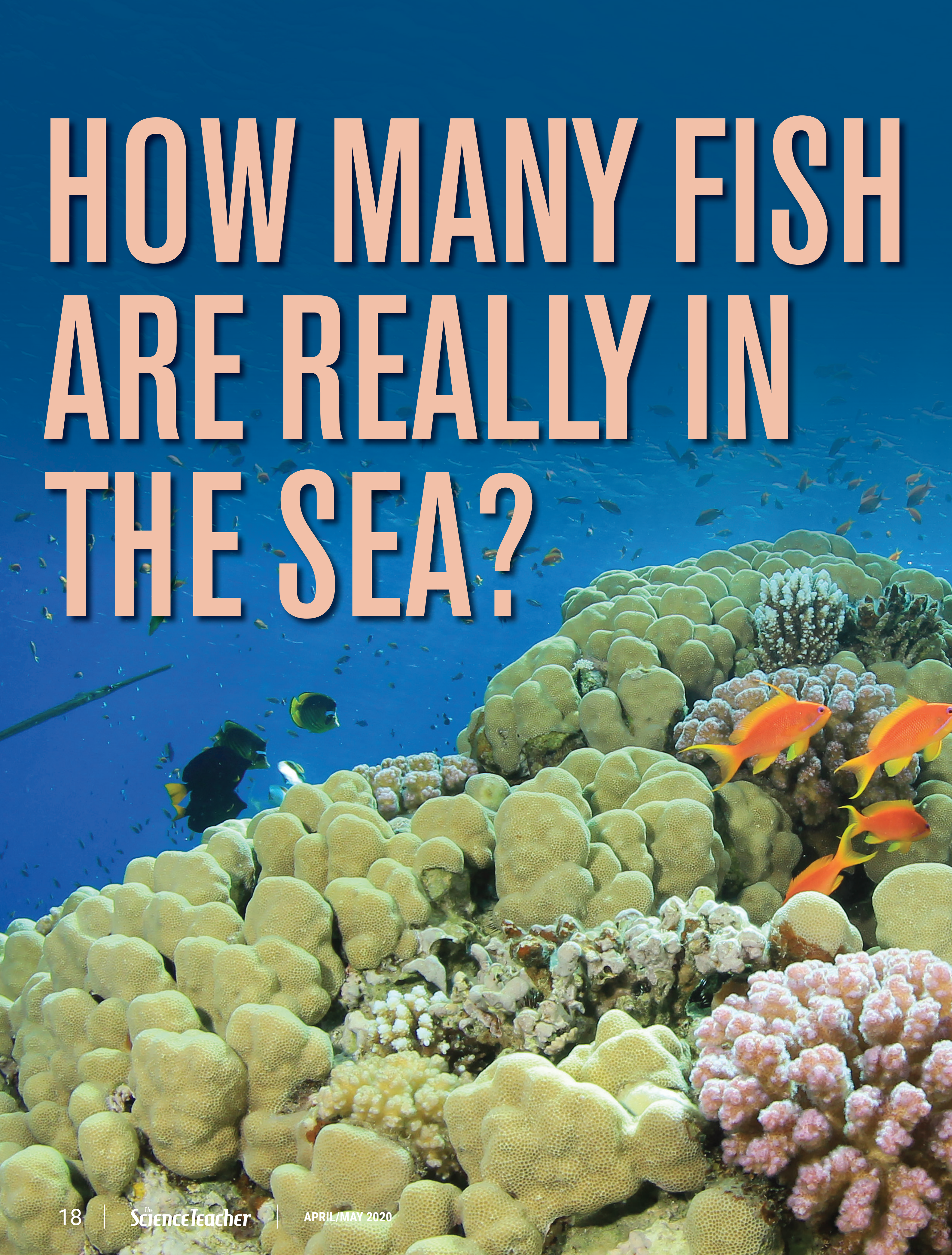
HOW MANY FISH ARE REALLY IN THE SEA?



