Marine Life and Oceanography on the Eastern Bering Sea Slope

SECONDARY CURRICULUM

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NOAA Fisheries Alaska Fisheries Science Center	North Pacific Research Board	Thalassa Education

For the past forty years, the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) has conducted surveys with trawl nets to monitor the populations of bottom fish and crab of the eastern Bering Sea shelf (10-200 m depth) and slope (200-1,200 m depth). During the summer of 2012, Dr. Gerald Hoff added oceanographic data-collecting equipment to the eastern Bering Sea slope survey nets for the first time. Funding for the equipment was provided by a grant from the North Pacific Research Board (NPRB). Dr. Hoff will use the data collected to monitor the relationships between environmental variables and the abundance, biomass, and distribution of fish and invertebrates in the eastern Bering Sea.

Curriculum Framework

The curriculum consists of one lesson with two labs. The labs are designed to reinforce and expand the lesson themes, and provide hands-on opportunities for students to investigate and integrate the information they have learned.

This curriculum accomplishes the following objectives:

- Analyze data collected by the National Marine Fisheries Service to understand the relationship between oceanographic conditions and deep water distributions of fish and invertebrates on the eastern Bering Sea slope (200-1,200 m depth).
- Learn about the science and research techniques used by NMFS to study oceanographic conditions and the distribution of fish and invertebrates on the eastern Bering Sea slope.
- Increase awareness of the need for more scientific research to understand the impacts of climate change on deep water ocean ecosystems.

Classroom assessment methods

Assessment methods vary with each lab; any of these methods can be given a point value. Methods include:

- Data analysis
- Geographical display of data using Ocean Data View (free software)
- Summary of observations using technical writing
- Verbal presentations

How much time do I need?

Teachers should allow one hour to become familiar with Ocean Data View and one hour to become familiar with the spreadsheets before teaching.

Each lab can be completed in 2 class periods of 55 minutes depending on the students' experience with Excel and Ocean Data View.

Acknowledgments
Funding for this curriculum was provided by the NPRB and NMFS/Alaska Fisheries Science Center (AFSC).

Labs were developed by Pam Goddard (Thalassa Education) and reviewed by Lauri Sadorus for Dr. Gerald Hoff (NOAA).

Please send any comments or inquiries to:
Gerald Hoff, PhD
Alaska Fisheries Science Center
National Marine Fisheries Service, NOAA
7600 Sand Point Way NE
Seattle, WA 98115
Phone 206-526-4580
Fax 206-526-4004
Email:Gerald.hoff@noaa.gov

Or

Pam Goddard
Thalassa Education & Outreach
p.goddard@thalassa-education.com
www.thalassa-education.com

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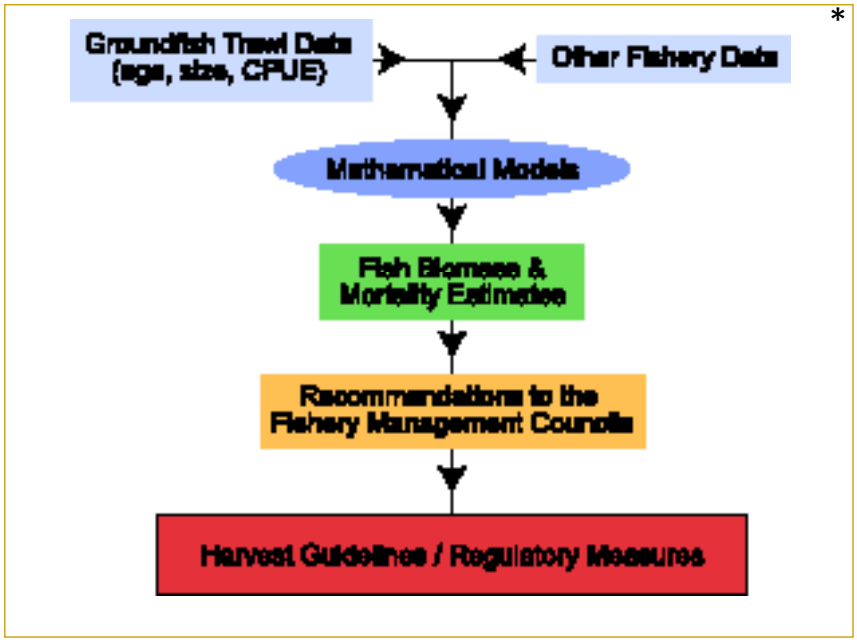
Alaska Fisheries Science Center's Groundfish Assessment Program

History and Background

The Alaska Fisheries Science Center's Groundfish Assessment Program of the National Marine Fisheries Service(NMFS), is responsible for conducting surveys to establish estimates of the distribution, biomass, and abundance of Alaska groundfish resources in the eastern Bering Sea, Gulf of Alaska, and Aleutian Islands. Data collected from the trawl surveys and other related sources are used in various mathematical models to help researchers analyze abundance and biomass (amount in numbers and weight) and mortality dynamics (died naturally, by being eaten, during fishing process). Fishery management scientists use the information to help recommend harvest guidelines and regulatory measures for commercial groundfish species in upcoming seasons.



The Groundfish Assessment Program, in cooperation with the Shellfish Assessment Program, conducts an annual bottom trawl survey for groundfish and invertebrates on the eastern Bering Sea shelf (20-200 m). This survey was initiated in 1971 and has been conducted annually since 1979. Major triennial surveys have been conducted for groundfish and invertebrate resources in the Aleutian Islands region, and in portions of the eastern Bering Sea slope (200-1,200 m) since 1977. Special purpose surveys and studies have been conducted to improve understanding of biological processes, interaction with the environment, and factors affecting the precision and accuracy of estimates of abundance, biomass, and population forecasts.

Catch per unit effort data (CPUE) derived from Groundfish surveys are used to calculate the abundance and biomass of all species caught. (See Appendix VI for a detailed description of CPUE.) The data are documented in scientific reports and incorporated into stock assessment advice provided to the Pacific Fishery Management Council, the North Pacific Fishery Management Council, international fishery management organizations, the fishing industry, and the general public.

CPUE data is calculated using kilograms per hectare (kg/ha) or numbers per hectare (#/ha). A hectare is a measurement of area 10,000 square meters (100 m x 100 m). Scientists and fisheries managers use the CPUE data to calculate both population and biomass for all commercially important fish and invertebrate species to determine the best harvest strategies for maintaining healthy stocks.

*Image Source: http://www.afsc.noaa.gov/RACE/groundfish/gfprof_objectives.htm

2012 Eastern Bering Sea Slope Survey

The eastern Bering Sea (EBS) slope is the transition area between the shallow waters of the shelf (0-200 m) and the deeper waters of the Bering Sea (>1,200 m). This combined area contains some of the largest fish biomass in the world. The shelf-slope interface is a highly dynamic area where nutrient-rich deep waters well-up onto the shelf, feeding primary productivity. More than 500 fish and invertebrate species dwell along the EBS slope and rely on the productivity of the shelf edge for survival.

The objective of the 2012 Eastern Bering Sea Slope Survey was to sample randomly-placed stations so that sampling effort reflected a variety of depths and subareas. The survey area was divided into 6 subareas running north to south (Appendix III, Figure 1), which may represent distinct biological realms (e.g. canyon areas [2,4], steep rough slope ares [3,5] and broad, gentle sloping area [1,6]). Each subarea was then divided into 5 depth strata, each covering approximately 200 meters in depth from 200-1,200 meters. Sampling effort was distributed within each subarea and depth stratum based on the area of the region (e.g. regions with a larger area were assigned more fishing effort or stations).

The catch of each successful trawl was weighed, sorted to species, processed for the collection of biological data (length, weight, stomach, age structures, tissue samples) and recorded. Approximately 136 fish species and 195 invertebrate species were identified. The summed catch weight of invertebrates accounted for approximately 6.7% of the total survey catch weight with the remaining 93.3% composed of fish weight, however invertebrates accounted for 59% of the species diversity.

Note

Several terms for the word sample are used in this curriculum. For the most part, these words are interchangeable.

haul, tow, catch, trawl, sample

References

For a detailed description of the Eastern Bering Sea Slope survey please see the following website and publications.

NOAA Fisheries/Alaska Fisheries Science Center
http://www.afsc.noaa.gov/default.htm

NOAA Fisheries/Alaska Fisheries Science Center/Eastern Bering Sea Group
http://www.afsc.noaa.gov/RACE/groundfish/ebs.htm

NOAA Fisheries/Alaska Fisheries Science Center/Groundfish Assessment Program
http://www.afsc.noaa.gov/RACE/groundfish/default.php

NOAA Fisheries: Alaska Fisheries Science Center, Fish Life History
http://access.afsc.noaa.gov/reem/lhweb/index.php

NOAA Fisheries: Alaska Fisheries Science Center, Early Fish Life History
http://access.afsc.noaa.gov/ichthyo/index.cfm

Hoff, G. R. 2013. Results of the 2012 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-258, 268 p.

Hoff, G.R. 2013. Relating deep ocean habitat conditions to faunal distribution, diversity and abundance64 on the eastern Bering Sea slope. NPRB Project 1101 Final Report,29p

CURRICULUM OVERVIEW

Marine Life and Oceanography on the Eastern Bering Sea Slope

Subject Area(s): Life Science, Math	**Grade Levels:** High School, College	**Teaching Time** 2 class periods or 55 minutes per lab

Lesson Topics:	fish and invertebrate catch per unit effort (CPUE), depth, temperature, salinity, pH, dissolved oxygen
Learning Objectives:	Students will use catch and oceanographic data provided by NOAA National Marine Fisheries Service to calculate descriptive statistics and a linear regression, and investigate the spatial distribution of the data using Ocean Data View.

Key words::	eastern Bering Sea slope, abundance, biomass, distribution, CPUE, dissolved oxygen, pH, temperature, salinity
Focus Question	• Is there a correlation between biomass or abundance of fish or invertebrate species and oceanographic conditions? • How do oceanographic conditions affect CPUE?

LABS		STATE STANDARDS		OCEAN LITERACY		
		AK	WA		Class Periods	Level
LAB ONE	Data analysis of CPUE and oceanographic conditions: Excel	SA2; SC3.2 SE1-3	M1.5 EALR 2; EALR 3	3 e,f; 5 a,d,e,f	2 @ 55 min	High School & College
LAB TWO	Spatial Analysis: Ocean Data View				2 @ 55 min	High School & College

See Appendix II for detailed information on educational standards.

