

Introduction

Desiree Zhuk

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Introduction

Historical challenges faced by southern sea otters (*Enhydra lutris*), in particular habitat loss and degradation due to human activities, have raised concerns about their population stagnation and limited genetic diversity in concentrated areas (Larson et al., 2012). There has also been a rise in recent years of white shark bites being the most common cause of death along the outer edges of the growing southern sea otter population (Miller et al., 2020), as sharks seem to confuse otters for young seals which are the shark's main prey source. The increasing occurrence of white sharks mistargeting southern sea otters is intensifying throughout the year, disrupting sea otter recovery efforts and necessitating a reevaluation of management strategies that traditionally overlook such dynamic predator-prey conflicts (Moxley et al., 2019). San Francisco Bay (SFB) may provide a vital population localization that can bypass the shark/sea otter conflict. This is because SFB is predominantly a shallow estuary with an average depth of 6m (Conomos et al., 1985), while white sharks avoid the surface and use water to 50m depth when near pinniped rookeries as part of their hunting strategy (Moxley et al., 2019). However, the successful re-colonization of sea otters in SFB, and the appropriateness of instigating a formal reintroduction effort, hinges on an understanding of how the animals can succeed in establishing their habitat in low risk areas away from vessel traffic with adequate foraging possibilities (Rudebusch et al., 2020). The purpose of this thesis study is to assess the benthic invertebrate communities across ten sites within the envisioned foraging range of California sea otters within SFB, mirroring their natural feeding behaviors. This data will be compared with invertebrate assemblages from Elkhorn Slough to evaluate the potential of these sites to support sustainable sea otter populations and to inform future conservation management. The project for class 710 in specific is to assess (1) diversity indexes and (2) abundances of benthic invertebrates using a fake dataset modelled to be a prediction of the data to be collected within the next year.

Analysis

The Null hypothesis is that all sites will have the same species diversity. The Alternate hypothesis is that some sites will have different species diversity.

The best statistical approach would be the Shannon diversity index. The higher the value of the Shannon index, the higher the diversity of species in a particular community. The lower the value of the Shannon index, the lower the diversity. A value of 0 indicates a community that only has one species. The best associated visualization would be a bar graph, to easily see the difference of the numerical output the Shannon index has.

```
library(tidyverse)
```

```
## Warning: package 'tidyverse' was built under R version 4.3.2
```

```
## Warning: package 'ggplot2' was built under R version 4.3.3
```

```
## Warning: package 'stringr' was built under R version 4.3.3
```

```
library(openintro)
```

```
## Warning: package 'openintro' was built under R version 4.3.2
```

```
## Warning: package 'airports' was built under R version 4.3.2
```

```
## Warning: package 'cherryblossom' was built under R version 4.3.2
```

```
## Warning: package 'usdata' was built under R version 4.3.2
```

```
library(plyr)
```

```
## Warning: package 'plyr' was built under R version 4.3.3
```

```
library(naniar)
```

```
## Warning: package 'naniar' was built under R version 4.3.3
```

```
library(vegan)
```

```
## Warning: package 'permute' was built under R version 4.3.2
```

```
library(ggpubr)
```

```
## Warning: package 'ggpubr' was built under R version 4.3.3
```

```
library(labdsv)
```

```
## Warning: package 'labdsv' was built under R version 4.3.3
```

```
# Importing data
```

```
benthic <- read.csv("FakeBenthicDataset.csv",header=TRUE)
```

```
# viewing the data
```

```
benthic
```

```
##           Date      Time      Location Weather Crab.Trap.or.Pitfall.Trap
## 1 6/14/2024 7:00 AM Pinole Shores Sunny Crab Trap
## 2 6/14/2024 7:00 AM Pinole Shores Sunny Crab Trap
## 3 6/14/2024 7:00 AM Pinole Shores Sunny Crab Trap
## 4 6/14/2024 7:00 AM Pinole Shores Sunny Crab Trap
## 5 6/14/2024 7:00 AM Pinole Shores Sunny Crab Trap
## 6 6/14/2024 7:00 AM Pinole Shores Sunny Crab Trap
## 7 6/14/2024 7:00 AM Pinole Shores Sunny Crab Trap
## 8 6/14/2024 7:00 AM Pinole Shores Sunny Crab Trap
## 9 6/14/2024 9:00 AM Point Pinole Sunny Crab Trap
## 10 6/14/2024 9:00 AM Point Pinole Sunny Crab Trap
```

