

Identifying marine fish and estimating fish abundance using underwater community observatories

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Many undergraduate biology students are fascinated by the ocean, marine organisms and how these organisms interact with the environment yet have no access to the marine environment. In this laboratory we bring students from across the world the opportunity to learn about marine fishes from the Pacific Northwest by collecting data from 2019 in an underwater camera from one of Ocean Networks Canada's cabled observatories. In this hands-on activity, students learn to collect and annotate data from video clips and estimate fish abundance and relative abundance. Students learn to plot their data against temporal variables (month, season, and time of day) and compare how total fish abundance and species-specific fish abundance vary over time.

Keywords: Ecology, Community structure, Fish abundance, Underwater cameras

Introduction

Many biology undergraduates are highly interested in the marine environment, marine organisms and how organisms interact with each other and the environment despite not having access to the marine realm as many university campuses across the world are not on the coast. Technological advances such as underwater observatories equipped with multiple different sensors and underwater cameras such as those from Ocean Networks Canada allow students to explore the marine environment regardless of their geographical location.

Typically, ecology laboratories must cover multiple different concepts and thus are time limited to explore how community structure varies across temporal scales (e.g., from months to a year) or must use existing and sometimes outdated datasets to observe such trends. Moreover, analyzing such datasets does not allow students to collect their own data and explore different sampling techniques, a crucial skill needed for their careers.

In this lab we combine the technological advance offered by a coastal underwater camera from the Ocean Networks Canada networks (Moran 2022) with community ecology concepts. In this hands-on exercise students from multiple geographical regions can collect data from underwater videos, construct datasets and subsequently analyze them to explore how the abundance of fishes from the Pacific Northwest differs across different time scales.

A curated list of videos covering a year of observations and ensuring at least one fish sighting per five-minute clip has been created and can be found in Appendix 1. The exercise is designed to be covered in two three-hour lab sections. The first section is dedicated to data collection and data entry while the second section allows students to analyze the data and visually represent it.

The lab requires a computer and an internet browser. Initial setup is relatively easy and only requires that the instructor previously decides how to assign the videos to be observed by student or group and to create a master spread sheet, ideally in Google Sheets.

Student Outline

Objectives

- Extract data from underwater videos
- Identify fishes to species
- Calculate and analyze fish abundance data
- Explore fish abundance variation at different temporal scales

Introduction

In ecology a community is defined as a group of species that share habitats and interact either directly or indirectly. When studying communities, ecologists usually set imaginary spatial boundaries to study the community but can also use the term in a narrower way to specify a group of similar organisms sharing the same habitat such as a bird community or a fish community. Two of the most important and common metrics to understand communities are the number of species, also known as **species richness**, and the number of individuals of each species – **abundance**. Moreover, by knowing the total number of individuals from each sample you can calculate the percentage that each species contributes to the total number of individual – the **relative abundance** (Smith and Smith 2012).

Community structure (i.e., species composition and abundance) varies both spatially and temporally based on environmental conditions and species interactions. In the ocean, environmental conditions fluctuate at different spatial and temporal scales and therefore exert pressure on how communities are structured. For example, salinity in the open ocean is normally 33–35 PSU but can be as low as 15 PSU in river mouths. Water temperature is warmer in the tropics and consistently decreases at higher latitudes, from sub-tropical to temperate and polar regions. Locally, particularly in temperate and polar regions, environmental variables have yearly variations that shape community structure. For example, water temperature is warmer in the summer and colder in the winter. Daylight is shorter over the winter and increases through the spring into the summer which has a direct effect on primary productivity.

Like many other biological communities, fish communities are shaped based on environmental factors and the interaction between species and the structure can change at different spatial and temporal scales. In this lab you will explore how a fish community structure changes over a year using data from an underwater fixed camera from a cabled observatory.

Ocean Networks Canada (ONC) is a not-for-profit research facility that operates and maintains cabled observatories to monitor the ocean and inform decision making from community, governmental, and industrial perspectives. The observatories support a diverse array of instruments deployed on the seafloor that continuously collect data on multiple oceanographic parameters such as salinity, dissolved oxygen, temperature, turbidity, current speed and direction, and underwater video and audio. The data collected are transmitted to the University of Victoria's archives through fiber optic cable and are freely available to students, researchers, and teachers through the data portal (www.data.oceannetworks.ca), providing a treasure trove of scientific information about the sea around us.

ONC has two large observatories, VENUS and NEPTUNE, that cover a number of different strategic ecosystems. VENUS is located in the Salish Sea and has instruments in Saanich Inlet and the Strait of Georgia. Saanich Inlet has been continuously monitored since 2006. NEPTUNE's operation started in 2009 and is located off the west coast of Vancouver Island, extending 250 km offshore: from the coast across the continental shelf and into the deep sea (Moran 2022). In addition to these large observatories, ONC has partnered with communities along British Columbia's north coast and in the Arctic to deploy underwater community observatories with several instruments and sensors that collect data in an effort to complement their understanding of local waters and how these are changing over time (Figure 1).

With the advancement of underwater technologies such as underwater observatories, it is quite possible to be a marine biologist without setting foot on a boat or in the water. Large open-access databases and monitoring programs now enable marine scientists to conduct research remotely, sometimes in real time, from literally anywhere in the world (if they have speedy internet). Long-term monitoring sites are being established in much of the world's oceans. Long time-series of information on biotic and abiotic features are invaluable for understanding the mechanisms and consequences of our actions (e.g., climate change, overfishing) on the marine environment.



Figure 1. Map highlighting Ocean Networks Canada's Community Observatories along the British Columbia coast and the Arctic Archipelag (<https://www.oceannetworks.ca/>).

One of the most-used instruments in observatories is the underwater camera which is key for biological observations and has some advantages over other surveying methods such as fishing or underwater visual census. For many years, underwater cameras have been used to determine fish abundance and assemblage in different habitats (e.g., Perry et al. 2018). However, the observations were limited to the battery capacity of the device. By having limitless power and an internet connection to archive the recorded data, more observations can be recorded over time and thus a more robust monitoring program is achieved. This high frequency monitoring may have the potential to contribute to fish stock assessments and biodiversity monitoring (Aguzzi et al. 2020).

The Campbell River observatory is located at the north end of the Strait of Georgia on the east coast of Vancouver Island (Figure 2). This observatory, deployed in 2016, is equipped with a shore station that has a weather station and shore camera at the Campbell River Discovery Fishing Pier. The shore station is cabled to an underwater platform on the sea bottom, at 6–10 m depth just off the pier and contains several different instruments. These instruments track and record local water property measurements (e.g., chlorophyll, conductivity, salinity, dissolved oxygen, air and water temperature, turbidity, etc.), the underwater sound of whales and vessels, and livestream video from an underwater camera that records five-minute clips once every hour. In this lab you will collect fish data from ONC's Campbell River community observatory underwater camera from 2019.