LAB ONE

Data Analysis of CPUE and Oceanographic Conditions

OBJECTIVE

Students will use Excel to analyze relationships between fish and invertebrate biomass and abundance as well as oceanographic variables on the eastern Bering Sea slope.

TIME REQUIRED

2 class periods of approximately 55 minutes each.

BACKGROUND

The Alaska Fisheries Science Center (AFSC) has been conducting triennial bottom trawl surveys of the eastern Bering Sea slope since 1979. Standard data collected at each station on the survey includes, but is not limited to: start and end latitude and longitude of the trawl net, length of time net is in the water, and distance net is towed, total catch weight, weight and number of each species of fish and invertebrates, bottom temperature, and bottom depth. Until 2012, oceanographic data were not collected during the slope surveys. A grant from the North Pacific Research Board (NPRB) allowed AFSC scientist Dr. Gerald Hoff to attach a data logger (Seaguard-Aanderaa), light meter (Wildlife MK-9), and Seabird SBE-9 to the trawl net to record bottom depth, bottom temperature, light levels, salinity, pH, oxygen levels, and turbidity of the water (see photographs, Appendix IV).

The Eastern Bering Sea (EBS) Slope dataset for this lab contains catch per unit effort (CPUE) and seven environmental variables: bottom depth (m), bottom temperature (^{o}C), light (unitless, relative term), salinity (psu), pH, and dissolved oxygen (DO: mg/L) for each sample along with basic information such as geographic coordinates (latitude/longitude) and haul number.

CPUE is a measure of either weight (kg/ha) or number (#/ha) of individuals, standardized to a unit of area, allowing direct comparisons among sampling sites and species. A hectare (ha) is a measurement of area that is 10,000 meters squared or 100 m x 100 m. Catch per unit effort was calculated for each station by dividing catch weight or number for each species by the estimated area the net covered (length of the tow * width of the net). See Appendices V and VI for a net diagram and a detailed description of how CPUE was calculated. For every successful haul/sample on the EBS Slope 2012 survey, CPUEs in both kilograms and numbers are provided for the 25 most abundant species along with total CPUEs for all species combined, and four groupings (shallow complex, deep complex, skates, and flatfish) that are defined in the metadata (descriptive information) sheet in the Excel file.

In Lab 1, Excel is used to explore the data provided (high school and college levels), calculate descriptive statistics for CPUE and each environmental factor (high school and college level), and examine relationships between the species and environmental factors (advanced high school and college level).

It may be helpful to have all students work with the species groupings, then assign each student a specific species to analyze more fully and to compare to results from other students.

MATERIALS

Worksheets 1.1, 1.2, 1.3, and 1.4
NOAAFisheries_EBS-Slope_Data_Student
NOAAFisheries_EBS-Slope_Data_Teacher-Key
http://www.afsc.noaa.gov/education/

PROCEDURES - DESCRIPTIVE STATISTICS (High School, College)

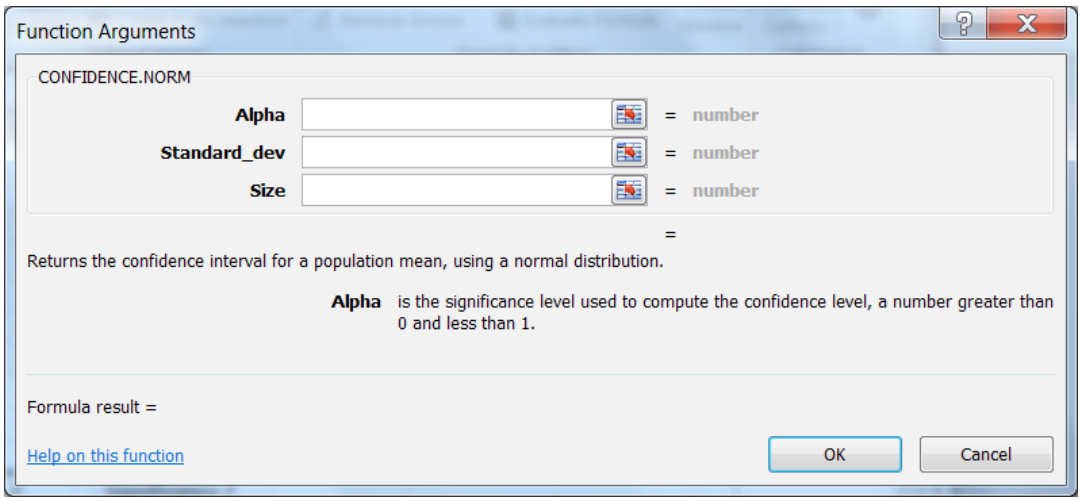
EXPLORING THE DATA

- Load data file on individual computers if possible.
- Take time to become familiar with the data in the spreadsheet
- Conduct simple sorting routines on the spreadsheet to look at patterns of CPUE related to the environmental factors. Use the *sort* command in the *data* tab.
- Or create pivot tables: environmental parameters on the vertical and species on the horizontal. The pivot table parameters can be grouped to make it easier to see patterns.

MEAN AND CONFIDENCE INTERVAL

Worksheet 1.1 and 1.2 Calculate the mean value along with 95% confidence intervals (CI) for each environmental parameter and each species and species grouping.

- These basic statistics are an effective way to make predictions about an area/population based on the sample data. The mean gives the average value across all samples. The CI give an estimated range for the studied habitat or population based on the sample values. The 95% CI means that the researcher can be 95% confident that any other samples from that same population/area would fall within that range. Alternatively, there is a 5% chance that the sample was predicted to be within the range, but is not.

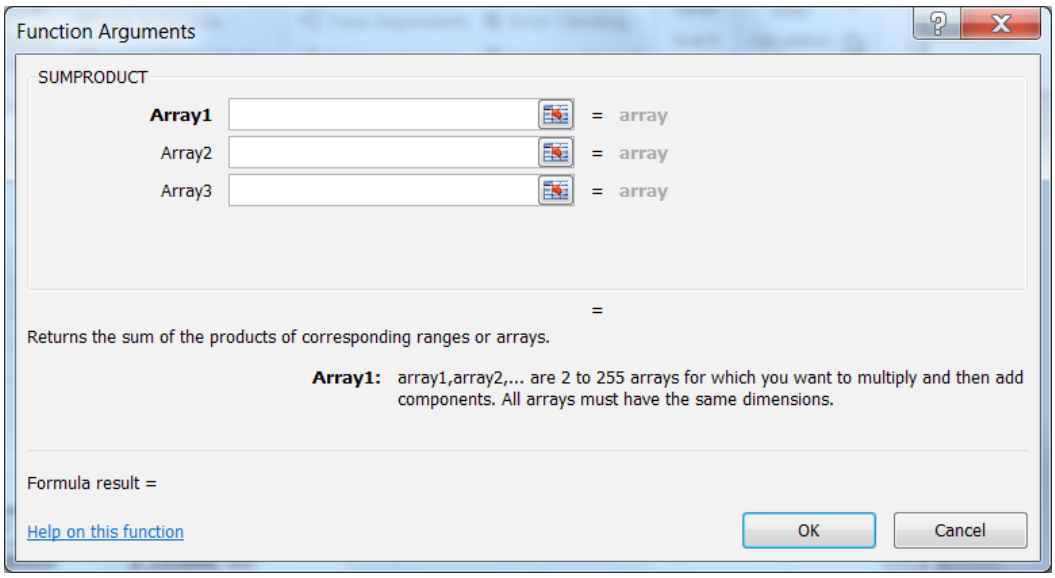


- For the arithmetic mean – select the Formula tab, click on the *More Functions* key, select *Statistical* (Mac Excel 2008- scroll down to the *Statistical)* then AVERAGE from the drop down menu. Then drag the cursor down the entire column of data for the factor or species being examined. Press Enter.
- For 95% confidence intervals - first calculate the standard deviation by following the steps above, and selecting STDEV.S (STDEV for Mac Excel 2008 and earlier) instead of AVERAGE. In a separate cell, select CONFIDENCE.NORM (CONDFIDENCE for Mac Excel 2008 and earlier) from the Statistical menu.
- Alpha is 0.05 and size is 184, which is the number of samples in the calculation. In the Standard deviation field, select the cell with that calculation. Press OK. The confidence intervals are calculated by taking the mean +/- the CI calculation.

Note: for advanced students, descriptive statistics can be calculated using the *Analysis Toolpak* add-in in Excel. To use this function, go to the Data tab and select the Data analysis key. Descriptive statistics is an option that will return a number of different parameters. Students should be versed in the meanings of the different outputs prior to use.

WEIGHTED MEAN

Worksheets 1.3 and 1.4 Calculate the weighted means by CPUE kg/ha for environmental parameters of each species in the dataset. The means are weighted so that station values where CPUE was higher will have more weight in the calculation than stations with lower CPUEs. This results in a more realistic look at where the bulk of the biomass for that species was found in relation to the environmental parameter being examined.
For the weighted mean – select the *Formula* tab, click on the *Math and Trig* key, select *SUMPRODUCT* from the drop down menu.



- For array 1, select the cells in the column of the environmental parameter that you are looking at, e.g. depth. For array 2, select the cells in the column of the species you are examining. The numbers in this column are CPUE. Press OK. Place the cursor in the formula window of the spreadsheet and finish the calculation by adding /SUM and then selecting the same column of cells under the species you are analyzing. Press enter. Ultimately, the formula should look something like this example:

  =SUMPRODUCT(Q10:Q193,AC10:AC193)/SUM(AC10:AC193)

  with **Q** being the column of environmental data such as depth or temperature and **A** being the column of CPUE data for a specific species.

- To find the range – simply sort the spreadsheet from smallest to largest for each parameter and look at resulting animal CPUE. The MIN and MAX functions can also be used. The MIN function will always return a zero for datasets containing a zero CPUE. The MINIF function can be used to find the minimum value >0

  =MINIF(A1:A100>0, A1:A100)) This is an array formula, calculate by entering: CTRL+SHIFT+ENTER.

DISCUSSION

BIOMASS, ABUNDANCE, AND DISTRIBUTION

- Is the bulk of the total CPUE (kg/ha) in shallow water, deep water, mid-water, or evenly distributed?
- How many stations are above and below what is considered hypoxic (defined in the Glossary, Appendix I) and how are the total CPUE and individual species distributed in relation to hypoxia?

  92 stations out of 184 are considered hypoxic (<2.0 mg/L of DO)

  The sum of the total CPUE kg/ha is evenly split between the hypoxic (34,378 kg/ha) and non-hypoxic (34,137 kg/ha) stations.