## 11	6/14/2024	9:00 AM	Point Pinole	Sunny	Crab Trap
## 12	6/14/2024	9:00 AM	Point Pinole	Sunny	Crab Trap
## 13	6/14/2024	9:00 AM	Point Pinole	Sunny	Crab Trap
## 14	6/14/2024	9:00 AM	Point Pinole	Sunny	Crab Trap
## 15	6/14/2024	9:00 AM	Point Pinole	Sunny	Crab Trap
## 16	6/14/2024	9:00 AM	Point Pinole	Sunny	Pitfall Trap
## 17	6/14/2024	9:00 AM	Point Pinole	Sunny	Pitfall Trap
## 18	6/14/2024	9:00 AM	Point Pinole	Sunny	Pitfall Trap
## 19	6/14/2024	9:00 AM	Point Pinole	Sunny	Pitfall Trap
## 20	6/14/2024	9:00 AM	Point Pinole	Sunny	Pitfall Trap
## 21	6/14/2024	9:00 AM	Point Pinole	Sunny	Pitfall Trap
## 22	6/14/2024	9:00 AM	Point Pinole	Sunny	Pitfall Trap
## 23	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 24	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 25	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 26	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 27	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 28	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 29	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 30	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 31	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 32	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 33	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 34	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 35	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 36	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 37	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 38	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 39	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 40	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 41	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 42	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 43	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 44	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 45	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 46	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 47	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 48	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 49	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 50	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 51	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 52	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 53	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 54	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 55	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 56	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 57	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 58	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 59	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
##			Species	Carapace.Length..mm.	Shell.Length
## 1			Metacarcinus magister	39	-
## 2			Metacarcinus magister	42	-
## 3			Metacarcinus magister	41	-
## 4			Hemigrapsus nudus	12	-