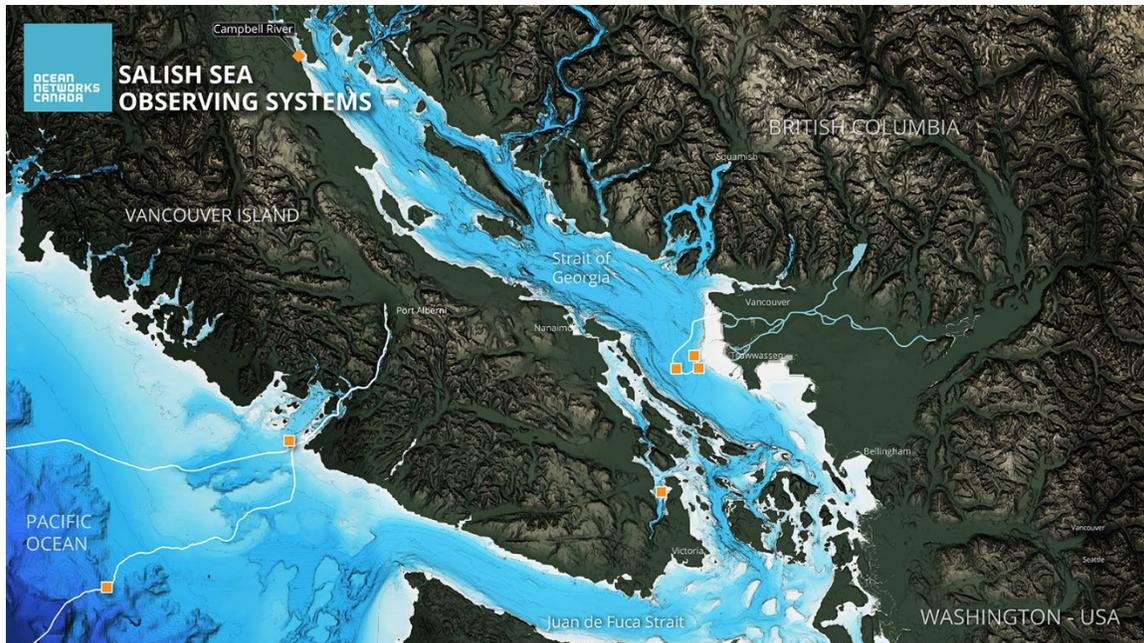


Figure 2. Map of the Strait of Georgia showing the location of the Campbell River Community observatory (<https://www.oceannetworks.ca/>)

Pre-lab questions

- Underwater cameras are a great tool for collecting data and monitoring marine life, but in the past alternative methods to collect data have been used successfully and continue to be predominantly used as only a small proportion of the ocean is monitored with advanced technology. In a few words describe how you would monitor fish populations in the absence of the current technology (hint: think in terms of both spatial extent and temporal resolution).
- As you can imagine both methods have some advantages and disadvantages relative to each other. Explain two advantages and disadvantages that each method has.
- In this lab you will calculate total fish abundance (for all fish combined) and abundance for each species and look at how this metric changes monthly, seasonally (winter, spring, summer, and fall) and with time of day (day and night). Describe how you think fish abundance will change over time for each of the temporal categories. Also, describe if you think that you will see the same, similar, or different patterns when looking at the species-specific abundance data.

Methods

Part A: Video data collection

In this lab you will work in pairs or groups of three depending on the number of computers available. Your instructor will assign each group several videos for you to watch either by streaming or downloading them.

How to watch the videos

The videos can either be streamed or downloaded through ONC's data portal, [Oceans 3.0](#). To stream the videos, go to SeaTube (<https://data.oceannetworks.ca/SeaTube>).

- On the left panel you will see a **Videos** tab with a long navigation tree. Scroll down until you find the **Location** branch. This is where all ONC's fixed camera location videos are found. Expand the Pacific branch by clicking (+) on **Pacific**.
- Click (+) on **Salish Sea** then click on **Discovery Passage** and **Campbell River Underwater Network**.
- Click on **2019** to expand the full year. All the months will become visible.
- Refer to Appendix A for the videos to be watched. For example, if you want to watch the first video (January 6 at 16:00 UTC) click on January and the 31 days of the month will become visible. By clicking on day 6 the time (in UTC) where footage was recorded becomes visible. Find time **16:00** and click on it. The video will start playing on the video panel on your browser.

To download a video and play it on video player software on your computer, go to www.data.oceannetworks.ca/DataSearch in ONC's data portal.

- As on SeaTube, there is a search tree on the left panel. Find the **Campbell River Underwater Network** by navigating the tree as explained above.
- Expand the tree and choose **Video Camera**. A new window will pop up with information about the camera. Click on the red button – **Select This Data Source**.
- You should now be in the **Data Product Selection** tab. There is a panel to customize dates on the left. Choose the correct year, month, and day in both **Date From** and **Date To**. In the time box, choose the time when the video starts (e.g., 16:00) and on the bottom box choose the end time (e.g., 16:10). Note that each clip is five minutes long but may run a few seconds past. As such, selecting ten minutes past the hour in the bottom box will ensure that you only download one full clip.

Recording data from each clip

Watch each clip carefully, although every clip has at least one fish in it, some fishes are easier to see than others, particularly flatfish which blend extremely well with the environment. Each time you see a fish or more than one fish at the same time pause the video, record the time within the clip when you saw the individual(s), and identify it to the lowest taxonomic level by following the fish ID guide in the Appendix. Note that sculpins are hard to identify to species so record them as **sculpin**. Once you have identified the fish, fill a table like the example provided in Table 1 **and following the coding of variables provided in Box 1**. By strictly following such codes everyone will have less cleaning to do once the full dataset is completed. For now, only fill the columns that do not need additional calculations.

Un-pause the video and continue watching. If a new fish enters the field of view and more than **10 seconds** have passed after the previous observation repeat the procedure above and record the observation in the table in a different row. Each fish observation must be in a different row even if they are in the same clip. For the purpose of this lab, we will assume that an individual entering the field of view after 10 seconds is a different individual, but will assume it is the same one if less than 10 seconds have passed and will not record it as a new observation.

Table 1. Example of how to complete the table for each observation. Note that each observation must go in one row.

Video	Date	Month	Season	day_night	time_start	Corr_time_start	time_of_obs	species	count
1	February 14, 2019	Feb	Winter	Night	10:00	2:00	1:32	Kelp greenling	1
1	February 14, 2019	Feb	Winter	Night	10:00	2:00	2:35	Lingcod	1
2	March 22, 2019	Mar	Spring	Night	01:00	5:00	3:33	Coper Rockfish	2
3	April 6, 2019	Apr	Spring	Day	18:00	10:00	0:57	Kelp greenling	3

Once you have watched all the videos you will enter your data to the master spreadsheet where all data will be available for subsequent analysis. But before uploading the data you will need to do some data selection and correction. The **time stamp** on all videos and environmental data is recorded as UTC (Coordinated Universal Time), the successor to Greenwich Meridian Time. The Campbell River observatory has an offset of -8: i.e., 8 hours behind UTC. This means that all times need to be corrected by subtracting 8 hours. This will be important when classifying times as day or night. Complete the missing columns and double check that all cells in the row are correct by following the instructions in Box 1.

Box 1 – Coding of variables	
Variable	Enter as
Video number	The video consecutive number given in Table 1 for each unique video
Date	MM/DD/YYYY
time_start	UTC time of start of video
corr_time_start	UTC time minus 8 hours
time_of_obs	Time of first sighting of a fish, in seconds since start of video
species	Common name. Use underscores if name has two words
Count	Number of individuals observed
Month	Month abbreviation. Jan, Feb, Mar..... etc.
day_night	Day (06:00–18:00 corrected time), night (18:00–06:00 corrected time)
season	Winter (21 Dec–19 March), spring (20 Mar–19 Jun), summer (20 Jun–21 Sept), fall (22 Sept–20 Dec)

Part B: Data Analysis

Once everyone has uploaded their data to the master spreadsheet, your instructor will create a copy that you will be able to manipulate. In this lab you will look at the relationship of fish abundance for all fishes together and by species with some temporal variables across one year such as month, season, and time of day.

While there are many different ways to calculate abundance and the relationship with some variables in a spreadsheet, we suggest you use pivot tables which will facilitate your calculations.

Total fish abundance

First you will focus on calculating fish abundance and relative abundance for all species together by month, season, and time of day.