The sum of the total CPUE #/ha is slightly lower (31,529 #/ha) at the hypoxic stations than at the non-hypoxic stations (38,776 #/ha).

- Are there species distribution patterns related to temperature, light, salinity, or pH?

  Yes, they are different for each species.

- Which species has the highest/lowest CPUE kg/ha?

  Pacific Ocean perch has the highest CPUE for both weight and number, 3,482 kg/ha and 4,942 #/ha.

  Golden king crab had the lowest CPUE kg/ha.

- Which species has the highest CPUE #/ha?

  Pacific Ocean perch has the highest CPUE #/ha (4,942)

- Why might the weighted mean give a better picture of a species profile than just the mean?

  The weighted mean shows not only the range where that animal was found, but also where the bulk of the biomass was compared to that range. This may give some indication of key habitat.

ENVIRONMENTAL VARIABLES

- Are these environmental variables independent of one another? How can you tell? If no, what variables appear correlated (i.e. change together).

  Environmental factors are very much correlated to one another, especially depth to other factors. For example, depth and light are related in that the greater the depth, the less light there is. This can be illustrated either through sorting exercises or simple graphs looking at one factor plotted against another.

- Can habitat be characterized by depth? Characterize shallow vs deep habitat.

  It should be possible for students to loosely define shallow vs deep habitat. Shallow: more variable, lower temperature at the surface, then rises mid-water (this is unique to very high latitudes. At lower latitudes, temperature would likely become increasingly colder from surface to depth), higher pH, higher DO, lower salinity. Deep: less variable, lower temperature than mid-water, lower pH, lower DO, higher salinity.

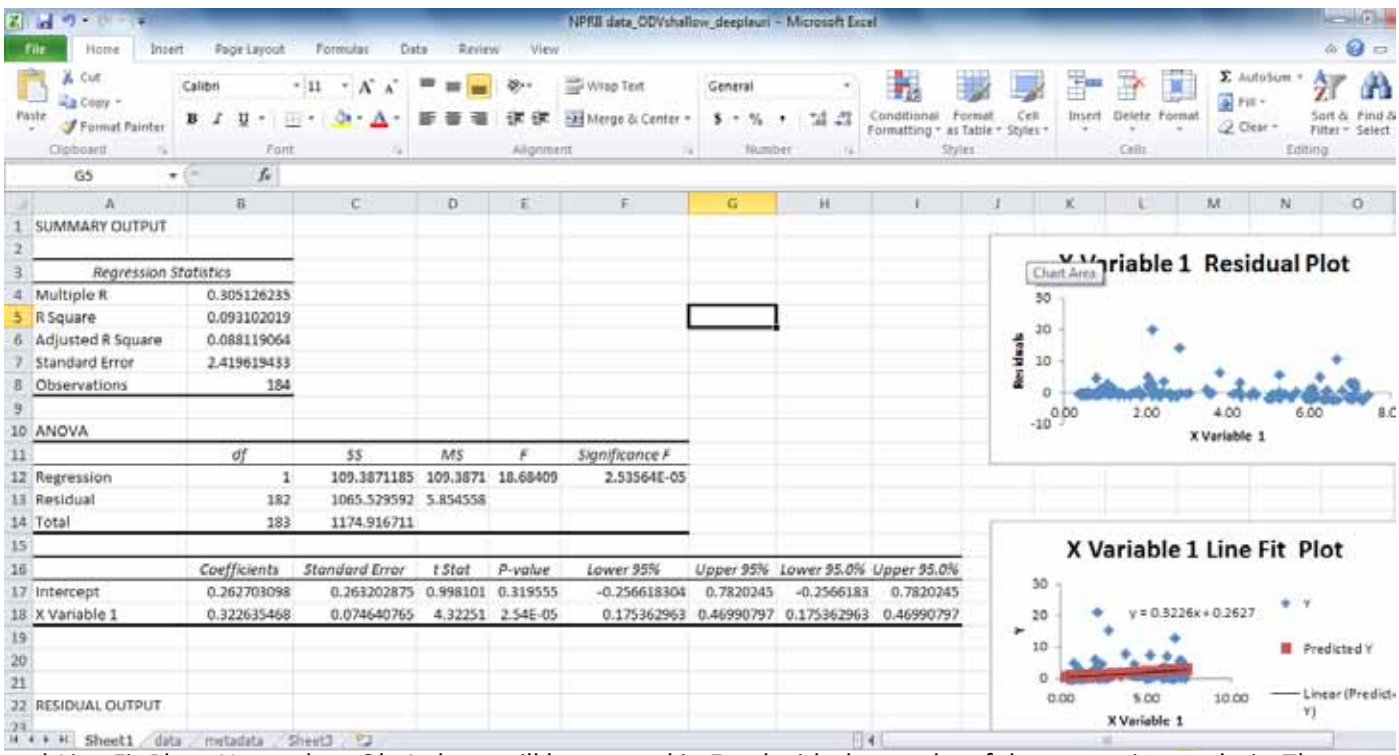
- Since the samples are expected to reflect the population/area, what types of things might be important in a sampling plan?
  - A spatially representative sample over the entire area/depth profile, consistency when taking the samples (i.e. sample the same way each time), adequate number of samples to represent the population, random sampling to ensure that the researcher is not “choosing” spots and thus could skew the data.

- What are the average environmental conditions within the study area?

PROCEDURES - EXAMINING RELATIONSHIPS (advanced high school and college)

Regression analysis

Regression is a useful tool in examining how one factor relates to another factor. This analysis can be accomplished on a Windows machine by loading the *Analysis toolpak* option in Excel then using the *Data analysis* key under the *Data* tab and selecting *Regression*. The output provides information on how closely one variable relates to another variable. If you are using a Mac you will need to load one of the third party programs recommended by Microsoft (http://support.microsoft.com/kb/2431349).If using StatPlus, have both your Excel file and StatPlus open, in StatPlus, select the *Statistics* tab and then the *Regression* tab. You will be prompted to select the dependent variable (column of CPUE data) and the independent variables (column of DO mg/L data in this example). Before calculating the regression, select the *Advanced* tab and check the boxes for *Residual Plot*



and *Line Fit Plots*. Now select *Ok*. A sheet will be created in Excel with the results of the regression analysis. The plots will be at the bottom of the residual data.

In this example, the Bering skate CPUE kg/ha (y-axis) was compared with DO (x-axis). Results show that the data have a positive correlation to one another (i.e. X Variable 1 is a positive coefficient with a low p-value indicating significance) meaning that Bering skate CPUE kg/ha increases as DO increases. This is also illustrated in the plot to the bottom right. In statistics, it is often stated that "correlation does not imply causation." It is important to note that just because there is a correlation between two variables it does not mean that one variable causes the other to increase or decrease. In this instance, the relationship between dissolved oxygen and Bering skate CPUE is still undefined. The other plot to the upper right is a residual plot that is used to examine how accurate the output may be. Residuals (and therefore the results of the regression) are considered satisfactory when they are evenly distributed across the plot surface and not clustered. If significant clustering exists, then data transformations can be used to minimize it. In this example, the adjusted R square indicates the amount of Bering skate variability explained by DO level, which is just under 0.09 or 9%.

DISCUSSION - EXAMINING RELATIONSHIPS (advanced high school and college)

- What is the relationship between CPUEs and environmental parameters? Note similarities and differences among species?
- What comprises a habitat?

  Habitat is a combination of all of the factors an organism encounters within its environment. Examples include physical features such as depth and latitude, environmental characteristics including water properties, food availability, and species relationships.
- Describe the habitat of the eastern Bering Sea slope.

  High latitude, wide range of depths, low temperatures, low DO, high diversity, lots of environmental variability in more shallow depths and stable conditions in deeper depths.
- Is it possible to include all features of a habitat in an analysis and/or be 100% certain of the analysis results for every animal? For scientists, how is certainty increased?

  No. There is no way to describe all features or count all fish in a natural habitat. There are many things not measured or simply unknown. The dataset comprises a sample and from that, conclusions can be drawn, but there is always the chance that the conclusions will be false. Some ways to increase the chances that results and conclusions are accurate is to: randomize sampling to ensure there is no bias, collect enough samples to properly represent habitat, distribute the sampling effort over the entire area, and conduct repeat data collections.

EXPLORE AND EXTEND

ALL LEVELS

- How many of the species are commercially harvested?
- Research and write a report on the life history of one of the species. Answer some of the following questions.
  - What ocean conditions are associated with the species?
  - How long does it live?
  - What does it eat?
  - Is it commercially harvested?
- Learn more about your sampling tool. Are nets 100% efficient/effective in capturing all individuals of each species?

ADVANCED HIGH SCHOOL and COLLEGE

- Assign each student a species to examine and have the student compare that species to each of the environmental variables based on regression analysis. Investigating what variables play the largest role in determining CPUE for that animal (adjusted R square) and correlations (positive/negative relationships) between species and variables will be useful.
- Have them report their findings and compare to results from other students. Are the results similar or different among species? Which species are most similar/opposite?

RESOURCES

NOAA Fisheries: Alaska Fisheries Science Center
Fish Life History
http://access.afsc.noaa.gov/reem/lhweb/index.php

Early Fish Life History
http://access.afsc.noaa.gov/ichthyo/index.cfm

LAB ONE | STUDENT WORKSHEET 1.1 | Mean and 95% Confidence Intervals (CI)

Student Name: _____

Species Name: _____

	Range	Mean	Standard Deviation	95% CI
CPUE (kg/ha)				
CPUE (#/ha)				
depth (m)				
temperature (°C)				
light				
salinity				
pH				
DO mg/L (ppm)				

LAB ONE | TEACHER KEY-WORKSHEET 1.1 | Mean and 95% Confidence Intervals (CI)

Student Name: _____

Species Name: Total CPUE (all species combined)

	Range	Mean	Standard Deviation	95% CI
CPUE (kg/ha)	27 - 5,168	382.1	554.67	80.14
CPUE (#/ha)	22 - 3,710	372.4	463.41	66.96
depth (m)	206 - 1,170	563	282.25	39.34
temperature (°C)	2.0 - 3.8	3.2	0.40	0.06
light	11.7 - 82.5	33.6	16.23	2.35
salinity	32.5 - 34.4	33.7	0.42	0.06
pH	7.5 - 8.0	7.6	0.13	0.02
DO mg/L (ppm)	0.5 - 10.6	3.7	3.42	0.49

Student Name: _____

Species Name: Alaska Skate

	Range	Mean	Standard Deviation	95% CI
CPUE (kg/ha)	0 - 51	1.2	5.42	0.78
CPUE (#/ha)	1.45 - 246	6.5	26.94	3.89
depth (m)	206 - 516.00	298.8	83.26	12.03
temperature (°C)	2.00 - 3.80	3.0	0.59	0.29
light	25.49 - 82.47	44.3	13.94	3.68
salinity	32.46 - 33.91	33.3	0.30	4.69
pH	7.55 - 7.98	7.8	0.11	1.09
DO mg/L (ppm)	1.51 - 10.64	7.7	2.77	0.22

LAB ONE

STUDENT WORKSHEET 1.2

Mean values for all species

As a class, complete this table with the mean value for each oceanographic variable.