Estimating reef fish abundance using trawl and underwater video data

SARAH GRASTY

Fisheries scientists make sure that fish populations (*fisheries*) are managed properly, neither over- or under-utilized, to maintain long-term economic and ecological stability. Scientists collect data and conduct surveys to determine fish populations, and then make recommendations about how many fish may be caught by commercial and recreational fishermen. In this lab, students tackle this type of applied science by becoming fisheries scientists who must collect, analyze, and interpret fish population data. They then make informed conclusions about the populations they have surveyed and analyzed to provide information needed for managers to make decisions about how to keep these populations healthy.

Over the last 30 years, the equipment used in fisheries assessments has evolved. Historically, extractive measures, such as traps, hook and line, and trawls were the most common. These methods can unfortunately result in lethal catches of non-target species (by-catch) and habitat damage (Chuenpagdee et al. 2003). Though these sampling methods do possess some unique advantages over non-extractive techniques (e.g., exact fish lengths, sex determination, disease presence, tissue samples), visual-based approaches are increasingly used to supplement fish population assessments.

Visual methods range from using scuba diving in shallow waters to relying on advanced technology that can reach deeper areas, survey longer, and collect data more frequently (Murphy and Jenkins 2010). Though there are many ways in which data can be collected for fisheries assessments, this activity will only focus on two: trawling and a towed video camera system called C-BASS (Figure 1; Lembke et al. 2017).

Students begin the lab by assessing reef fish populations in the offshore (20 to 200 m depth) region of the eastern Gulf of Mexico using data from a towed camera system, then work their way through analysis and interpretation by relying heavily on using a geographic information systems (GIS) program. They then use data from a trawl survey to make comparisons with the camera-based results. Completion of this lab will expose students to some of the practical skills necessary to complete scientific fieldwork, analyze data, and present findings.