## 5	Hemigrapsus nudus	25	-	-
## 6	Hemigrapsus oregonensis	21	-	-
## 7	Metacarcinus magister	53	-	-
## 8	Cancer productus	80	-	-
## 9	Hemigrapsus oregonensis	23	-	-
## 10	Leptocottus armatus	-	-	-
## 11	Cancer productus	57	-	-
## 12	Metacarcinus magister	49	-	-
## 13	Leptocottus armatus	-	-	-
## 14	Leptocottus armatus	-	-	-
## 15	Cancer productus	41	-	-
## 16	Gemma gemma		5	-
## 17	Pachygrapsus crassipes	41	-	-
## 18	Ostrea lurida		61	-
## 19	Hemigrapsus nudus	16	-	-
## 20	Hemigrapsus oregonensis	19	-	-
## 21	Sipuncula spp.	-	-	68
## 22	Hemigrapsus oregonensis	24	-	-
## 23	Leptocottus armatus	-	-	-
## 24	Cancer productus	68	-	-
## 25	Cancer productus	23	-	-
## 26	Leptocottus armatus	-	-	-
## 27	Hemigrapsus nudus	21	-	-
## 28	Metacarcinus gracilis	78	-	-
## 29	Metacarcinus gracilis	45	-	-
## 30	Metacarcinus magister	48	-	-
## 31	Metacarcinus magister	39	-	-
## 32	Metacarcinus gracilis	56	-	-
## 33	Cancer productus	78	-	-
## 34	Hemigrapsus nudus	18	-	-
## 35	Metacarcinus magister	38	-	-
## 36	Leptocottus armatus	-	-	-
## 37	Metacarcinus magister	41	-	-
## 38	Pachygrapsus crassipes	43	-	-
## 39	Leptocottus armatus	-	-	-
## 40	Metacarcinus gracilis	23	-	-
## 41	Pachygrapsus crassipes	45	-	-
## 42	Metacarcinus magister	47	-	-
## 43	Metacarcinus gracilis	40	-	-
## 44	Metacarcinus magister	4	-	-
## 45	Pachygrapsus crassipes	32	-	-
## 46	Hemigrapsus nudus	23	-	-
## 47	Cancer productus	101	-	-
## 48	Ostrea lurida	-	45	-
## 49	Gemma gemma	-	6	-
## 50	Hemigrapsus nudus	11	-	-
## 51	Gemma gemma	-	3	-
## 52	Hemigrapsus nudus	15	-	-
## 53	Ostrea lurida	-	53	-
## 54	Hemigrapsus oregonensis	16	-	-
## 55	Ostrea lurida	-	67	-
## 56	Hemigrapsus oregonensis	17	-	-
## 57	Pachygrapsus crassipes	28	-	-
## 58	Ostrea lurida	-	61	-

```
summary(benthic)
```

```
##      Date           Time           Location           Weather
## Length:59         Length:59         Length:59         Length:59
## Class :character   Class :character   Class :character   Class :character
## Mode  :character   Mode  :character   Mode  :character   Mode  :character
## Crab.Trap.or.Pitfall.Trap Species      Carapace.Length..mm.
## Length:59         Length:59         Length:59
## Class :character   Class :character   Class :character
## Mode  :character   Mode  :character   Mode  :character
## Shell.Length       Worm.Length
## Length:59         Length:59
## Class :character   Class :character
## Mode  :character   Mode  :character
```

```
# change - to NA
```

```
benthic$Carapace.Length..mm._NA <- gsub("-", 0, benthic$Carapace.Length..mm.) %>% as.numeric() %>% tidy
benthic$Shell.Length_NA <- gsub("-", 0, benthic$Shell.Length) %>% as.numeric() %>% tidyr::replace_na(0)
benthic$Worm.Length_NA <- gsub("-", 0, benthic$Worm.Length) %>% as.numeric() %>% tidyr::replace_na(0)

benthic %>% naniar::replace_with_na(replace = list(x = 0))
```

```
## Warning: Missing from data: 'x'
```

```
##      Date      Time      Location Weather Crab.Trap.or.Pitfall.Trap
## 1 6/14/2024 7:00 AM Pinole Shores Sunny      Crab Trap
## 2 6/14/2024 7:00 AM Pinole Shores Sunny      Crab Trap
## 3 6/14/2024 7:00 AM Pinole Shores Sunny      Crab Trap
## 4 6/14/2024 7:00 AM Pinole Shores Sunny      Crab Trap
## 5 6/14/2024 7:00 AM Pinole Shores Sunny      Crab Trap
## 6 6/14/2024 7:00 AM Pinole Shores Sunny      Crab Trap
## 7 6/14/2024 7:00 AM Pinole Shores Sunny      Crab Trap
## 8 6/14/2024 7:00 AM Pinole Shores Sunny      Crab Trap
## 9 6/14/2024 9:00 AM Point Pinole Sunny      Crab Trap
## 10 6/14/2024 9:00 AM Point Pinole Sunny      Crab Trap
## 11 6/14/2024 9:00 AM Point Pinole Sunny      Crab Trap
## 12 6/14/2024 9:00 AM Point Pinole Sunny      Crab Trap
## 13 6/14/2024 9:00 AM Point Pinole Sunny      Crab Trap
## 14 6/14/2024 9:00 AM Point Pinole Sunny      Crab Trap
## 15 6/14/2024 9:00 AM Point Pinole Sunny      Crab Trap
## 16 6/14/2024 9:00 AM Point Pinole Sunny      Pitfall Trap
## 17 6/14/2024 9:00 AM Point Pinole Sunny      Pitfall Trap
## 18 6/14/2024 9:00 AM Point Pinole Sunny      Pitfall Trap
## 19 6/14/2024 9:00 AM Point Pinole Sunny      Pitfall Trap
## 20 6/14/2024 9:00 AM Point Pinole Sunny      Pitfall Trap
## 21 6/14/2024 9:00 AM Point Pinole Sunny      Pitfall Trap
## 22 6/14/2024 9:00 AM Point Pinole Sunny      Pitfall Trap
## 23 6/14/2024 12:00 PM Castro Cove Sunny      Crab Trap
## 24 6/14/2024 12:00 PM Castro Cove Sunny      Crab Trap
## 25 6/14/2024 12:00 PM Castro Cove Sunny      Crab Trap
```