Mean Values								
Species	CPUE #/ha	CPUE kg/ha	depth (m)	temp	light	salinity	pH	DO mg/L (ppm)
skates								
flatfish								
Alaska skate								
Aleutian skate								
arrowtooth flounder								
Bering skate								
bigmouth sculpin								
commander skate								
flathead sole								
giant grenadier								
golden king crab								
Greenland turbot								
Kamchatka flounder								
Pacific cod								
Pacific grenadier								
Pacific halibut								
Pacific ocean perch								
popeye grenadier								
rex sole								
roughtail skate								
sablefish								
shortraker rockfish								
shortspine thornyhead								
triangle tanner crab								
walleye pollock								
western eelpout								
whiteblotched skate								

LAB ONE | TEACHER KEY WORKSHEET 1.2 | Mean values for all species

As a class, complete this table with the mean value for each oceanographic variable.

Mean Values								
Species	CPUE #/ha	CPUE kg/ha	depth (m)	temp	light	salinity	pH	DO mg/L (ppm)
skates		18.56	553	3.2	33.8	33.7	7.7	3.8
flatfish		52.74	517	3.3	35.4	33.7	7.7	4.1
Alaska skate	1.22	6.45	299	3.0	44.3	33.3	7.8	7.7
Aleutian skate	1.95	7.10	520	3.3	34.4	33.7	7.7	3.9
arrowtooth flounder	21.09	23.52	398	3.3	40.3	33.5	7.7	5.3
Bering skate	0.90	1.10	375	3.3	42.2	33.5	7.7	5.8
bigmouth sculpin	0.40	1.34	346	3.2	42.8	33.4	7.7	6.4
commander skate	0.96	1.42	674	3.3	26.9	34.0	7.6	1.6
flathead sole	18.79	6.96	341	3.3	43.8	33.4	7.7	6.4
giant grenadier	48.50	176.35	683	3.3	26.5	34.0	7.6	1.8
golden king crab	1.04	0.62	453	3.4	35.6	33.6	7.7	4.2
Greenland turbot	3.91	5.82	559	3.3	31.2	33.8	7.6	3.2
Kamchatka flounder	8.18	10.25	508	3.3	35.6	33.7	7.7	4.1
Pacific cod	0.67	1.71	263	2.9	49.2	33.2	7.8	8.6
Pacific grenadier	5.21	1.02	965	2.9	18.7	34.2	7.5	0.7
Pacific halibut	0.36	2.35	355	3.2	39.3	33.4	7.7	6.2
Pacific ocean perch	94.12	69.96	328	3.2	43.8	33.4	7.8	6.7
popeye grenadier	110.31	17.54	781	3.2	23.7	34.1	7.6	1.1
rex sole	5.21	3.84	349	3.3	44.0	33.4	7.7	6.2
roughtail skate	0.39	0.68	892	3.0	20.6	34.2	7.5	0.8
sablefish	0.94	2.59	662	3.4	27.5	34.0	7.6	1.6
shortraker rockfish	0.53	2.87	433	3.6	36.6	33.6	7.7	3.9
shortspine thornyhead	15.28	9.20	610	3.4	29.7	33.9	7.6	2.2
triangle tanner crab	23.49	1.54	777	3.2	23.2	34.0	7.6	1.3
walleye pollock	11.85	11.76	382	3.2	41.5	33.4	7.7	6.1
western eelpout	6.30	4.55	670	3.3	27.3	34.0	7.6	1.7
whiteblotched skate	0.56	1.81	423	3.4	35.9	33.6	7.7	4.8

LAB ONE | STUDENT WORKSHEET 1.3 | Weighted Mean

Student Name: _____

Species Name: _____

	Range		Weighted Mean (by CPUE kg/ha)	Weighted Mean (by CPUE #/ha)
	Minimum	Maximum		
depth (m)				
temperature (°C)				
light				
salinity				
pH				
DO mg/L (ppm)				

LAB ONE | TEACHER KEY WORKSHEET 1.3 | Weighted Mean

Student Name: _____

Species Name: Alaska skate

	Range			
	Minimum	Maximum	Weighted Mean (by CPUE kg/ha)	Weighted Mean (by CPUE #/ha)
depth (m)	206	516	298	296
temperature (°C)	2.0	3.8	2.8	2.8
light	25.5	82.5	45.3	45.7
salinity	32.5	33.9	33.3	33.3
pH	7.6	8.0	7.8	7.8
DO mg/L (ppm)	1.5	10.6	7.8	7.9

LAB ONE | STUDENT WORKSHEET 1.4 | Weighted means for a species

As a class, complete this table with the weighted mean by CPUE (kg/ha) for each oceanographic variable.

	Weighted mean (by CPUE kg/ha)					
Species Name:	Depth (m)	Temp (°C)	Light	Salinity	pH	DO (mg/L or ppm)
skates						
flatfish						
Aleutian skate						
Alaska skate						
arrowtooth flounder						
Bering skate						
bigmouth sculpin						
commander skate						
flathead sole						
giant grenadier						
golden king crab						
Greenland turbot						
Kamchatka flounder						
Pacific cod						
Pacific grenadier						
Pacific halibut						
Pacific ocean perch						
popeye grenadier						
rex sole						
roughtail skate						
sablefish						
shortraker rockfish						
shortspine thornyhead						
triangle tanner crab						
walleye pollock						
western eelpout						
whiteblotched skate						

Table 1. Range and weighted mean (by CPUE kg/ha) values for environmental parameters of species encountered during the 2012 Eastern Bering Sea Slope survey.

	Weighted Mean (by CPUE kg/ha)					
Species	depth (m)	temp	light	salinity	pH	DO mg/L (ppm)
skates	414	3.2	38.5	33.5	7.7	5.5
flatfish	412	3.4	37.2	33.6	7.7	4.6
Alaska skate	298	2.8	45.3	33.3	7.8	7.8
Aleutian skate	416	3.4	38.2	33.6	7.7	5.0
arrowtooth flounder	392	3.4	36.7	33.6	7.7	4.8
Bering skate	356	3.3	41.3	33.4	7.7	6.1
bigmouth sculpin	315	3.1	46.9	33.3	7.8	7.1
commander skate	678	3.3	25.8	34.0	7.6	1.3
flathead sole	333	3.3	44.1	33.4	7.7	6.2
giant grenadier	709	3.3	25.5	34.0	7.6	1.5
golden king crab	394	3.3	37.3	33.5	7.7	5.3
Greenland turbot	517	3.4	31.0	33.8	7.6	2.8
Kamchatka flounder	489	3.5	32.1	33.8	7.6	3.3
Pacific cod	254	2.9	51.0	33.1	7.8	8.7
Pacific grenadier	1034	2.8	16.8	34.2	7.5	0.6
Pacific halibut	348	3.3	45.7	33.4	7.7	6.0
Pacific ocean perch	247	3.2	56.0	33.2	7.8	8.3
popeye grenadier	877	3.0	21.4	34.1	7.5	0.8
rex sole	344	3.4	46.0	33.4	7.7	6.0
roughtail skate	934	2.9	20.0	34.2	7.5	0.7
sablefish	632	3.4	28.1	34.0	7.6	1.6
shortraker rockfish	325	3.4	52.8	33.3	7.7	6.5
shortspine thornyhead	529	3.5	32.2	33.8	7.6	2.8
triangle tanner crab	927	3.0	19.6	34.2	7.6	0.7
walleye pollock	262	2.9	52.8	33.2	7.8	8.5
western eelpout	601	3.4	28.4	34.0	7.5	1.5
whiteblotched skate	456	3.5	31.2	33.7	7.7	3.8

LAB ONE | TEACHER KEY WORKSHEET 1.4 | Weighted means for all species

Table 1. Range and weighted mean (by CPUE #/ha) values for environmental parameters of species encountered during the 2012 Eastern Bering Sea Slope survey.

	Weighted Mean (by CPUE #/ha)					
Species	depth	temp	light	salinity	pH	DO mg/L (ppm)
skates	530	3.2	33.4	33.7	7.7	4.1
flatfish	363	3.3	41.0	33.5	7.7	5.7
Alaska skate	296	2.8	45.7	33.3	7.8	7.9
Aleutian skate	576	3.3	31.1	33.8	7.6	3.0
arrowtooth flounder	371	3.3	38.3	33.5	7.7	5.5
Bering skate	334	3.2	42.3	33.4	7.8	6.7
bigmouth sculpin	313	3.0	47.7	33.3	7.8	7.2
commander skate	765	3.2	22.6	34.1	7.6	1.0
flathead sole	305	3.1	47.1	33.4	7.8	7.0
giant grenadier	752	3.2	24.2	34.0	7.6	1.3
golden king crab	506	3.4	32.8	33.7	7.6	3.2
Greenland turbot	428	3.4	34.6	33.6	7.7	4.1
Kamchatka flounder	453	3.4	34.7	33.7	7.7	4.0
Pacific cod	251	2.9	51.4	33.1	7.8	8.8
Pacific grenadier	1023	2.9	17.1	34.2	7.5	0.6
Pacific halibut	329	3.3	46.0	33.3	7.8	6.4
Pacific ocean perch	247	3.2	56.8	33.2	7.8	8.3
popeye grenadier	874	3.0	21.1	34.1	7.6	0.8
rex sole	347	3.4	44.9	33.4	7.7	6.0
roughtail skate	961	2.9	19.7	34.2	7.5	0.7
sablefish	610	3.4	28.7	33.9	7.6	1.8
shortraker rockfish	380	3.5	44.6	33.5	7.7	5.1
shortspine thornyhead	463	3.5	34.8	33.7	7.6	3.7
triangle tanner crab	929	3.0	19.7	34.2	7.6	0.6
walleye pollock	267	2.8	50.3	33.2	7.8	8.6
western eelpout	648	3.4	27.2	34.0	7.5	1.4
whiteblotched skate	499	3.5	28.3	33.8	7.6	3.2

Ocean Data View: Spatial Analysis

OBJECTIVE

Students will analyze the spatial relationship between fish and invertebrate species and oceanographic data, and create plots using Ocean Data View software.