In the copy of the Google Sheet use pivot tables to calculate the total number of fish by month, season, and time of day. After that calculate relative abundance and fill in the table.

Table 2. The number and relative abundance of fish observed by month

Month	Number of fish	Relative abundance
January		
February		
March		
April		
May		
July		
August		
September		
October		
November		
December		
Total		

Next, plot the relative abundance results in a barplot. Remember that the independent or explanatory variable goes in the x-axis and the dependent or response variable will define your y-axis. A good figure should have a figure legend and axes must be clearly labeled.

In a few sentences describe the results observed. When is fish abundance highest, lowest? Is there a pattern over the year?

You will now look at the data through the four seasons of the year. In doing so, we are grouping some months together. Complete the table below with the number of individuals and relative abundance for each season by using the pivot table function in the spreadsheet.

Table 3. The number and relative abundance of fish observed by season

Season	Number of fish	Relative abundance
Winter		
Spring		
Summer		
Fall		
Total		

Make a barplot similar to the one that you made for each month of the year.

- In a few sentences describe the patterns observed. Are they similar to the monthly data?
- From the two barplots (monthly and by seasons), which one do you think provides a better overview of the fish abundance at Campbell River over a year?
- Based on the patterns observed in both plots and on the environment fish live in the Pacific Northwest, explain why you think you observe these patterns.

Finally, you will look at day and night differences in fish abundance. To start, complete the table below. Once again use the pivot table function to help you calculate such abundances.

Table 4. The number and relative abundance of fish observed during the day and at night

Time of day	Number of fish	Relative abundance
Day		
Night		
Total		

Plot the data in a barplot as you have done for the monthly and the seasonal data.

Describe the patterns observed. Are there differences in observations between day and night when you look at all the species combined?

Species abundance

You already have a good understanding of the data and how total fish abundance varies daily, monthly, and seasonally. However, often the overall temporal variation may differ from one species (or group) to another. In this section you will look at the data at a higher resolution (by species) and compare how the abundance of different species varies monthly, seasonally, and daily.

First, calculate the total abundance for each species and complete the table and plot the results. This time your independent or explanatory variable will be different (i.e., it won't be temporal). Plot the results from the highest to the lowest abundant to better visualize the data.

Table 5. The number and relative abundance of individuals of each species identified

Species	Number of individuals	Relative abundance
Total		

Briefly describe the results observed. In particular, focus on how abundance differs across species: is it the same for all species or are there some species that are more abundant than others?

For the next three analyzes you will work with the **seven** most abundant species. First, you will explore how the abundance of each species varies monthly over 2019. Fill in the table with the number of individuals in each month that had individuals of that species in it. Then complete the table adding 0 to the months where no individuals of any given species were observed.

Table 6. The number of individuals of each species for each month. Abu = Abundance and RA = Relative Abundance.

Month	Species													
	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA
January														
February														
March														
April														
May														
July														
August														
September														
October														
November														
December														
Total														

To better visualize these data, plot the relative abundance of each species in a separate figure. Begin by making a barplot of the most abundant species and so on for each of the seven most abundant species. Create a multipanel plot by organizing the figures in a 3x3 matrix for better interpretation.

- Describe the patterns observed and compare the abundance across species over time. Some important questions to keep in mind while thinking about your description: Are the abundances of all species similar over time? Are all species present throughout the year? When does the abundance peak for most species?

- Compare these species-specific abundance plots to the overall species abundance. How are they similar? How do they differ?
- You already have an idea of how the abundance of different species varies monthly over 2019. Now you will explore how the abundance of the seven most abundant species changes over seasons. Fill the table with the number of individuals and relative abundance of the species that were observed in each season. Complete the table by adding 0 to the species where no data were recorded for each season.

Table 7. The number of individuals of each species for each season. Abu = Abundance and RA = Relative Abundance.

Season	Species													
	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA
Winter														
Spring														
Summer														
Fall														
Total														

As above, create a separate barplot for each of the seven species starting from the most abundant to the least abundant species. Create a 3x3 multipanel plot to better visualize the data.

- Describe the patterns observed for the most important species. As you do, consider whether all species are present across all four seasons. What season show the highest abundance for most species?
- Compare the season data for the overall fish abundance and the species-specific abundance. What trends are similar for both? How do these two approaches differ?

Finally, you will see if there are differences in the abundance of species at day and night. Fill the table for each species and complete the table by adding 0's to the empty cells.

Table 8. The number of individuals of each species for day and night. Abu = Abundance and RA = Relative Abundance.

	Species													
Season														
	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA
Day														
Night														
Total														

Once again, make a barplot for each of the seven species starting from the most abundant to the least abundant. Make a 3x3 multipanel plot to observe all plots together.

- In a few sentences describe the overall plots. How many species show similar abundance during both the day and night? Are there some species that are only observed during the day or only at night?
- Compare these species-specific time of day data to the overall fish abundance day and night data and describe the differences you observe between them. Do both approaches give you the same insight into the data?

Cited References

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Materials

A computer with Internet access, a browser such as Chrome or Firefox, Google Sheets and a Media Player software for each pair or group of three students will be needed.

Notes for the Instructor

Lab introduction

About the dataset

The fish data were collected by Mauricio Carrasquilla as part of his work at ONC to develop teaching material for post-secondary institutions. Data were collected for the whole of 2019 by observing 12 videos from each day (i.e., every two hours) except for June when the camera was covered with algae. The final product was a very large dataset with many hours of recordings without fish (~75% of videos). To minimize the time students spend watching recordings without fish and to construct a manageable dataset for students to analyze while maintaining the general trends observed in the original data, a subset of the initial dataset was created. The result of this effort is a table with a list of 109 videos in Appendix A. An Excel file with the results for these 109 clips can be provided upon request to mcarrasq@uvic.ca.

Laboratory preparation

This lab is intended for second year students who are enrolled or have taken a basic ecology course and have knowledge on the importance of counting individuals (i.e., abundance) in populations and communities and how to calculate relative abundance from abundance data. The lab has been designed to be completed in two three-hour lab sections. In the first section students should receive a short introduction by the instructor (~ 20 minutes) at the beginning of the lab, answer the prelab questions (20 minutes), and collect and enter data to the master spreadsheet. In the second section (or as lab report or homework) students should work on the data analysis section which includes completing tables, making graphs, and answering all questions.

This lab is easy and inexpensive to prepare as it only requires computers and internet access. Each clip listed has at least one fish in it and instructors can assign videos to groups for students to observe depending on the class size, and lab time. Assuming a class of 25 students each one should watch about four clips and thus eight clips should be assigned for pairs and 12 for groups of three, etc.

Prior to the lab have a plan on how to assign videos to each group to maximize the time students can spend working in the lab. Since fish abundance and community structure changes across time we recommend providing each group videos from different months covering the whole year. In Google Sheets prepare a master spreadsheet with headings similar to the example in Table 1 in the student handout and provide a link to all students for each group to enter their data once data collection is completed. It is very important to emphasize that the coding in Box 1 of the handout must be strictly followed to ensure consistency across different student groups and thus avoid issues when analyzing the data. When all groups have uploaded their data to the master spread sheet create a copy that students will be able to manipulate without losing the class data in the original spreadsheet.

We recommend Google Sheets over MS Excel because some students may not have a Microsoft license and those who do may have different versions whereby menus and functions may slightly differ between versions. Google Sheets is free, can be accessed through the internet and will ensure consistency across groups when creating and manipulating pivot tables.