## 26	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 27	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 28	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 29	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 30	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 31	6/14/2024	12:00 PM	Castro Cove	Sunny	Crab Trap
## 32	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 33	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 34	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 35	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 36	6/14/2024	1:00 PM	Point San Pablo	Sunny	Crab Trap
## 37	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 38	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 39	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 40	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 41	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 42	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 43	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 44	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 45	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 46	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 47	6/14/2024	3:00 PM	Richardson Bay	Foggy	Crab Trap
## 48	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 49	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 50	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 51	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 52	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 53	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 54	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 55	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 56	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 57	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 58	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
## 59	6/14/2024	3:00 PM	Richardson Bay	Foggy	Pitfall Trap
##	Species Carapace.Length..mm. Shell.Length Worm.Length				
## 1	Metacarcinus	magister	39	-	-
## 2	Metacarcinus	magister	42	-	-
## 3	Metacarcinus	magister	41	-	-
## 4	Hemigrapsus	nudus	12	-	-
## 5	Hemigrapsus	nudus	25	-	-
## 6	Hemigrapsus	oregonensis	21	-	-
## 7	Metacarcinus	magister	53	-	-
## 8	Cancer	productus	80	-	-
## 9	Hemigrapsus	oregonensis	23	-	-
## 10	Leptocottus	armatus	-	-	-
## 11	Cancer	productus	57	-	-
## 12	Metacarcinus	magister	49	-	-
## 13	Leptocottus	armatus	-	-	-
## 14	Leptocottus	armatus	-	-	-
## 15	Cancer	productus	41	-	-
## 16	Gemma	gemma		5	-
## 17	Pachygrapsus	crassipes	41	-	-
## 18	Ostrea	lurida		61	-
## 19	Hemigrapsus	nudus	16	-	-

## 20	Hemigrapsus oregonensis	19	-	-
## 21	Sipuncula spp.	-	-	68
## 22	Hemigrapsus oregonensis	24	-	-
## 23	Leptocottus armatus	-	-	-
## 24	Cancer productus	68	-	-
## 25	Cancer productus	23	-	-
## 26	Leptocottus armatus	-	-	-
## 27	Hemigrapsus nudus	21	-	-
## 28	Metacarcinus gracilis	78	-	-
## 29	Metacarcinus gracilis	45	-	-
## 30	Metacarcinus magister	48	-	-
## 31	Metacarcinus magister	39	-	-
## 32	Metacarcinus gracilis	56	-	-
## 33	Cancer productus	78	-	-
## 34	Hemigrapsus nudus	18	-	-
## 35	Metacarcinus magister	38	-	-
## 36	Leptocottus armatus	-	-	-
## 37	Metacarcinus magister	41	-	-
## 38	Pachygrapsus crassipes	43	-	-
## 39	Leptocottus armatus	-	-	-
## 40	Metacarcinus gracilis	23	-	-
## 41	Pachygrapsus crassipes	45	-	-
## 42	Metacarcinus magister	47	-	-
## 43	Metacarcinus gracilis	40	-	-
## 44	Metacarcinus magister	4	-	-
## 45	Pachygrapsus crassipes	32	-	-
## 46	Hemigrapsus nudus	23	-	-
## 47	Cancer productus	101	-	-
## 48	Ostrea lurida	-	45	-
## 49	Gemma gemma	-	6	-
## 50	Hemigrapsus nudus	11	-	-
## 51	Gemma gemma	-	3	-
## 52	Hemigrapsus nudus	15	-	-
## 53	Ostrea lurida	-	53	-
## 54	Hemigrapsus oregonensis	16	-	-
## 55	Ostrea lurida	-	67	-
## 56	Hemigrapsus oregonensis	17	-	-
## 57	Pachygrapsus crassipes	28	-	-
## 58	Ostrea lurida	-	61	-
## 59	Sipuncula spp.	-	-	142
##	Carapace.Length..mm._NA	Shell.Length_NA	Worm.Length_NA	
## 1	39	0	0	
## 2	42	0	0	
## 3	41	0	0	
## 4	12	0	0	
## 5	25	0	0	
## 6	21	0	0	
## 7	53	0	0	
## 8	80	0	0	
## 9	23	0	0	
## 10	0	0	0	
## 11	57	0	0	
## 12	49	0	0	
## 13	0	0	0	

