan. 2010.
[49] J. Chen and B. Cowie, "Scientists talking to students through videos," *International Journal of Science and Mathematics Education*, vol. 12, no. 2, pp. 445–465, Apr. 2014.
[50] M. Gutierrez and A. Hottmann, "Video education media, education and lifelong learning: a European insight," Kulturring in Berlin, E.V., Berlin, Tech. Rep., 2011.
[51] D. Elster, "Biology in Context: teachers' professional development in learning communities," *Journal of Biological Education*, vol. 43, no. 2, pp. 53–61, Mar. 2009.
[52] P. Scott, E. Mortimer, and J. Ametller, "Pedagogical link-making: a fundamental aspect of teaching and learning scientific conceptual knowledge," *Studies in Science Education*, vol. 47, no. 1, pp. 3–36, Mar. 2011.