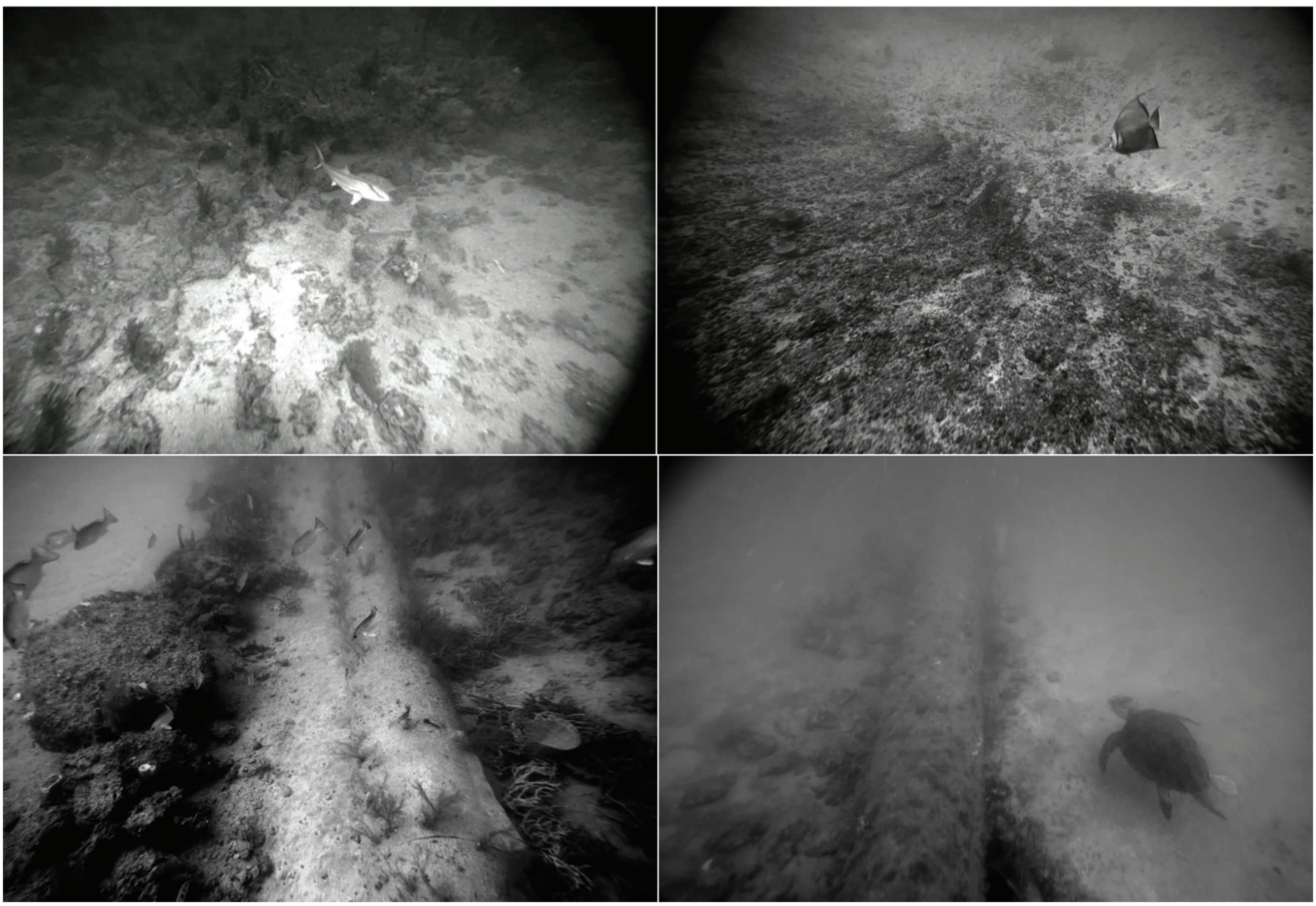
This activity relies heavily on active learning to ensure that students better understand the lab's concepts (Taraban et al. 2007). This work also facilitates critical thinking and higher-level problem solving (Gillies 2008), both of which are required to successfully complete the lab and subsequent assessment tasks. This activity can be used with grade levels 9–12 but is more suitable for 11th and 12th graders who may have more experience with GIS, spreadsheet work, and independent learning.

This activity is computer-intensive, so it works best when students work in pairs or small groups of no more than three to ensure everyone can contribute and stay involved. The estimated amount of time needed for this project is approximately four hours. There are natural break points to extend the lab over multiple days. The two-part assessment portion can be completed as homework or done in-class with another 1.5 hours of time. A concise overview of the concepts taught in this activity can be found in Figure 2.

FIGURE 1

Examples of imagery from the towed camera system, C-BASS.

Developed by scientists and engineers at the University of South Florida's College of Marine Science, this instrument is used to survey reef fish, sea turtle, and habitats in the eastern Gulf of Mexico in water depths of 20 to 200 m (60 to 600 ft.).



Background Information Video Series and Discussion (25–30 min)

To kick off the lab, show the class a series of YouTube videos and discuss as a group to make sure that all students understand the background information needed to execute the lab. All videos are linked on the Resources page of the lab website and are in the correct viewing order.

Fisheries management is an all-encompassing term and can mean a lot of different things depending on what the management needs are for a certain fishery. The first video in the series, *Fisheries Economics & Policy: Intro to Fisheries Management* (4 m 44 sec), provides students with information about what fisheries management is and why it is important.

The next video, *The ABCs of Stock Assessments* (4 m 13 sec), gives context on stock assessment science using a fishery in the Pacific Northwest. In this lab, the students focus on two stock assessment data collection approaches: trawl and camera-based data. The video *Fisheries Independent Monitoring: Reef Fish Video Survey* shows how scientists from the Florida Fish and Wildlife Research Institute collect camera-based data for fisheries assessments (2 m 11 sec).