TIME REQUIREMENT

2 class periods of approximately 55 minutes each

BACKGROUND

Oceanographic conditions on the eastern Bering Sea (EBS) slope are relatively stable when compared to the upper shelf, estuarine and surface waters. Temperature, pH, and oxygen levels remain stable within a year and across multiple years. In general, deep-dwelling species have low metabolic rates, late maturity and limited food resources, leading to a scavenging lifestyle. These species have adapted to the stable conditions and can be more sensitive to subtle changes in water conditions than most shallower occurring species. Ocean diversity and the interactions between the ecosystem and species at all levels are influenced by climate change, the associated carbon dioxide sequestration, and ocean acidification. The effects are expected to be greater in shallower environments, but effects are also predicted for the deep sea environments. As fisheries expand into deeper environments, a more detailed understanding of the effects of climate change and fishing on deep sea organisms will lead to better information for management decisions.

The EBS slope contains some of the largest fish biomass in the world. The shelf-slope interface is incised with a series of deepwater canyons, several of which cut deeply into the shelf environment. The habitat is characterized as being homogeneous soft sand and mud with small patches of boulder fields or rock outcroppings. The EBS shelf-slope interface is a highly dynamic area where nutrient-rich deep slope waters are up-welled onto the shelf, feeding primary production. Light and primary production do not penetrate into deeper waters beyond about 300 m, creating an environment that relies solely on the settlement of food particles from upper water column primary production to supply food resources to the deeper ecosystems. More than 500 fish and invertebrate species dwell along the EBS upper slope and all rely on the productivity of the shelf edge. Annual water temperatures vary little along the upper slope. During winter, the shallow waters of the EBS shelf are covered by vast areas of ice and extremely cold water temperatures, altering the distribution of important upper trophic level species. Many shelf species find refuge in the deeper, relatively “warm” waters of the upper slope, and depend on this seasonal habitat to survive the harsh EBS winters. Major disturbances to the upper photic zone, evident from climate change, may produce drastic and long-lasting effects to deeper-dwelling ecosystems due to this dependency. In addition, because of the stability of the deep ocean systems, slight disturbances to conditions such as temperature, pH, dissolved oxygen and salinity may also affect recruitment, food availability, distribution, and behavior of a variety of deep water species.

MATERIALS

- Ocean Data View (ODV)
- Ocean Data View data file folder: NOAAFisheries_ODV_EBS-Slope

PROCEDURES: Installing Ocean Data View

- Download a free copy of Ocean Data View (ODV) and install it on as many computers as necessary. Students may work individually or in pairs.
- Copy the ODV folder provided with this curriculum to a network drive or onto each computer that will be running ODV.
- Start Ocean Data View. Go to File and Open the ODV file NMFS_EBS-Slope_data.odv

RESOURCES

Ocean Data View (ODV) Schlitzer, R., Ocean Data View, http://odv.awi.de/en/home/.

PROCEDURES - OCEAN DATA VIEW (all ages)

Ocean Data View (ODV) is a free software that provides spatial display and analysis of oceanographic data. For these exercises the X and Y variables will be longitude (X) and latitude (Y). The Z-variables will be selected from the data provided with the curriculum.

VARIABLES OF INTEREST (z-variables):

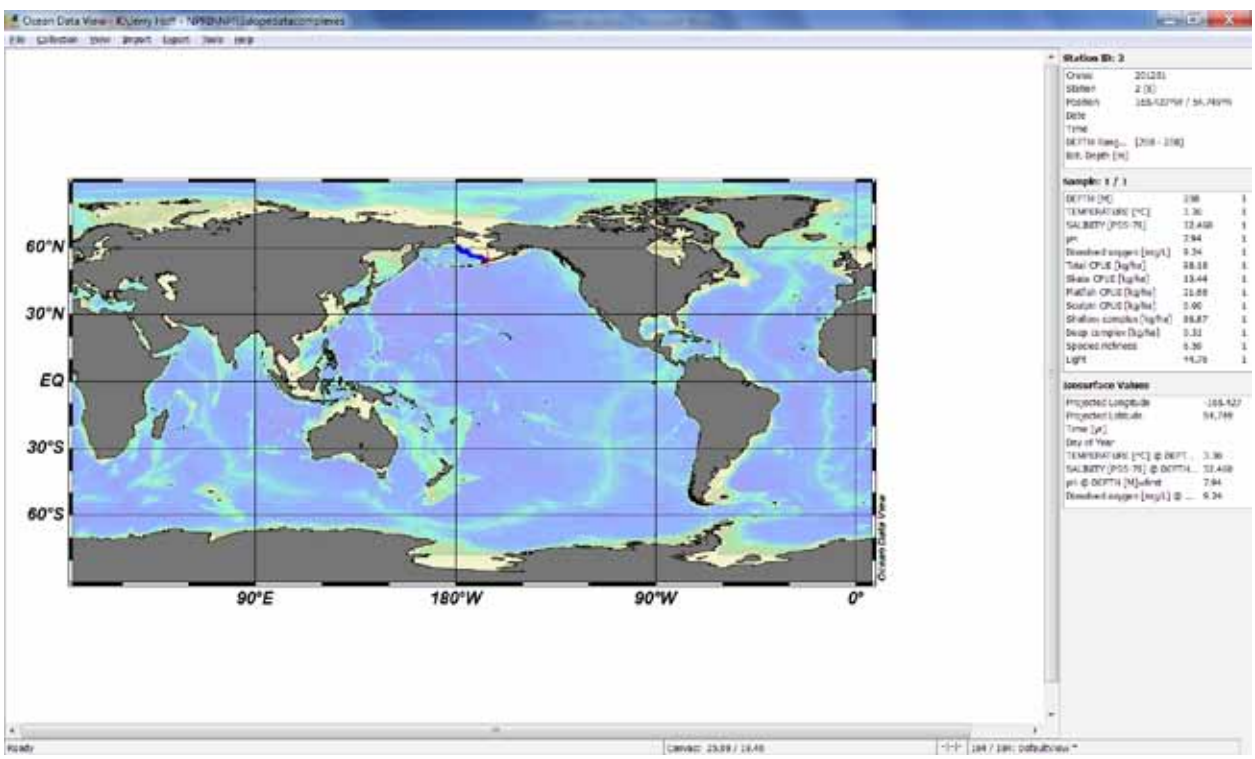
Depth, salinity, temperature, pH, light, dissolved oxygen
Species richness, Total CPUE, Skate CPUE, Flatfish CPUE, Shallow complex, Deep complex, and CPUE (Kg/ha) for each individual species

Deep complex: Pacific grenadier, triangle tanner crab, roughtail skate, popeye grenadier, giant grenadier, Commander skate, sablefish, western eelpout, shortspine thornyhead, Greenland turbot, Kamchatka flounder, whiteblotched skate

Shallow complex: arrowtooth flounder, Aleutian skate, golden king crab, Bering skate, Pacific halibut, flathead sole, rex sole, shortraker rockfish, bigmouth sculpin, Alaska skate, Pacific cod, walleye pollock, Pacific ocean perch

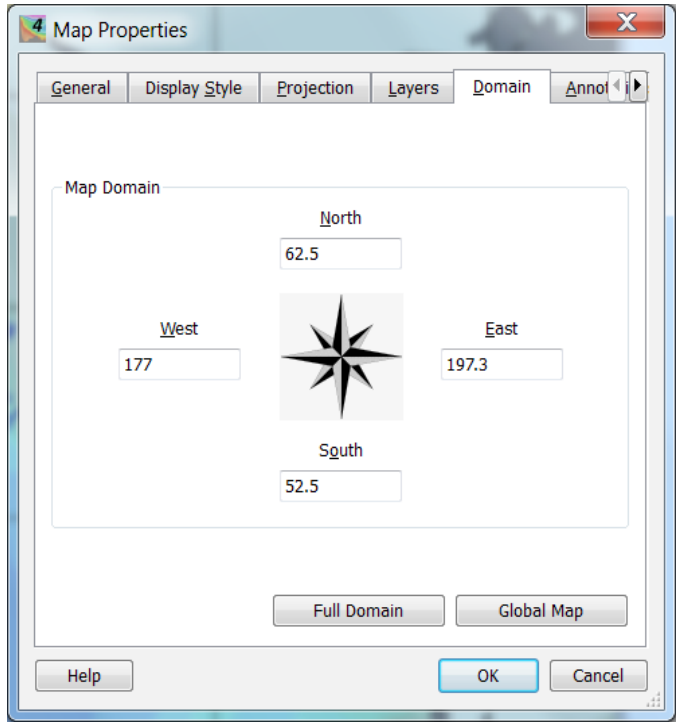
GETTING STARTED

In ODV, start with the global map to orient students to the sampling area.



ZOOM IN:

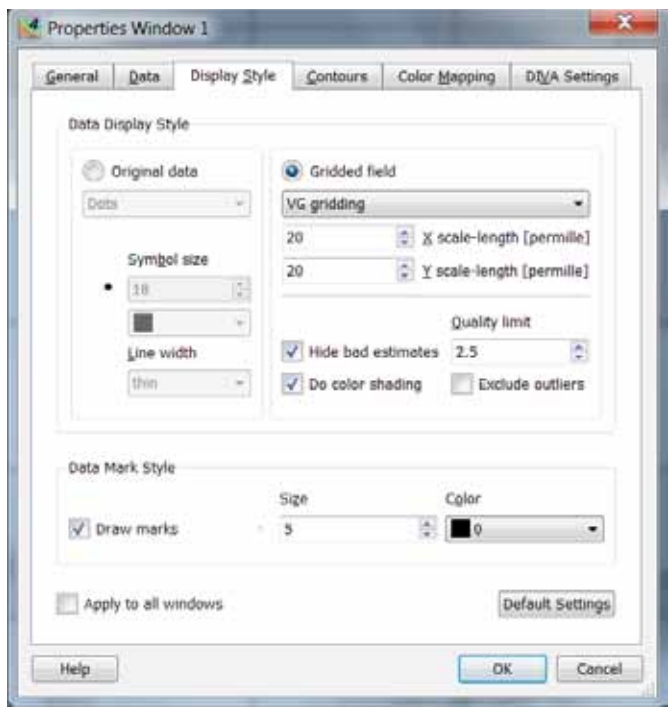
1. Right click
2. Select *Map properties* and click on the *Domain* tab.
3. Set the coordinates as shown below. Press OK.