Challenges

During the lab students may face two different challenges, identifying fish and working in spreadsheets. Since this lab is focused on coastal species of the Pacific Northwest, students from different geographical locations can find the identifying process daunting. To facilitate this, we have created a short guide with the species that are present in the dataset. While most are classified to species, some such as flatfish are classified as a group because identifying them to species from the videos is difficult. Although a big effort has been made to select the videos where fish are easy to identify, some clips may have fish that are challenging for students to accurately identify because of the distance from the camera where they appear. As a result, minor differences in the class spreadsheet can be possible.

Students may be unfamiliar on how to use a spreadsheet, particularly working with Pivot tables and creating graphs from such tables. To overcome this problem, we suggest asking students to work on improving their skills prior to the lab. We also recommend a short tutorial on how to use pivot tables by the instructor.

Alternatively, instructors may ask students to create their graphs manually which can enhance the student's understanding of the data while preventing software and/or computer issues that may otherwise use valuable time.

While this version is intended for second-year students, many other versions with added complexity can be created with the existing dataset. For example, upper-level students with some statistical knowledge can calculate means and standard deviations and conduct statistical tests to test if abundance differs across months, seasons, and/or time of day. While this version focuses on Google Sheets for analysis and plotting, upper-level students may be familiar with other statistical packages such as R in which all of the analyses and plots can be done. Similarly, exploring species richness and biodiversity indices and how these vary over time is also possible with the dataset. The Campbell River underwater observatory has other instruments collecting environmental data such as salinity, water temperature, dissolved oxygen, and chlorophyll concentration. These data can be related to fish abundance to further explore how fish abundance varies over a year. Please feel free to modify this version of the lab to suite your learning outcomes and student goals and do not hesitate to contact Mauricio Carrasquilla (mcarrasq@uvic.ca) should you require help on developing the new version.

Cited References

Moran, K. 2022. Canada's Internet-Connected Ocean. *Frontiers in Marine Science* 8: 8.

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About the Authors

Dr. Mauricio Carrasquilla holds a PhD from the Biology Department at the University of Victoria in Canada, a master's degree in Natural Resources from Instituto Politecnico Nacional in Mexico, and a bachelor's degree from Jorge Tadeo University in Colombia. Mauricio was an Instructor at the University of Victoria for six months in 2018 and is currently a Post-Secondary Education coordinator at Ocean Networks Canada where he works with students, professors, and instructors to develop teaching material using real live data from Ocean Networks Canada observatories.

Dr. Dave Riddell is a Post-Secondary Education Coordinator with Ocean Networks Canada at the University of Victoria. In this role he supports the teaching and learning of marine and environmental science in universities, colleges, and communities through the design and delivery of courses and field programs centered around data from ONC's underwater observatories and mobile sensors. Dave's research background is in ecotoxicology (MSc, PhD: University of Stirling), with a focus on the roles of community science and community-based research in addressing local environmental problems. He brings these research experiences to his teaching and program

design. As an educator (BEd: St. Thomas University), Dave's work is trauma-informed and embraces critical pedagogy, open education, and transformative praxis.

Dr. Isabelle Côté is a Professor of Marine Ecology at Simon Fraser University since 2005 and has been teaching marine-related topics for 30 years. She holds a PhD in Behavioral Ecology from the University of Toronto, a master's degree in Zoology from the University of Alberta and bachelor's degree in Marine Biology from McGill University. Her research has focused on understanding the ecological impacts of marine invasive species and how multiple stressors can impact the resilience of natural marine ecosystems.

Appendix A

This table has a list of 109 five-minute videos each of which has at least one fish in it. Instructors may distribute the videos to students based on the number of computers available and the size of the group. The results shown in the figures include all the data from these videos. As such, results can vary should the instructor decide to use a subset of this list.

Month	Day	Start time UTC	Video	Month	Day	Start time UTC	Video	Month	Day	Start time UTC	Video
Jan	06	16:00	1	May	01	1:00	40	Sep	01	1:00	76
	07	1:00	2		02	23:00	41		01	18:00	77
	10	21:00	3		05	2:00	42		07	23:00	78
	11	16:00	4		06	13:00	43		08	8:00	79
	13	16:00	5		07	2:00	44		20	10:00	80
	14	20:00	6		08	8:00	45		13	0:00	81
	15	16:00	7		08	10:00	46		17	9:00	82
	16	16:00	8		08	20:00	47		19	22:00	83
	17	16:00	9		09	16:00	48		22	23:00	84
Feb	01	5:00	10		10	14:00	49		25	14:00	85
	02	4:00	11	15	22:00	50	29	0:00	86		
	02	10:00	12	20	18:00	51	Oct	06	13:00	87	
	03	19:00	13	27	14:00	52		06	18:00	88	
	18	0:00	14	Jul	02	8:00		53	07	1:00	89
	21	18:00	15		03	0:00		54	09	15:00	90
	22	4:00	16		03	6:00		55	10	15:00	91
	22	18:00	17		03	11:00		56	12	16:00	92
	22	20:00	18		04	8:00		57	17	1:00	93
	27	18:00	19		05	19:00		58	20	2:00	94

Mar	02	2:00	20			06	19:00	59			22	15:00	95
	02	22:00	21			08	20:00	60			23	14:00	96
	06	13:00	22			10	8:00	61		Nov	01	1:00	97
	09	2:00	23			11	19:00	62			04	16:00	98
	09	8:00	24			31	6:00	63			21	19:00	99
	09	23:00	25			21	2:00	64			22	1:00	100
	16	12:00	26		Aug	01	7:00	65			29	6:00	101
	26	0:00	27			01	11:00	66		Dec	02	22:00	102
Apr	02	23:00	28		09	21:00	67		05		16:00	103	
	03	20:00	29		10	0:00	68		07		13:00	104	
	10	21:00	30		13	14:00	69		14		8:00	105	
	11	18:00	31		28	14:00	70		17		16:00	106	
	12	15:00	32		28	15:00	71		18		17:00	107	
	12	18:00	33		30	0:00	72		23		16:00	108	
	14	14:00	34		30	7:00	73		30		16:00	109	
	17	23:00	35		31	7:00	74						
	22	2:00	36		31	19:00	75						
	23	20:00	37										
27	2:00	38											
28	8:00	39											

Appendix B: Quick guide to marine fishes of BC

Family *Hexagrammidae*

Kelp greenling (p. 2)

Lingcod (p. 3)

Family *Squalidae*

Dogfish (p. 3)

Family *Gadidae*

Pacific cod (p. 4)

Family *Scorpaenidae*

Copper rockfish (p. 4)

Family *Embiotocidae*

Striped seaperch (p. 5)

Kelp perch (p. 6)

Shiner perch (p. 6)

Family *Cottidae*

Sculpins (p. 7-9)

Cabezón (p. 9)

Family *Stichaeidae*

Prickleback (p. 9)

Family *Paralichthyidae* or *Pleuronectidae*

Flatfish (p. 10)

Kelp Greenling ♀ - *Hexagrammos decagrammus*



Fusiform. Two distinct dorsal fins. Females blue gray or brownish with brownish or golden spots, and yellow fins. Square tail. Tend to swim close to the bottom. (Photo: Jackson Chu/Fisheries and Oceans Canada)

Kelp Greenling ♂



Males gray with blue blotches and black spots (snowflake pattern) on the head and upper part of their body. Up to 60 cm long. (Photo: Alex Spicer)

Lingcod - *Ophiodon elongatus*



Fusiform. Single long, moderately notched dorsal fin. Obvious, pale lateral line. Large mouth (with large teeth). Square tail. Head and body covered with numerous dark spots and blotches. Can darken or lighten to blend with background. Up to 1.5 m long. Tend to swim close to the bottom. (Photo: Lingcod by Ed Bierman) License: <https://creativecommons.org/licenses/by/2.0/legalcode>

Dogfish - *Squalus* sp.