The students will be working with video data from a system similar to that depicted in the video, but instead of stationary video they "use" a towed (mobile) video system. Further context on this type of instrument is provided in the next video, *C-SCAMP Overview* (4 m 42 sec). Finally, a video from Seafood Watch titled *How Seafood Is Caught: Bottom Trawling* (52 sec) shows students what a trawl is and how it catches fish.

After viewing the introductory videos, students should have a good understanding of what fisheries management is and how the data used by managers are collected. To check for comprehension, five to ten minutes are used for a short group discussion led by the teacher, and students fill in the flow chart (Figure 3) with information learned from the four videos.

MATERIALS

- Projector or TV connected to a computer with internet to show the introduction videos.
- Computers or Laptops with 64-bit processing, ≥ 8GB of RAM, internet, and ≥25 GB of storage space for each group; QGIS, SMPlayer (Windows Media or Quicktime would be sufficient but they have less functionality and control), and Microsoft Excel. Ensure that access to these computers is available for the duration of the activity.
- Zip file of lab data files. This contains all necessary GIS files, video data sets, and video analysis data sheet. All materials are located at *https://sites.google.com/view/howmanyfish* (Be sure that access to this website from your school's network is allowed.)
- Printed copies of the Lab Guide for each student.

Once this is completed, students are ready to perform the lab. Each group should be provided copies of the Lab Guide handout, which describes the scenario they will follow, as well as how to choose the location they want to sample.

Lab Activity

Part 1: Planning the Towed Video Camera Survey (20–30 min)

The first step in planning a towed camera survey is to determine where to deploy the system. This often requires a cost-benefit analysis between the high cost of research vessel time and how far away the places of interest are located. Researchers often plan fieldwork using a GIS program to view information about very specific locations.

FIGURE 2

Scaffolding for a concise summary of this lab and its concepts.

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Introduction and Overarching Issues

- Fish are important to humans for a variety of reasons, we therefore must ensure their populations remain healthy. This applies to a myriad of other natural resources as well.
- There are many ways to collect data to assess fish populations and they all have their own drawbacks and advantages.
- Managing natural resources is hard but managing something that exists underwater presents additional, unique challenges!
- The five introductory videos are used to go over this information. A short group discussion is then used to reinforce the base concepts needed to successfully complete and understand the lab.

Purpose of the Lab

- Students are tasked with becoming fisheries scientists. This requires starting with data collection and analysis and they must then work all the way through interpretation and drawing conclusions. A considerable number of practical skills are either learned or practiced through this lab, most significantly data analysis and the use of a Geographic Information System (GIS) to view and interpret data, both of which are used significantly in scientific work from environmental chemistry and biology to civil and environmental engineering.
- In addition to teaching students practical, applied scientific skills, this lab could also serve as a case study in natural resource management and science. Students should be able to see how complex it can be to manage and study natural resources, especially when dealing with organisms that live in a place that is hard to sample (i.e. in the water) and are affected by many other factors besides just fishing (e.g. habitat availability and quality, climate change, etc.). They then must realize that regardless of data quality and availability, management decisions must still be made based on the best available data and interpretations of those data by experts in that field otherwise we could risk losing access to some of our most important natural resources.

Expanding the Concepts

- Monitoring resources is necessary for proper management and the data for this can be obtained many ways. There is no one perfect survey method or instrument but innovations are constantly happening which improve methods or instruments. We can also sometimes combine datasets to address their respective drawbacks.
- Fisheries management has come to mean a lot more than just observing trends in population size. Scientists are now focusing more on ecosystem-based management where the whole system is taken into consideration and not just the single species that is under management.
    - Habitat influences distribution and it can also be used to help bolster populations if the right portions of it are protected from any kind of fishing activity.
    - Environmental factors, such as temperature, salinity, and dissolved oxygen content, are also important to consider as this can influence where fish are found.
    - Prey availability and water quality (e.g. toxin concentrations) will affect the health of fish in the area so these are also important to understand when managing a fishery with an ecosystem perspective.