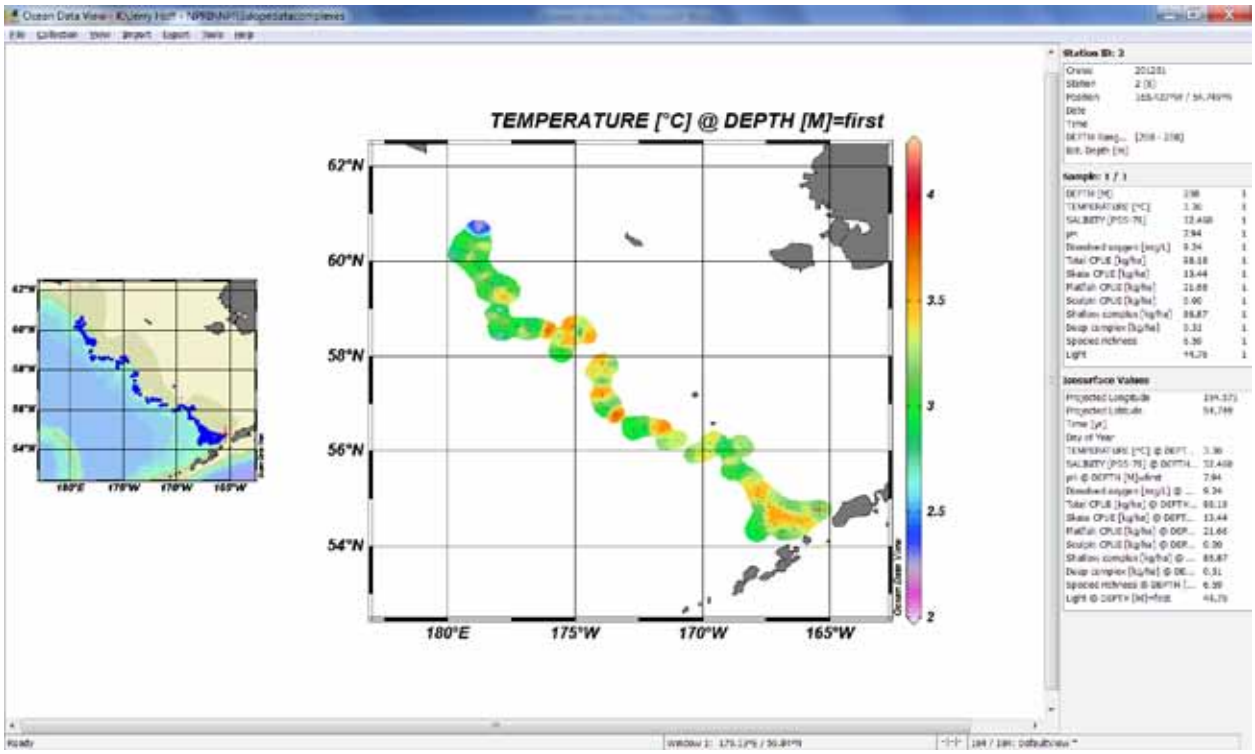


STATION FEATURES

1. Click on the *View* tab at the top of the screen.
2. Select *Layout templates*/SURFACE window.
3. Right click on the new window.
4. Select *Properties* and click the *Display Style* tab.
5. Settings: Choose *Gridded field*, Data mark style at size 5, and X and Y length at 20 as shown below. Press OK.

This creates an iso-surface map. The actual data collection sites are shown as black dots. The program interpolates among stations to form a continuous rendition of predicted conditions on the sampled grounds.





From here, the variables can be changed to look at environmental and species CPUE observations and predictions across the sampled grounds. The key is along the right side and the units are given in the window heading. Individual stations can be looked at by clicking on the black dot of choice. The values for that station will be listed on the right side of the screen as shown above.

To change the variables:

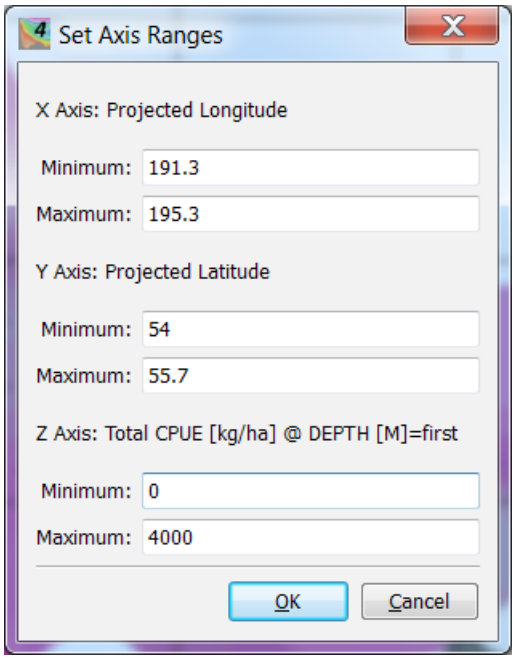
1. Right click on the surface map and select *Z Variable*.
2. Choose the desired variable.
3. When switching from one variable to the next, it may be necessary to R click again on the surface window and select *Full Range*. This resets the scale bar.

It is best to begin with *Depth* as the *Z variable* to understand the bathymetry. As variables are changed, note how they are different or the same from shallow to deep, from north to south, and from east to west.

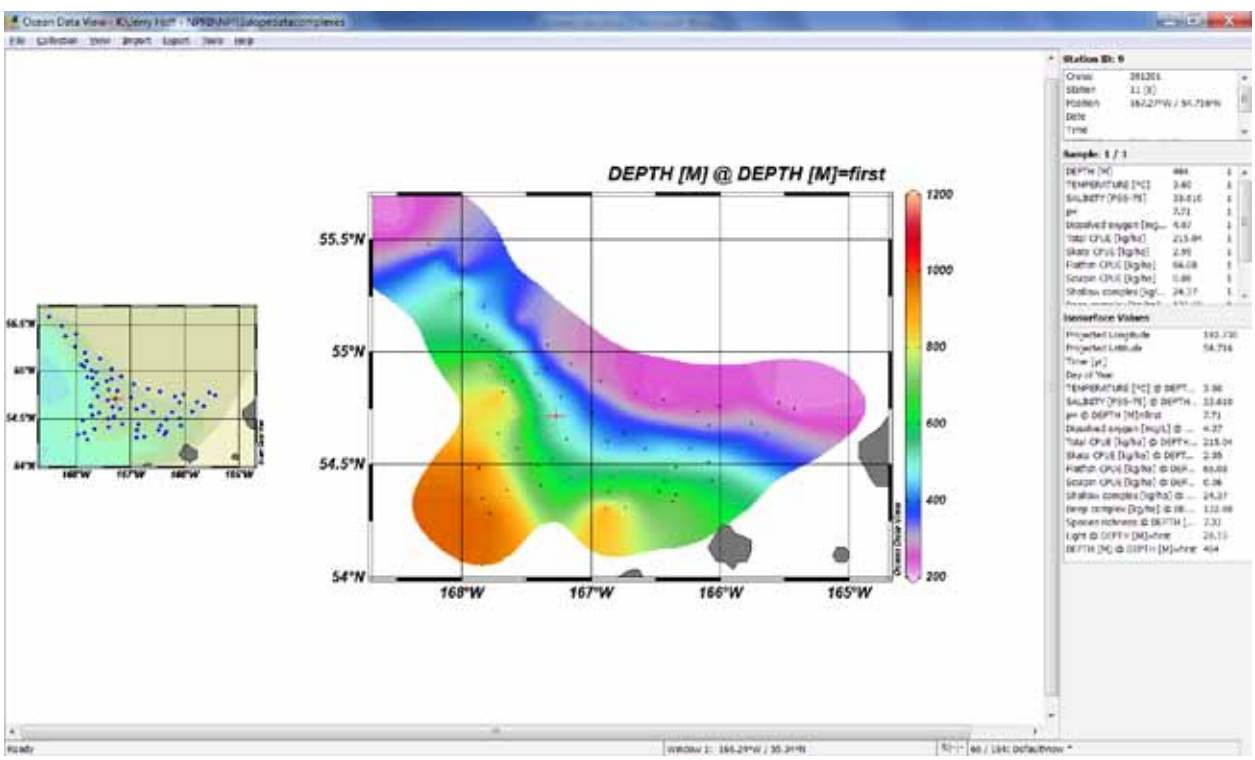
The area to the south is a more gradual slope than the remaining area, and allows a good glimpse at the differences among depths.

Zoom in on the this area to the south

1. Right click on the surface window.
2. Select *Set Ranges* and set the x-axis and y-axis minimum and maximums as shown below. Click OK. This sets the view to the EBS slope survey area.



This will result in a zoomed map of the southern slope. To make the stations more visible, right click on the map, select *properties/display style* and change the data mark size to 7. Press OK. This increases the size of the stations on the screen.