Long, flattened, pointed snout with small, underslung mouth. No anal fin. Spine in front of each dorsal. Heterocercal tail. May have white spots on back and sides. Up to 1.5 m long. (Photo: Chu et al 2018/Ocean Networks Canada)

Pacific Cod - *Gadus macrocephalus*



Fusiform. Three separate dorsal fins. Two anal fins. Square tail. Long chin barbel. Silver gray to brown body with brown or greenish spots and scrawl marking. Up to 1.2 m long. Tend to swim close to the bottom. (Photo: Jackson Chu/Fisheries and Oceans Canada)

Copper Rockfish - *Sebastes caurinus*



Deep-bodied. Single dorsal fin with deep notches between strong spines. Square tail. Well-defined white stripe running along the rear half of the lateral line spines. Two orange-brown diagonal facial stripes. Up to 66 cm long. (Photo: Copper Rockfish by Kathleen Reed) License: <https://creativecommons.org/licenses/by-nc-sa/2.0/legalcode>

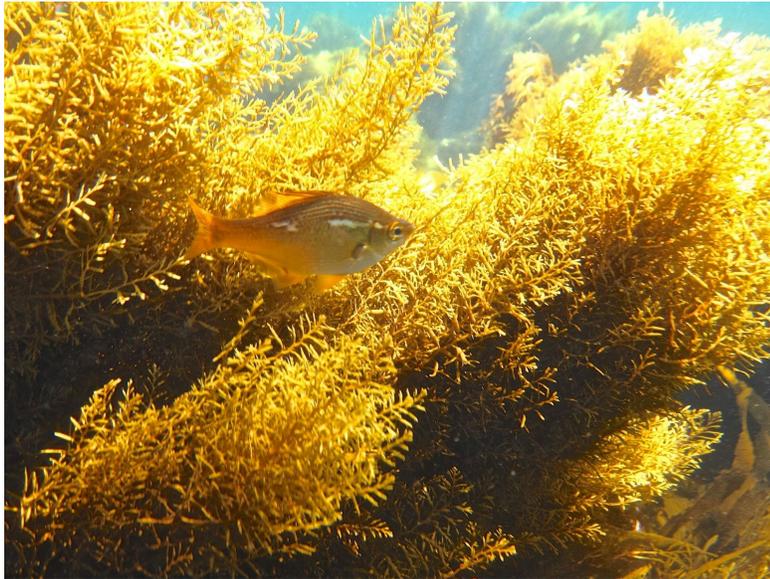
Striped Seaperch - *Embiotoca lateralis*



Disk-shaped. Single dorsal fin with longer rays at the back of the body. Copper-brown to reddish body with numerous, narrow blue/silver stripes along the sides.

Stripes may be hard to distinguish and fish may appear uniformly dark. Forked tail often yellow. Up to 40 cm long. Swims mid-water, often in schools. (Photo: *Striped Seaperch* by Kathleen Reed) License: <https://creativecommons.org/licenses/by-nc-sa/2.0/legalcode>

Kelp Perch – *Brachyistius frenatus*



Deep-bodied. Head concave above the eyes. Single dorsal often retracted. Forked tail. Gold/copper sheen over the whole body, with two pale mid-body blotches. Fins yellow or clear. Up to 22 cm. Swims mid-water, often in schools. (Photo: Kelp Perch by Roban Kramer) License: <https://creativecommons.org/licenses/by-sa/2.0/legalcode>

Shiner Perch - *Cymatogaster aggregata*



Deep-bodied. Bright silver with two or three yellowish bars on sides. Black spot common above upper lip. Forked tail. Up to 16 cm long. Swims mid-water, often in schools. (Photo: Jackson Chu/Fisheries and Oceans Canada)

Tidepool Sculpin – *Oligocottus maculosus*



Heavy-set. Two separate dorsal fins. Large, fan-like pectoral fins. Body greenish gray to reddish brown. Whitish saddle mid-body starts in the middle of the first dorsal fin. Benthic. Up to 9 cm long. (Photo: Jackson Chu/Fisheries and Oceans Canada)

Scalyhead Sculpin - *Artedius harringtoni*



Heavy-set. Two separate dorsal fins. Large, fan-like pectoral fins. White spot at base of tail. Round white spots on sides and belly. Benthic. Up to 10 cm long. (Photographer Jim Auzins via www.jimauzinsphoto.ca)

Padded Sculpin – *Artedius fenestralis*



Heavy-set. Two separate dorsal fins. Large, fan-like pectoral fins. Often with three or four dark bands on body. Benthic. Up to 14 cm long. (Photo: Jackson Chu/Fisheries and Oceans Canada)

Sailfin Sculpin – *Nautichthys oculofasciatus*



Heavy-set. Two separate dorsal fins. The first dorsal is strikingly elongated; the second dorsal is undulating. Large, fan-like pectoral fins. Diagonal dark band across the eye and cheek. Benthic. Up to 20 cm long. (Photo: Alex Spicer)

Cabezon - *Scorpaenichthys marmoratus*



Heavy-set. Two separate dorsal fins. Large, fan-like pectoral fins. Cirri above the eyes (if you can see them). Body red to brown with marbled coloration throughout in shades of brown. Benthic. Our largest sculpin, up to 100 cm long. (Photo: Alex Spicer)

Prickleback



Eel-like. Single long dorsal fin. May have a facial pattern. Variable colouration. Benthic. Up to 20 cm. (Photo: Jackson Chu/Fisheries and Oceans Canada)

Flatfish



Flat. Both eyes on one side of the body. Lies with one side of the body on the bottom. (*Photo: Jackson Chu/Fisheries and Oceans Canada*)

Appendix C: Sample Results

The results presented below are based on the dataset collected by Mauricio Carrasquilla. However, minor differences can be expected based on how accurately some fish species are identified by students. While abundances can slightly differ the overall trend for the temporal categories should remain the same as the ones presented here.

Pre-lab questions

- Underwater cameras are a great tool for collecting data and monitoring marine life, but in the past alternative methods to collect data have been used successfully and continue to be predominantly used as only a small proportion of the ocean is monitored with advanced technology. In a few words describe how you would monitor fish populations in the absence of the current technology (hint: think in terms of both spatial extent and temporal resolution).

The most common method to conduct fish surveys is by underwater visual census. With this technique multiple sampling sites can be chosen and thus a better spatial extent can be sampled. Similarly, one could design an experiment that samples at different times of days and through many years. However, sampling at night may be extremely challenging. Also, high temporal resolution unlikely as sampling is limited to the number of people conducting the survey and to oxygen supply if scuba diving.

- As you can imagine both methods have some advantages and disadvantages relative to each other. Explain two advantages and disadvantages that each method has.