Part 2: Video Data Analysis (1–1.5 hours)

The subsets of video that each group will analyze depend on the transects they choose. For example, if a group chooses transects 5, 8, 10, and 11, they would select those folders from the Master folder ("Video Data Sets"), then copy and paste them into the "Selected" folder (Lab Files\Video Datasets\Selected Transects) then work out of that directory.

In the video analysis spreadsheet, students completely fill out each row. Some of these inputs are important metadata about each video, such as transect number, the video number, and geo-referencing ID. This information is necessary to relate the data back to the GIS map and see what areas had which fish.

Though just the counts of fish can tell researchers some information about the populations being surveyed, it is much more useful when the data are standardized so that they can be compared with other data sets, in this case with trawl data. This means that both data sets will have numbers that are directly comparable, regardless of the equipment used for collection.

FIGURE 3

Flow chart to facilitate a short group discussion on fisheries management.

The black text in each box are the prompts for the students while the red, italicized information is a guide for the teacher or facilitator of the lab to make sure that the brainstorm session reinforces the key concepts needed for the lab.

Fisheries Management

What is a Fishery? *A portion of a fish species' population (also called the stock) that is caught for an economic purpose. Examples of this include shrimp caught in the Gulf of Mexico, as well as the salmon from the Pacific Northwest which you may see on a sushi menu or in your dog's commercial dog food ingredient list!*

Why is it important to properly manage fisheries? *Tragedy of the Commons; When there is open access, people fish as much as they can to outcompete others which can cause a stock to collapse. However, with proper management, it can help ensure that a fish stock can renew itself each year and thereby facilitate longevity for the people who want to keep fishing the population. Aside from economic reasons, making sure a fishery stays healthy helps to make sure the whole ecosystem it's a part of stays healthy!*

↓

Data Inputs

What are some ways in which data are collected for fisheries management? *Trawl nets, hook-and-line (fishing rods), long-lining (miles and miles of fishing line and hooks attached to buoys), SCUBA diver surveys, underwater cameras (stationary, on remotely operated vehicles, towed systems), and MANY MORE!*

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Assessment

Though knowing how many fish are in a fishery is important, what are some other pieces of information you think would be useful when determining the status and overall health of a population? *Habitat availability & quality, climate change impacts, prey availability, direct human impacts such as chemical spills, invasive species, frequency of illegal fishing, & MUCH MORE!*

Why is it important to use more than one source of data? *Almost no method of data collection is exempt from some type of drawback, but by combining datasets, you can try to alleviate those drawbacks from one method that may be well covered by another method. For example, a trawl cannot sample if there is habitat that has high vertical relief (such as a coral reef) because it would get snagged. However, a diver could potentially visually survey on the high-relief habitat while the trawl surveys in the sandy areas around that feature.*

Students will convert their counts into densities, or number of fish observed per unit area.

Part 3: Analyzing Catch Data from a Trawl Survey (20–30 min)

Students then do some analysis on the trawl data before they can make comparisons to the trends observed using the towed camera data set. To do this, they will need to carry out a very similar process to what they did for the video analysis by converting fish counts from the trawls to densities.

Part 4: Wrap-Up and Comparing the Data Sets (30–45 min)

Once the students finish the fish counts for their selected transects, the next step is to link those counts to where the video was recorded using the QGIS map for both the video-based and trawl-based data sets (Figure 4). This is known as *georeferencing*. This portion of the lab is somewhat complicated so students may need assistance, but if the Lab Guide is followed

FIGURE 4

Example of what the map will look like in QGIS as the students complete the lab.

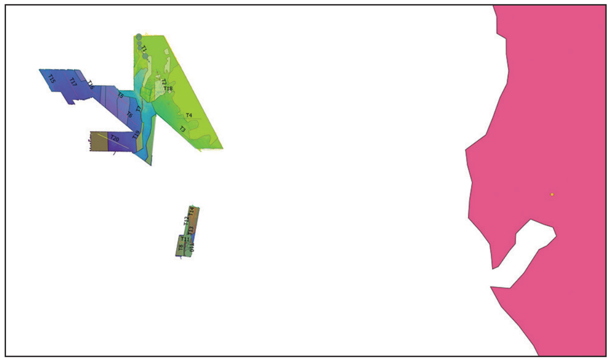

TABLE 1

Sample rubric for a group report where students are expected to produce a professional summary of their findings.