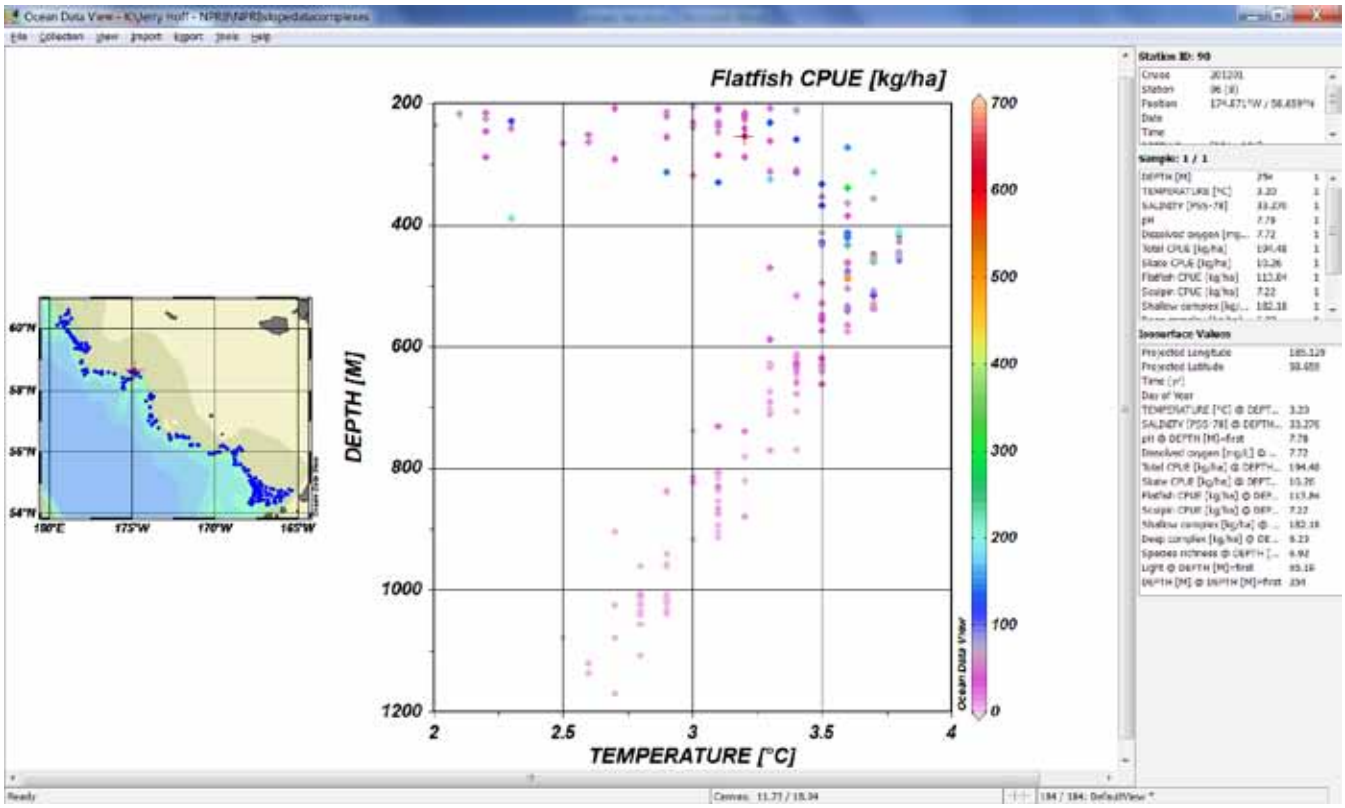


On the new map, begin once again with depth and then change the Z-variable as was done with the larger map, i.e. right click on the map, choose *Z-variable* and select the variable of interest. Press OK.

Note the difference among the environmental conditions and species complexes from shallow to deep.

COMPARING VARIABLES

This exercise allows the comparison of variables with one another. For example, it allows students to look at how flatfish CPUE compares with temperature and depth, as shown in the example below. Note here in the example that temperature is on the x-axis, depth on the y-axis and flatfish CPUE is shown as colors.

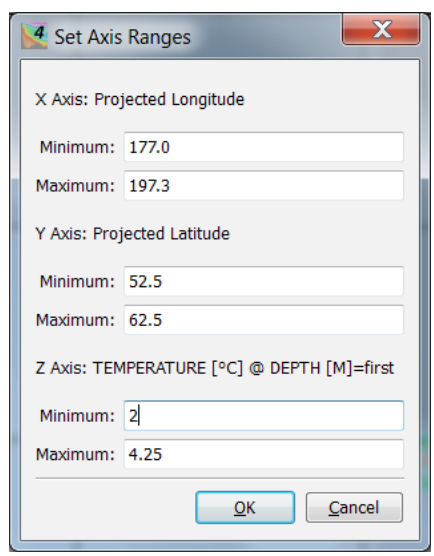


To get started:

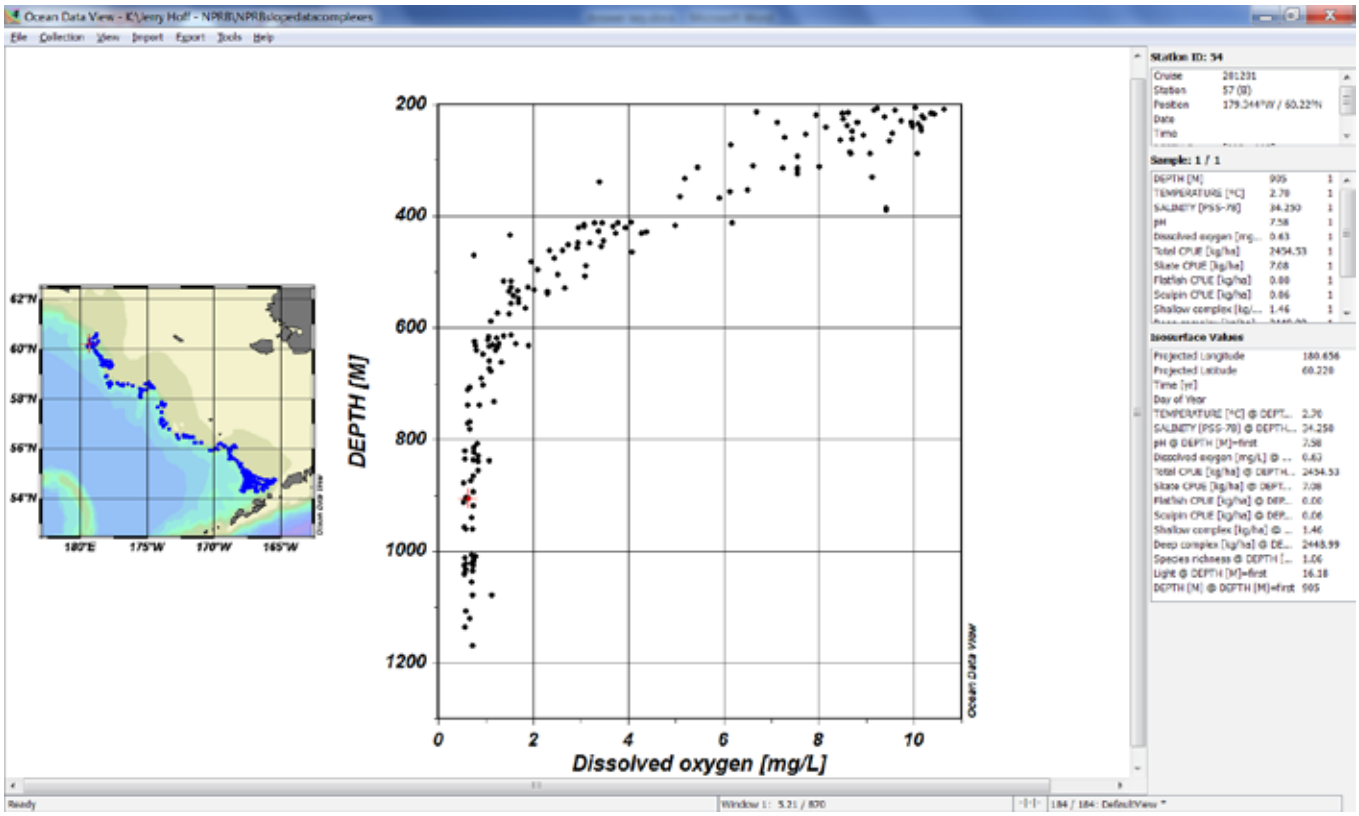
1. Zoom back out to the full area view by right clicking on the surface window and setting the X axis and Y axis coordinates as shown below. Press OK.

2. On the *View* tab at the top of the screen, choose *Layout templates* and select 1 *SCATTER Window*.

3. Begin by looking at two variables at a time. A good place to begin is with station depth on the y-axis and another variable of interest on the x-axis. Change the x-axis to see how that property changes with depth such as in the example below:



LAB TWO Ocean Data View: Spatial Analysis



In this example, DO is high at the more shallow stations and decreases dramatically in the top 500 meters or so and then stabilizes below this point.

1. To set/change variables, right click on the window and click on the variable (x or y) to change its properties.
2. Eventually add in a third variable (Z) which will be color coded as in the example at the beginning of this section.

Some interesting scatterplot comparisons:

X	Y	Z	Shows
All environmental variables	Depth	-	• Large changes in shallow water and leveling out mid-depth to stable values
All species variables	Depth	-	• Species groupings tend to occupy very specific depth strata. • Species richness (diversity) decreases with depth
Species richness	Depth	Total CPUE	• Richness is high where total CPUE is low and richness is lower when CPUE is high. This suggests species aggregations (i.e. species group together in clumps).
Species. richness	Depth	All species groupings	• Same holds true as with Total CPUE except in the case of Skate CPUE which shows some cases with high CPUE and high diversity (richness). Flatfish shows this as well to a lesser extent.

DISCUSSION

- How are environmental conditions different between shallow and deep?
- Is there a north/south difference in temperature?

  Cooler in the north, warmer to the south
- Describe the shallow water environmental conditions?

  More variable

  Rapid changes with depth

  Temperature low at surface, warmer mid-depth, then cooler again with greater depth

  DO higher in shallow water and lower at depth

  Light decreases with depth

  Lower salinity
- Describe the deep water environmental conditions

  Stable

  Low temperature

  Low DO

  Higher salinity

  Less/no light
- What is the relationship between individual species and species groups with depth?

  Species appear to occupy relatively specific depth strata, and tend to aggregate as opposed to evenly disperse.
- What do you notice about species diversity?

  Diversity is higher where CPUE is lower and vice-versa.
- How do the species tolerate changes in environmental parameters?

  Comparing the occupied depth strata for the species groupings along with environmental conditions at those depths indicates acceptable animal tolerances of the various environmental parameters.

EXPLORE AND EXTEND

- Research ocean acidification. What are the consequences of increasing acidification?
- Ocean acidification is a result of the changing climate. What other environmental variables are changing? How will these changes affect the oceans and the organisms living in the oceans?
- What are hypoxic zones and where are they found?
- How does the environment of the eastern Bering Sea slope compare to that of the eastern Bering Sea shelf or the Gulf of Alaska?
- Analyze the data with more sophisticated statistics.

RESOURCES

- NOAA Ocean Acidification: http://oceanacidification.noaa.gov/
- NOAA Pacific Marine Environmental Laboratory Carbon Program:
  - http://www.pmel.noaa.gov/co2/story/Ocean+Acidification
- NOAA Integrated Ocean Observing System Ocean Adicification:
  - http://www.ioos.noaa.gov/ocean_acidification/welcome.html
- NOAA Ocean Acidification Program on Facebook:
  - https://www.facebook.com/NoaaOceanAcidificationProgram

APPENDIX I Glossary

abundance The number of fish in a population.

anoxia Oxygen deficiency or absence of oxygen.

anthropogenic Originating in human activity.

Bering Sea Waters off the coast of Alaska north of the Aleutian Islands and south of the Bering Strait

Bering Sea shelf Shallow waters, 10-200 meters deep, off coast of AK.

Bering Sea slope Deep water, 200-1,200 meters deep, at the edge of the Bering Sea continental shelf.

biomass Measure of the quantity, usually by weight in pounds or metric tons, of a stock at a given time.

bottom trawl A fishing net that is dragged along the ocean floor to collect fish and invertebrates.