Underwater cameras:

Advantages:

*High temporal resolution (e.g., sampling every hour for five minutes)
Collects data day and night*

Disadvantages:

*System may fail
Samples at one unique point over time*

Visual census:

Advantages:

*Better spatial extent
Allows for a good experimental design*

Disadvantages:

*Challenging to sample at night
Limited to manpower and good environmental conditions for sampling.*

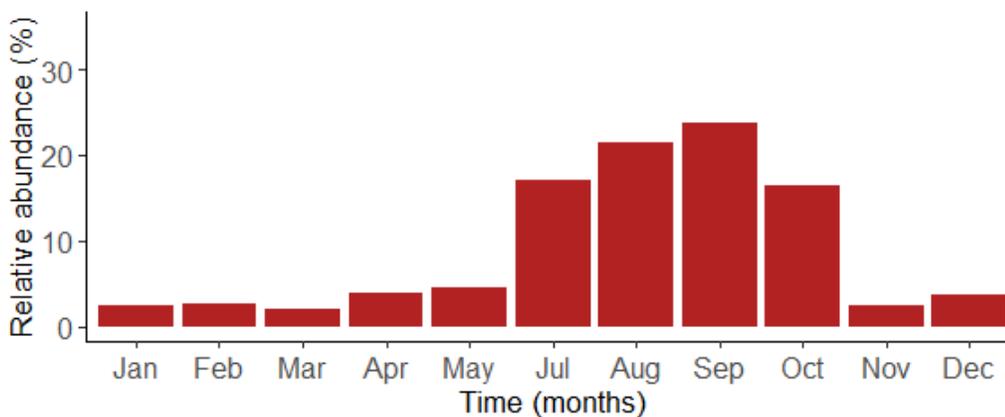
- In this lab you will calculate total fish abundance (for all fish combined) and abundance for each species and look at how this metric changes monthly, seasonally (winter, spring, summer, and fall), and time of day (day and night). Describe how you think fish abundance will change over time for each of the temporal categories. Also, describe if you think that you will see the same, similar, or different patterns when looking at the species-specific abundance data.

Total fish abundance

First you will focus on calculating fish abundance and relative abundance for all species together by month, season, and time of day. In Excel, calculate the number of fish observed for each month and complete the table below.

Month	Number of fish	Relative abundance
January	10	2.39
February	11	2.63
March	8	1.91
April	16	3.83
May	19	4.55
July	71	17
August	90	21.5
September	99	23.7
October	69	16.5
November	10	2.39
December	15	3.59
Total	418	

Next, plot the relative abundance results in a barplot. Remember that the independent or explanatory variable goes in the x-axis and the dependent or response variable will define your y-axis. A good figure should have a legend and axes must be clearly labeled.



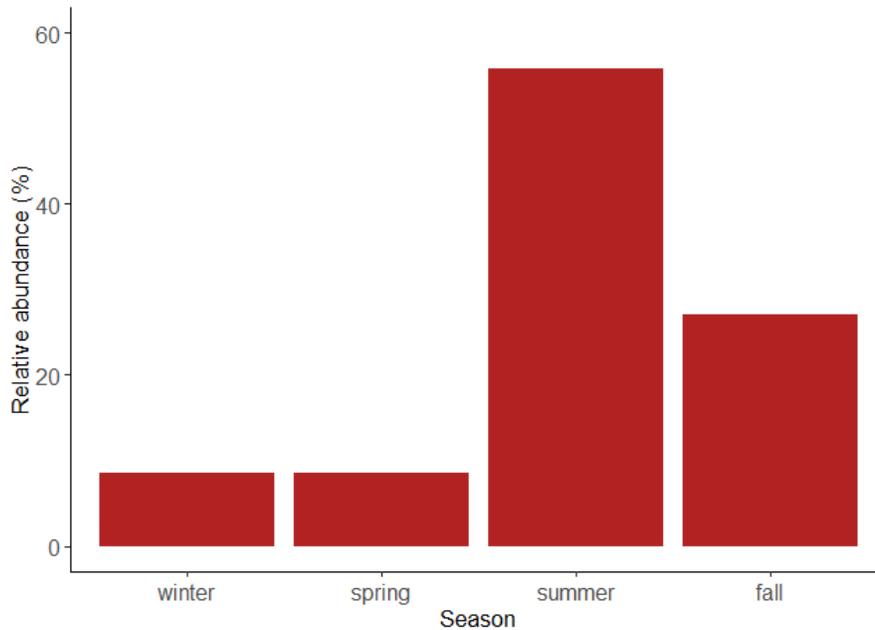
In a few sentences describe the results observed. When is fish abundance highest, lowest? Is there a pattern over the year?

Fish abundance is low from January to March and then starts increasing from April to September. It decreases in October and November and December have very low abundance similar to January and February. Fish abundance has a bell shape whereby abundance starts low, peaks in September, and starts decreasing after that.

You will now look at the data through the four seasons of the year. In doing so, we are grouping some months together. Complete the table below with the number of individuals and relative abundance for each season.

Season	Number of fish	Relative abundance
Winter	36	8.61
Spring	36	9.61
Summer	233	55.7
Fall	113	27
Total	418	

Make a barplot similar to the one that you made for each month of the year.



- In a few sentences describe the patterns observed. Are they similar to the month data?

Summer shows the highest fish abundance followed by the fall. Winter and spring have lower abundance.

- From the two barplots (monthly and by seasons), which one do you think provides a better overview of the fish abundance at Campbell River over a year?

While the overall trend is similar when observed seasonally some resolution is lost when grouping abundance by season.

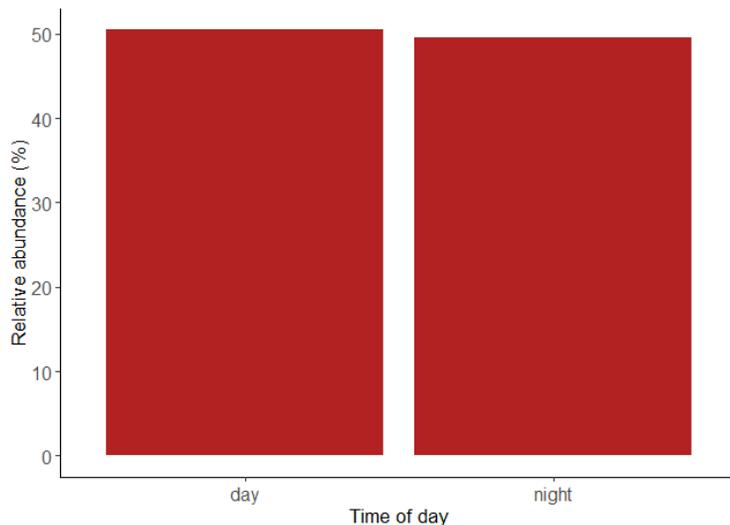
- Based on the patterns observed in both plots and based on the environment fish live in the Pacific Northwest, explain why you think you observe these patterns.

Water temperature rises in the summer and continues into the fall and may contribute to higher fish abundance particularly of juvenile fish as many species use coastal areas as nursery grounds. Similarly, nutrient availability increases in the spring which translates into higher primary productivity and thus a few months later may represent higher fish abundance.

Finally, you will look at day and night differences in fish abundance. To start, complete the table below

Time of day	Number of fish	Relative abundance
Day	211	50.5
Night	207	49.5
Total	418	

Plot the data in a barplot like you have done for the monthly and the seasonal data.



Describe the patterns observed. Are there differences in observations between day and night when you look at all the species combined?

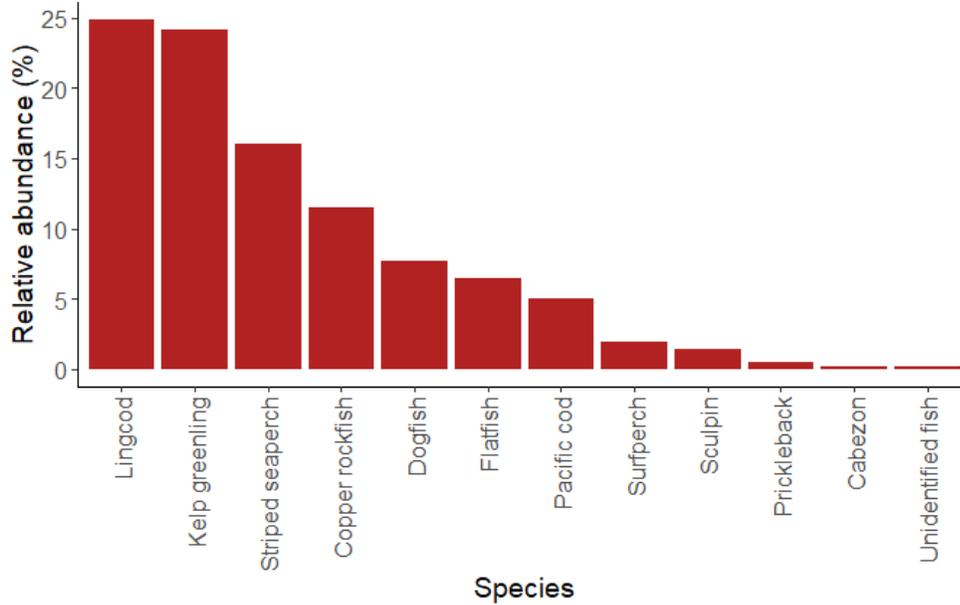
The difference between fish abundance at day and night is meaningless when all species are grouped together.