	CRITERIA				POINTS
	1	2	3	4	
Report Structure	Report has no structure and did not follow the example, formatting is poor or non-existent (i.e., no bolding, spacing, headings, etc. to indicate different portions of the report).	More than one section missing, example was somewhat followed, formatting is somewhat poor.	Mostly follows the example, no more than one section missing, formatting is adequate.	Follows example, all sections the report are included, formatting looks professional (i.e., bolding, spacing, tables, etc.) and resembles or matches the example.	
Writing	Poorly written and organized, unclear, hard to follow.	Most of the report is poorly written, some portions are acceptable.	Most of the report is adequately written and organized, reasonably clear, and easy to follow.	Well-written and organized, clear, easy to follow.	
Quality of Information	Very little content pertaining to the activity and its results are included.	Most pertinent information is included but significant detail is missing.	Report is fairly detailed but is missing some relevant information.	Report is extremely detailed and includes all relevant information to the objectives of the activity.	
Grammar and Spelling	Frequent grammar or spelling errors throughout the document.	Several grammar or spelling errors.	Few grammar or spelling errors.	No grammar or spelling errors.	
				TOTAL	/16

step-by-step, they will be able to display their data on the map and interpret how different habitats support varying numbers and species of fish. This allows students to visually interpret their findings; any patterns in the data should be easily observable, and the students will be able to determine if the densities estimated from trawl and video data are comparable or appear to be telling different "stories."

Assessment

When most scientific fieldwork ends, scientists must write a report. An example of such a report is linked on the Resources page (Example of C-BASS Cruise Report—see Lab Materials and Resources "On the Web"). As part of the assessment for this lesson, groups will perform a similar write-up summarizing the background introduced at the beginning of the lab, what they did, how they made their planning decisions, and their findings. This can be done as homework or additional in-class work, and each group needs to submit only one report.

To engage more critical thinking, each student then submits short-essay responses to the Wrap-Up Questions (see "On the Web"). These questions are designed to make students draw conclusions based on their data, versus just simply presenting the data from the report, just as a scientist would have to do when making recommendations to fisheries managers. Answers to these questions may vary widely and as such, the answers provided on the sample are meant only to check that students have grasped the main point of the question. The report and responses to the wrap-up questions can be evaluated using the rubrics in Tables 1 and 2 (see "On the Web").

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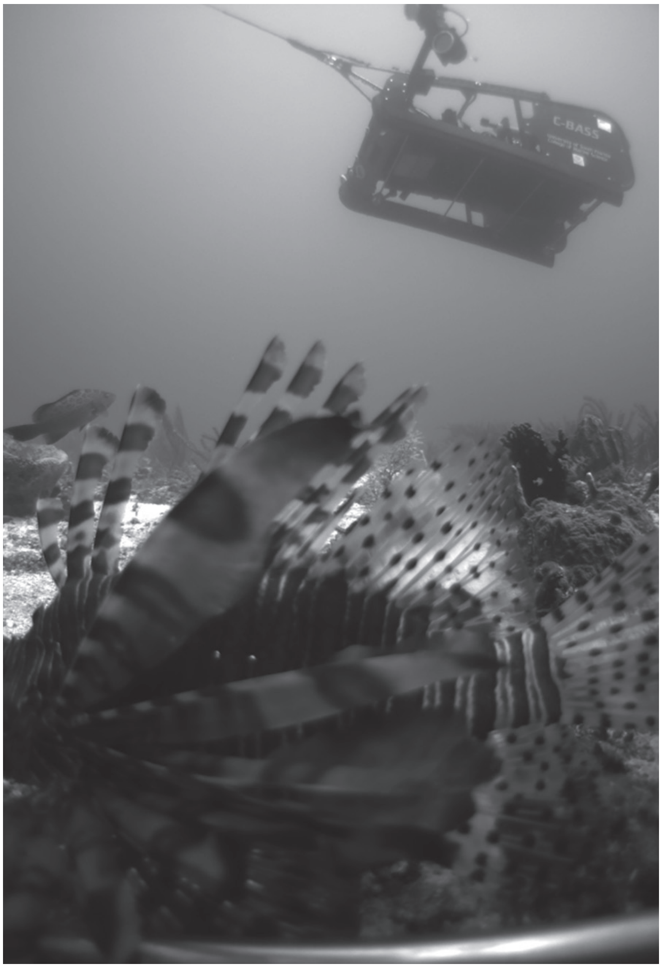
Teacher feedback