CPUE Catch per Unit of Effort. The quantity of fish caught (in number or weight) with one standard unit of fishing effort; e.g. number of fish or weight (kg) of fish caught per hectare (10,000 m^2). Hectares are calculated by multiplying the distance that the net was in contact with the ocean floor or distance fished (km) by the width of the net (m) and dividing by 10 to convert to hectares.

deep complex Defined as the animals where the bulk of their total biomass (CPUE kg/ha) was found near the deepest end of their depth range. Includes Pacific grenadier, Triangle tanner crab, roughtail skate, popeye grenadier, giant grenadier, Commander skate, sablefish, western eelpout, shortspine thornyhead, Greenland turbot, Kamchatka flounder, whiteblotched skate.

demersal Living in close relation with the bottom and depending on it. Cods, groupers, crabs, and lobsters are demersal species. The term usually refers to the living mode of the adult, i.e. demersal fish.

dissolved oxygen The amount of oxygen dissolved and therefore available to sustain marine life, in a body of water.

diversity The amount of

ecosystem A community of living organisms and their environment, and the interactions between the two. Humans are an integral part of an ecosystem.

fauna The animals of a particular region or habitat. The grouping of animals to a location or time.

groundfish Collective term loosely applied to most commercially harvested marine fish other than salmon, herring, mackerel, and tuna. Although many groundfish are demersal or bottom dwellers (e.g. yellowfin sole), other species are semidemersal or pelagic (e.g. pollock, cod).

hectare a measurement of area 10,000 m^2 (100 m x 100 m)

hypoxia Low oxygen. Water with less than 2 parts per million (ppm) or 2 mg/l of oxygen is considered hypoxic.

metadata Information that describes the data being analyzed.

NOAA An abbreviation for the National Oceanic and Atmospheric Administration, a federal government agency in the Department of Commerce, created in 1970. NOAA scientists conduct research on the world's oceans and atmosphere.

ocean acidification A reduction in the pH of seawater that is caused by the absorption of carbon dioxide.

otolith Otoliths or "earstones" are found in the heads of all fishes except sharks, rays, and lampreys. The otolith of each fish species has a distinctive shape. Otoliths are used to determine the age of the individual they came from. It is similar to counting rings on a tree.

pelagic Inhabiting the water column as opposed to being associated with the sea floor; generally occurring anywhere from the surface to 1,000 meters.

pH A scale that measures how acidic or basic a substance is. The scale ranges from 0-14 with 7 being neutral. Historical pH of surface seawater is about 8.2 but has decreased in recent years due to ocean acidification.

photic zone The region of water that is penetrated by light.

primary production (marine) The synthesis of new organic material through photosynthesis by marine phytoplankton

recruitment The number of fish surviving to enter the fishery or to some life history stage such as settlement or maturity.

APPENDIX I Glossary

shallow complex Defined as the animals where the bulk of their total biomass (CPUE kg/ha) was found near the shallowest end of their depth range. Includes arrowtooth flounder, Aleutian skate, Bering skate, golden king crab, Pacific halibut, flathead sole, rex sole, shortraker rockfish, bigmouth sculpin, Alaska skate, Pacific cod, walleye pollock, Pacific ocean perch.
species diversity The number of individuals from each species within a sample or community.
species richness A measure of how many species were in a given sample or a community.
tissue samples Tissue samples are taken to study genetics, diseases, and sexual maturity.

APPENDIX II Educational Standards

Ocean Literacy Principles

3 The ocean is a major influence on weather and climate.

e The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere.

f The ocean has had, and will continue to have , a significant influence on climate change by absorbing, storing , and moving heat, carbon and water.

5 The ocean supports a great diversity of life and ecosystems.

a Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.

d Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

e The ocean is three-dimensional, offering vast living space and diverse habitats form the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

f Ocean habitats are defined by environmental factors. Due to the interaction of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, ie., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

6 The ocean and humans are inextricably interconnected.

a The ocean affects every human life. It supplies freshwater and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.

b From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Alaska State Science Standards

Science as Inquiry and Process

SC2 Students develop an understanding of the structure, function, behavior, development, life cycles, and diversity of living organisms.

SC3.2 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by analyzing the potential impacts of changes within an ecosystem.

SE1 Students develop an understanding of how scientific knowledge and technology are used in making decisions about issues, innovations, and responses to problems and everyday events.

SE2 Students develop an understanding that solving problems involves different ways of thinking, perspectives, and curiosity that lead to the exploration of multiple paths that are analyzed using scientific, technological, and social merits.

SE3 Students develop an understanding of how scientific discoveries and technological innovations affect and are affected by our lives and cultures

Alaska State Science Standards

Statistics and Probability Standards

Interpreting Categorical and Quantitative Data

Washington State Science Standards 9-12

EALR 2 Inquiry Conducting Analyses and Thinking Logically: Increased understanding of the kinds of questions that scientists ask and how the results reflect the research methods and the criteria that scientific arguments are judged by.

EALR 3 Application. Big Idea: Application (APP). Core Content: Science, Technology, and Society: apply what they have learned to address societal issues and cultural differences. Students learn that science and technology are interdependent, that science and technology influence society, and that society influences science and technology. Students continue to increase their abilities to work with other students and to use mathematics and information technologies (when available) to solve problems. They transfer insights from those increased abilities when considering local, regional, and global issues. These insights and capabilities will help prepare students to solve societal and personal problems in future years.

Washington State Math Standards 9-12

M1.5 Data and distributions: Data/Statistics/Probability. Students select mathematical models for data sets and use those models to represent, describe, and compare data sets. They analyze the linear relationship between two statistical variables and make and defend appropriate predictions, conjectures, and generalizations based on data. Students understand limitations of conclusions drawn from the results of a study or an experiment and recognize common misconceptions and misrepresentations.

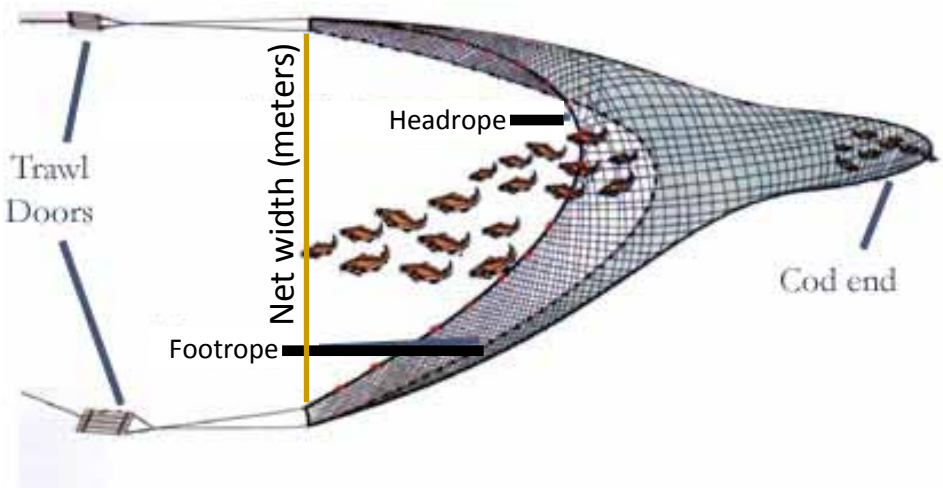
APPENDIX III Figure 1: Survey Location

Figure 1. Map of survey and study area in the eastern Bering Sea. Location of trawl survey is contained in the six sub-areas along the slope from 200-1,200 m.

APPENDIX IV Figure 2: Oceanographic Equipment

Figure 2. Electronic oceanographic data loggers used during this study. The Seabird SBE collected depth and temperature (upper left), the Seaguard oceanographic data logger used to collect depth, temperature, salinity, pH, oxygen, and turbidity (upper right) and the Wildlife MK9 light meter used to measure relative light levels.

APPENDIX V Bottom Trawl Diagram



APPENDIX VI CPUE - Catch per Unit of Effort

Catch per unit effort (CPUE) is a measure of either weight (kg/ha) or number (#/ha) of individuals, standardized to a unit of area, allowing direct comparisons among sampling sites and species. CPUE is a widely accepted estimator of fish abundance used to manage fish populations around the world. It is assumed that CPUE is directly proportional to the actual abundance of a stock.

CPUE example: CPUE (kg/ha) for Alaska Skate in a haul

1. Determine the weight of Alaska skate caught in a haul. There are two different methods used to calculate the total weight of a species in the catch.

   1) weigh all of the individuals caught in one tow or sample for a specific species

   2) take a subsample of the total catch, weigh all of the different species in the subsample, and determine the total weight of each species for the tow or sample through extrapolation.

2. Calculate the area the trawl covered during the tow.

   Area = distance the net was towed * average width of the net

   Distance fished is calculated in kilometers using a geographical positioning system (GPS)

   Net width is measured in meters and is an average value obtained from equipment attached to the net that records the width of the net every couple of seconds.

3. Equation for CPUE(kg/ha)

$$\text{CPUE (kg/ha)} = \frac{\text{weight (kg) of a species caught during one haul}}{\text{Area:* (tow length (km) x net width (m/1,000)) x 100}}$$

*The area calculation must be converted to hectares. A hectare (ha) is a measurement of area that is 10,000 m^2 (100 m x 100) m or 0.01 km^2.

To get from (km*m) to hectares, there are two steps.
1. Convert meters to km: divide meters by 1,000. Area is now in km^2.
2. Convert km^2 to hectares: multiple km^2 by 100.
NOTE: Dividing (length (km)* net width (m)) by 10 is a shortcut for the previous two steps.

$$\text{CPUE (kg/ha)} = \frac{\text{weight (kg) of Alaska skate caught during one haul}}{\text{area sampled during the haul - (length (km) x width (m)) / 10}}$$

4. Example: Haul #1 contained 500 kg of Alaska skate. The distance fished was 2.754 km and net width = 17.457 m. What is the CPUE (kg/ha) of Alaska skate?

$$\text{CPUE (kg/ha)} = \frac{500 \text{ kg}}{(2.754 \text{ km} * 17.457 \text{ m})/10}$$

$$= 500\text{kg} / 4.8077\text{ha}$$

$$= 140.00 \text{ kg/ha is the CPUE for Alaska skate in Haul \#1}$$

Translation: A foot ball field is 48,000 ft^2 (300 ft by 160 ft) or 0.45 hectares. Put two football fields next to each other and their area will equal 0.90 hectares. If each Alaska skate weighed 1.0 kg, then there would be 140 Alaska skates spread throughout the 2 football fields.