Species abundance

You already have a good understanding of the data and how total fish abundance varies daily, monthly, and seasonally. However, often the overall temporal variation may differ from one species (or group) to another. In this section you will look at the data at a higher resolution (by species) and compare how the abundance of different species varies monthly, seasonally, and daily.

First, calculate the total abundance for each species and complete the table and plot the results. This time your independent or explanatory variable will be different (i.e., it won't be temporal). Plot the results from the highest to the lowest abundant to better visualize the data.

Species	Number of individuals	Relative abundance
Lingcod	104	24.9
Kelp Greenling	101	24.2
Striped Seaperch	67	16
Copper rockfish	48	11.5
Dogfish	32	7.66
Flatfish	27	6.46
Pacific cod	21	5.02
Surfperch	8	1.91
Sculpin	6	1.44
Prickleback	2	0.48
Cabezon	1	0.24
Unidentified fish	1	0.24
Total	418	



- Briefly describe the results observed. Focus on how abundance differs across species: is it the same for all species or are there some species that are more abundant than others?

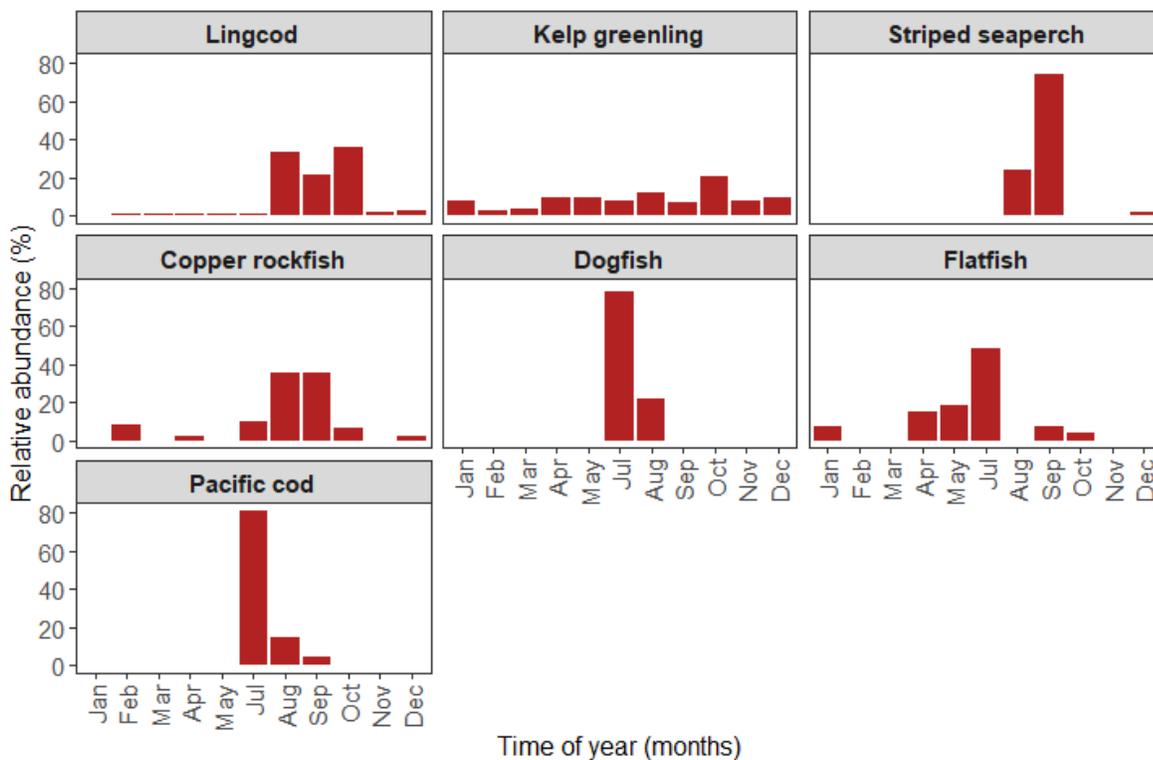
There are two species, Lingcod and Kelp greenling, that are most abundant than the rest. There is a fast abundance decrease (exponential) after Kelp greenling. It is important to point out to students that many communities have a similar species abundance distribution whereby there are few highly abundant species (dominant) followed by many rare species.

For the next three analyzes you will work with the **seven** most abundant species. First, you will explore how the abundance of each species varies monthly over 2019. Fill the table with the number of individuals in each month that had individuals of that species in it. Then complete the table adding 0 to the months where no individuals of any given species were observed.

Month	Species													
	Lingcod		Kelp greenling		Striped seaperch		Copper rockfish		Dogfish		Flatfish		Pacific cod	
	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA
January			8	7.92	0	0	0	0	0	0	2	7.41	0	0
February	1	0.96	4	3.96	0	0	0	0	0	0	0	0	0	0
March	1	0.96	4	3.96	0	0	0	0	0	0	0	0	0	0
April	1	0.96	10	9.90	0	0	1	2.08	0	0	4	14.8	0	0
May	1	0.96	10	9.90	0	0	0	0	0	0	5	18.5	0	0

July	1	0.96	8	7.92	0	0	5	10.4	25	78.1	13	48.1	17	81
August	35	33.7	12	11.9	16	23.9	17	35.4	7	21.9	0	0	3	14.3
September	22	21.2	7	6.93	50	74.6	17	35.4	0	0	2	7.41	1	4.76
October	37	35.6	21	20.8	0	0	3	6.25	0	0	1	3.70	0	0
November	2	1.92	8	7.92	0	0	0	0	0	0	0	0	0	0
December	3	2.88	10	9.90	1	1.49	1	2.08	0	0	0	0	0	0
Total	104		101		67		48		32		27		21	

To better visualize these data, plot the relative abundance of each species in a separate figure. Begin by making a barplot of the most abundant species and so on for each of the seven most abundant species. Create a multipanel plot by organizing the figures in a 3x3 matrix for better interpretation.



- Briefly describe the patterns observed and compare the abundance across species over time. Some important questions to keep in mind while thinking about your description: Are the abundances of all species similar over time? Are all species present throughout the year? When does the abundance peak for most species?

Kelp greenling and Lingcod are observed throughout the year, but Lingcod clearly has higher abundance in July, August, and September relative to the other months of the year while the abundance of Kelp greenling is more consistent over time. The rest of the species have an abundance peak ranging between July and August and in many cases abundances rapidly decrease to zero in the next two months.