A modified version of this lab was completed with rising freshman high school students during The *Oceanography Camp for Girls*, a marine science summer camp at the University of South

TABLE 2

Sample rubric for short-essay questions that students complete individually and task them with elaborating on their decision-making processes and encourages higher-level critical thinking about what their findings mean in a natural resource management context.

	CRITERIA			SCORE
	1	2	3	
Completion and Writing Quality	None of the questions were answered with full, well-formed sentences and/or responses have several significant grammatical/spelling errors.	Most of the questions had full, well-written responses with few significant grammatical/spelling errors.	All questions had full, well-written responses with no significant grammatical/spelling errors.	
Development and Support	None of the information presented or provided via the resources were used to answer the questions.	Student pulls in some information from the activity and resources to supplement answers.	All questions had substantial information gleaned from the activity lab guide and other resources.	
Comprehension	Answers do not indicate that the concepts were well understood.	Answers indicate that student generally understands the concepts from the lesson.	Student clearly understands the real-world concepts demonstrated by the lesson and took time to use the resources to support their responses.	
			TOTAL	/ 9



Florida. Two 120-minute blocks of time were needed to complete the activity, which only focused on using the towed camera data. The students had few issues following the GIS tutorial despite none of them having previously used the software. There was some difficulty when trying to correctly identify the fish on the towed underwater video. This has been addressed by asking students to categorize fish into generalized groups (e.g., grouper, snapper) as opposed to specific species. This does not detract from the goals of the lab as the students will still be able to observe overall trends in fish presence among different habitat types.

Conclusion

This lab takes students through a simplified process of how fisheries scientists must integrate data from multiple sources to determine the status of fished populations. The tasks encourage critical thinking and problem solving while also teaching students basic geographic information system (GIS) skills. At the end of the activity, students use the data they collected and analyzed to observe fish trends over different habitat types, and they must draw conclusions about what the data are telling them so that they may make recommendations to fisheries managers. By the end of the activity, students should:

- Have a basic understanding of fisheries management and why it's important.
- Possess basic GIS skills and an understanding of why it's an important tool in science.
- Be able to explain the decision-making process for the conclusions they make. ■

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ON THE WEB

Lab materials and resources: *https://sites.google.com/view/howmanyfish*.

YouTube Videos:

Fisheries Economics & Policy: Intro to Fisheries Management: *https://www.youtube.com/watch?v=Z4AXnZOsrK8&t=193s*

The ABC's of Stock Assessments: *https://www.youtube.com/watch?v=3UbWMdpavUE&t=46s*

Fisheries Independent Monitoring: Reef Fish Video Survey: *https://www.youtube.com/watch?v=crBctx-NzOQ*

C-SCAMP Overview: *https://www.youtube.com/watch?v=W8dIAyzCXEw*

How Seafood Is Caught: Bottom Trawling: *https://www.youtube.com/watch?v=BcJFSl_YJHk*

Rubrics

Meat and Seafood Production & Consumption: *https://ourworldindata.org/meat-and-seafood-production-consumption*

Wrap-Up Questions: *https://www.nsta.org/highschool/connections.aspx*

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