## 14	0	0	0
## 15	41	0	0
## 16	0	5	0
## 17	41	0	0
## 18	0	61	0
## 19	16	0	0
## 20	19	0	0
## 21	0	0	68
## 22	24	0	0
## 23	0	0	0
## 24	68	0	0
## 25	23	0	0
## 26	0	0	0
## 27	21	0	0
## 28	78	0	0
## 29	45	0	0
## 30	48	0	0
## 31	39	0	0
## 32	56	0	0
## 33	78	0	0
## 34	18	0	0
## 35	38	0	0
## 36	0	0	0
## 37	41	0	0
## 38	43	0	0
## 39	0	0	0
## 40	23	0	0
## 41	45	0	0
## 42	47	0	0
## 43	40	0	0
## 44	4	0	0
## 45	32	0	0
## 46	23	0	0
## 47	101	0	0
## 48	0	45	0
## 49	0	6	0
## 50	11	0	0
## 51	0	3	0
## 52	15	0	0
## 53	0	53	0
## 54	16	0	0
## 55	0	67	0
## 56	17	0	0
## 57	28	0	0
## 58	0	61	0
## 59	0	0	142

```
numspecies <- benthic %>% dplyr::count (Location, Species)
numspecies
```

##	Location	Species	n
## 1	Castro Cove	Cancer productus	2
## 2	Castro Cove	Hemigrapsus nudus	1
## 3	Castro Cove	Leptocottus armatus	2


```
## 4      Castro Cove  Metacarcinus gracilis 2
## 5      Castro Cove  Metacarcinus magister 2
## 6      Pinole Shores      Cancer productus 1
## 7      Pinole Shores      Hemigrapsus nudus 2
## 8      Pinole Shores Hemigrapsus oregonensis 1
## 9      Pinole Shores  Metacarcinus magister 4
## 10     Point Pinole      Cancer productus 2
## 11     Point Pinole      Gemma gemma 1
## 12     Point Pinole      Hemigrapsus nudus 1
## 13     Point Pinole Hemigrapsus oregonensis 3
## 14     Point Pinole      Leptocottus armatus 3
## 15     Point Pinole  Metacarcinus magister 1
## 16     Point Pinole      Ostrea lurida 1
## 17     Point Pinole  Pachygrapsus crassipes 1
## 18     Point Pinole      Sipuncula spp. 1
## 19 Point San Pablo      Cancer productus 1
## 20 Point San Pablo      Hemigrapsus nudus 1
## 21 Point San Pablo      Leptocottus armatus 1
## 22 Point San Pablo  Metacarcinus gracilis 1
## 23 Point San Pablo  Metacarcinus magister 1
## 24 Richardson Bay      Cancer productus 1
## 25 Richardson Bay      Gemma gemma 2
## 26 Richardson Bay      Hemigrapsus nudus 3
## 27 Richardson Bay Hemigrapsus oregonensis 2
## 28 Richardson Bay      Leptocottus armatus 1
## 29 Richardson Bay  Metacarcinus gracilis 2
## 30 Richardson Bay  Metacarcinus magister 3
## 31 Richardson Bay      Ostrea lurida 4
## 32 Richardson Bay  Pachygrapsus crassipes 4
## 33 Richardson Bay      Sipuncula spp. 1
```