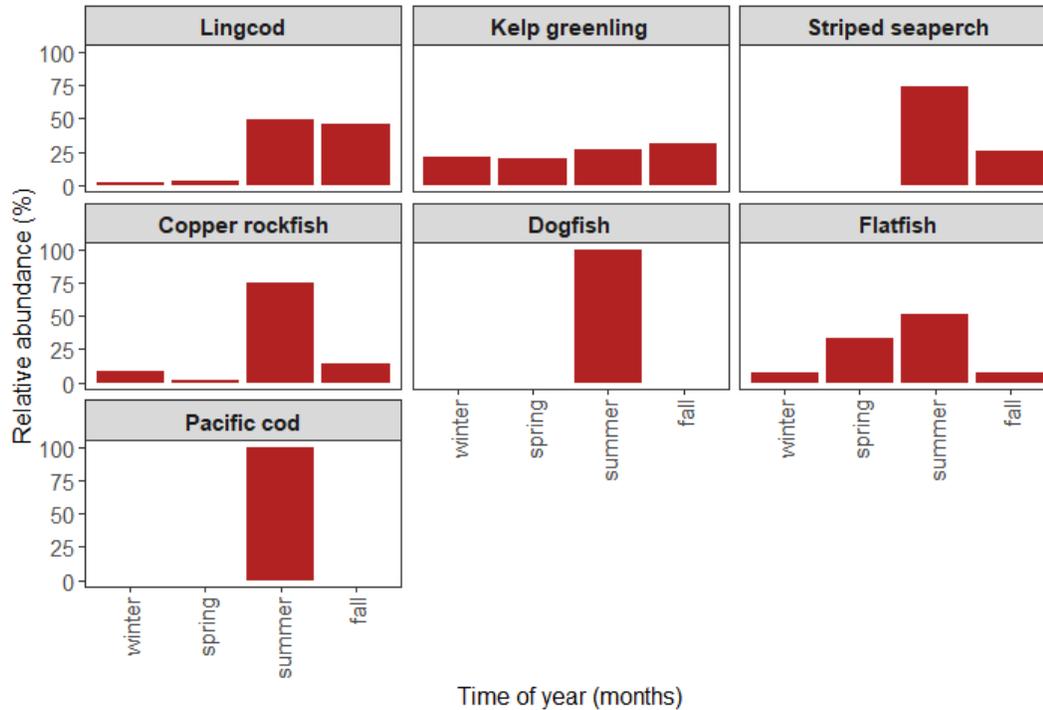
- Compare these species-specific abundance plots to the overall species abundance. How are they similar? How do they differ?

The species-specific plots provide higher resolution information at the species level and show that some species are not present throughout the year. Conversely, the total abundance plots show how the overall community numbers vary across the year.

You already have an idea of how the abundance of different species varies monthly over 2019. Now you will explore how the abundance of the seven most abundant species changes over seasons. Fill the table with the number of individuals and relative abundance of the species that were observed in each season. Complete the table by adding 0 to the species where no data were recorded for each season.

Season	Species													
	Lingcod		Kelp greenling		Striped seaperch		Copper rockfish		Dogfish		Flatfish		Pacific cod	
	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA
Winter	2	1.92	22	21.8	0	0	4	8.33	0	0	2	7.41	0	0
Spring	3	2.88	20	19.8	0	0	1	2.08	0	0	9	33.3	0	0
Summer	51	49	27	26.7	50	74.6	36	75	32	100	14	51.9	21	100
Fall	48	46.2	32	31.7	17	25.4	7	14.6	0	0	2	7.41	0	0
Total	104		101		67		48		32		27		21	

As above, create a separate barplot for each of the seven species starting from the most abundant to the least abundant species. Create a 3x3 multipanel plot to better visualize the data.



- Describe the patterns observed for the most important species. As you do, consider whether all species are present across all four seasons. What season show the highest abundance for most species?

Kelp greenling was the only species that showed similar abundance over the four seasons. Although Lingcod, Copper rockfish and Flatfish were also present in all four seasons, their abundance was higher in the summer, fall, and summer, respectively.

In contrast, Pacific cod and Dogfish were only present in the summer while Striped seaperch was most abundant in the summer, but some individuals were present in the fall.

- Compare the season data for the overall fish abundance and the species-specific abundance. What trends are similar for both? How do these two approaches differ?

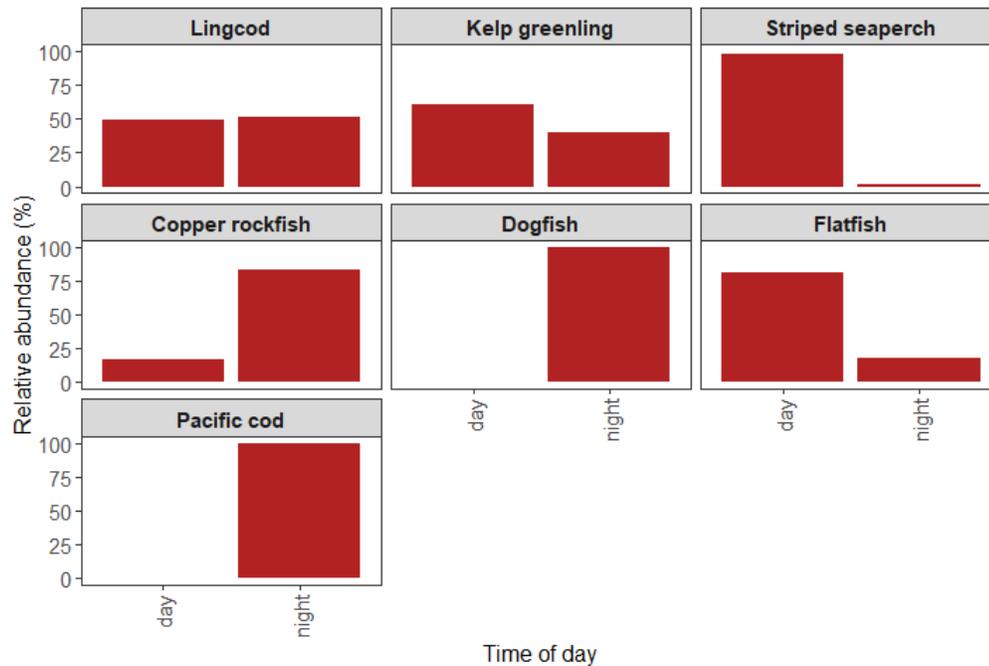
Although trends are similar some resolution is lost when grouping abundance by seasons. In some cases, a monthly observation may be more informative than at the season level.

Finally, you will see if there are differences in the abundance of species at day and night. Fill the table for each species and complete the table by adding 0's to the empty cells.

Season	Species													
	Lingcod		Kelp greenling		Striped seaperch		Copper rockfish		Dogfish		Flatfish		Pacific cod	
	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA	Abu	RA
Day	51	49	61	60.4	66	98.5	8	16.7	0	0	22	81.5	0	0
Night	53	51	40	39.6	1	1.49	40	83.3	32	100	5	18.5	21	100

Total	104		101		67		48		32		27		21	
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Once again, make a barplot for each of the seven species starting from the most abundant to the least abundant. Make a 3x3 multipanel plot to observe all plots together.



- In a few sentences describe the overall plots. How many species show similar abundance during both the day and night? Are there some species that are only observed during the day or only at night?

Lingcod, Copper rockfish, Kelp greenling and Flatfish were observed both at night and daytime. However, only Lingcod had similar abundance at both time periods. Conversely, Kelp greenling and Flatfish had a higher abundance during the day while Copper rockfish were mostly seen at night. Pacific cod and Dogfish were strictly observed at night while Striped seaperch was observed during the day.

- Compare these species-specific time of day data to the overall fish abundance day and night data and describe the differences you observe between them. Do both approaches give you the same insight into the data?

Species-specific data for time of day are completely different to the total fish abundance data. While the latter provide information on some behavioral aspects of each particular species, all fish combined is uninformative as the presence of some species at night compensates for those absent during the day and vice versa.

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