```
data_wide <- spread(numspecies, Species, n)
data_wide
```

```
##      Location Cancer productus Gemma gemma Hemigrapsus nudus
## 1      Castro Cove      2      NA      1
## 2      Pinole Shores      1      NA      2
## 3      Point Pinole      2      1      1
## 4 Point San Pablo      1      NA      1
## 5 Richardson Bay      1      2      3
##      Hemigrapsus oregonensis Leptocottus armatus Metacarcinus gracilis
## 1      NA      2      2
## 2      1      NA      NA
## 3      3      3      NA
## 4      NA      1      1
## 5      2      1      2
##      Metacarcinus magister Ostrea lurida Pachygrapsus crassipes Sipuncula spp.
## 1      2      NA      NA      NA
## 2      4      NA      NA      NA
## 3      1      1      1      1
## 4      1      NA      NA      NA
## 5      3      4      4      1
```

```

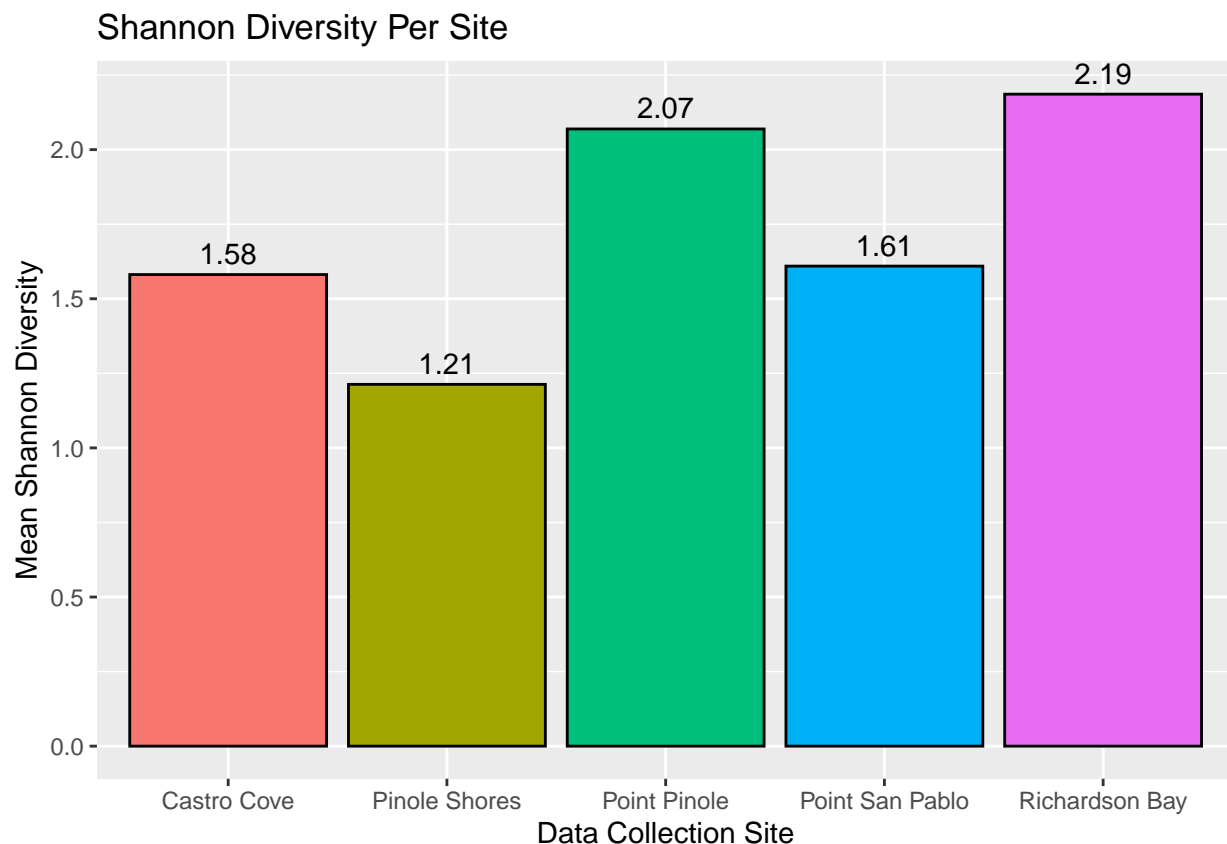
data_wide[is.na(data_wide)] <- 0

rownames(data_wide) <- data_wide$Location
data_wide$Location <- NULL

#shannon diversity test on species present
shannon <- diversity(data_wide,index = "shannon") %>% as.data.frame()
shannon$Location <- rownames(shannon)

plot_shandiv <- ggplot(shannon, aes(x = Location, y = ., fill = Location)) +
  geom_text(aes(label=round(., 2)), vjust=-0.5) +
  geom_col(color = "black") +
  theme(legend.position = "none") +
  labs(x = "Data Collection Site",
       y = "Mean Shannon Diversity",
       title = "Shannon Diversity Per Site")
plot_shandiv

```



We reject the Null hypothesis as each site clearly have different species diversity index values. Richardson Bay has the highest value of 2.19 which means it is the most species diverse out of all the sites. Pinole Shores has the least amount of diversity with a value of 1.21. Interestingly enough, Point Pinole and Pinole Shores have vastly different species diversity even though they are located directly beside one another. Further research into the habitats of these location may provide insights for the difference in diversity.

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