A Preliminary Investigation of Groundwater and Surface Water Impacts on Nearshore Biological Communities in Saipan Lagoon

Mariana Islands Water Operator Association - August 16, 2016
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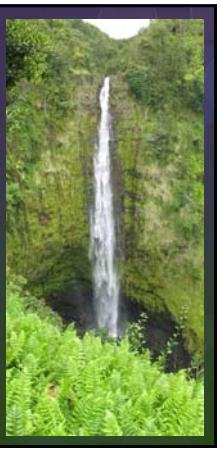
Introduction

- Water moves through our watershed in 2 ways:
  - Surface flow
    - Rivers and streams
  - Subterranean flow
    - Groundwater
  - Both ground and surface water acquire chemical constituents as they move to the ocean (e.g. nutrients)



Introduction

- Subterranean flow is often released into the marine environment as **Submarine Groundwater Discharge (SGD)**
- SGD delivers nutrients to coastal environments
- SGD negatively correlates with depth and distance
- SGD has patterns related to tides and seasons

Waiopae

- Near the eastern most point in the state
- Exposed coastline

Waiopae

- Puna, Hawaii
- The substrate here is young porous conductive basalt
- 460 cm of rain per year
- Virtually no surface runoff

Waiopae

- Marine Life Conservation District (MLCD)
- Series of inter-connected tide-pools and lagoons
- Small rural community
- Waste disposed via cesspools and septic tanks

Results

event 4 (n=28), event 5 (n=14), event 6 (n=20), nitrate pool (n=62)

Water Quality Correlations		
comparison (sample event)	**r-value**	**p-value**
nitrate & salinity (4)	-0.950	<0.001
nitrate & salinity (5)	-0.991	<0.001
nitrate & salinity (6)	-0.758	<0.001
nitrate & salinity (pool)	-0.706	<0.001
total-nitrogen & salinity (6)	-0.978	<0.001
ortho-phosphate & salinity (6)	-0.977	<0.001
total-phosphorus & salinity (6)	-0.642	0.002
ammonia & salinity (6)	0.838	<0.001

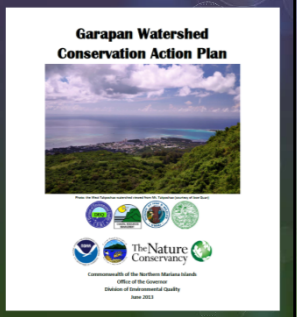
Puako Cess Pools

- Develop an implementation plan for an onsite treatment plant
- Finalize the preliminary engineering report
- Determine management and ownership options
- Begin land acquisition inquiry
- Outline next steps for funding avenues

http://coral.org/puako/ Wiegner et al., 2016

Garapan CAP

- Strategy F: Research and Monitoring
  - OBJECTIVE F1: By the end of FY2016, all high priority water quality problem areas within the watershed have been identified
  - OBJECTIVE F2: By 2016, the Climate Change Adaptation Plan will be finished and data used for informing regulations
  - OBJECTIVE F3: By FY2018, funding is secured and capacity identified to support long-term ecological monitoring within the watershed

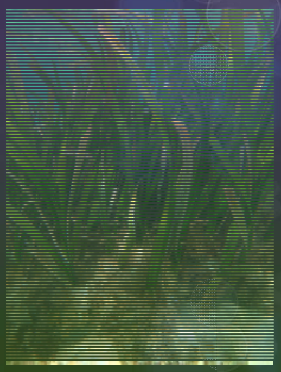


Funding

Coral Reef Conservation Program FY14 funding:

Preliminary Investigation of Groundwater and Surface Water Impacts on Near Shore Biological Communities in Saipan Lagoon

NOAA CORAL REEF CONSERVATION PROGRAM

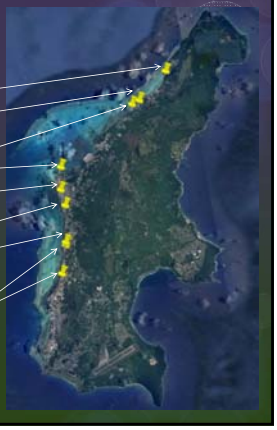


Site Selection

- Saipan lagoon coastline divided in three sections (north, mid, south)
  - A groundwater, surface-water, and reference site was selected for each section
- Three Groundwater
  - Referenced APEC groundwater study
  - Surveyed Saipan lagoon for areas of high groundwater input
- Three Surface-water
  - Consulted experts for areas of high surface-water input
  - Surveyed Saipan lagoon for areas of high surface-water input
- Three Reference
  - Randomly selected

Sites

- 1 Paupau (north, groundwater)
- 2 Aqua (north, reference)
- 3 Iguel Ranch (north, surface-water)
- 4 AMP (mid, reference)
- 5 Hafa (mid, surface-water)
- 6 Fishing Base (mid, groundwater)
- 7 Quartermaster (south, surface-water)
- 8 Pump Station 12 (south, reference)
- 9 Oleai (south, groundwater)

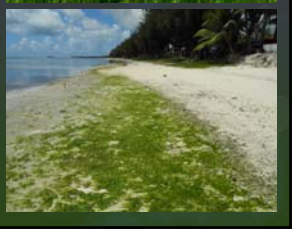


Methods Water Quality

- 9 sites – monthly samples for 12 months
- In situ measurements (YSI)
  - temperature, salinity, pH, and dissolved oxygen
- Turbidimeter
  - Turbidity
- DEQ Lab
  - TSS and Enterococci
- UOG WERI
  - nitrite/nitrate, ammonium, total nitrogen, orthophosphorus, total phosphorus

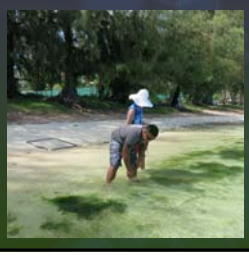
Methods Biological

- Seagrass and Intertidal
- Summer (June-July 2015)
- Winter (February 2016)



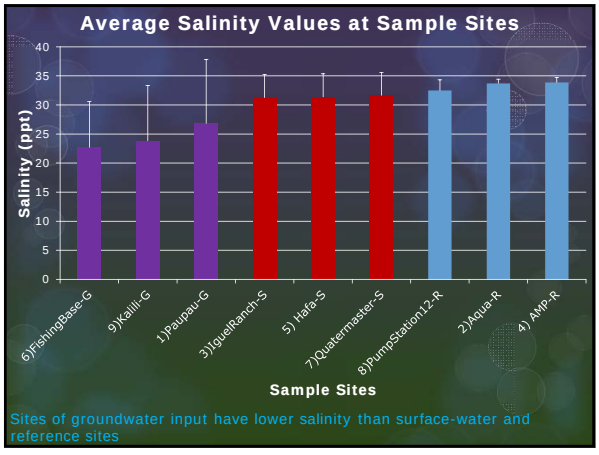
Methods Biological

- Five 10m transects per site
- Percent Cover
  - 0.25 m^2 quadrat at each meter
  - Species under 10 points identified per quadrat
- Diversity
  - 1 m^2 quadrat, three within each transect
  - All species identified within quadrat
- Macro Invertebrates
  - 1 m^2 quadrat, three within each transect
  - All macro invertebrates counted within each quadrat

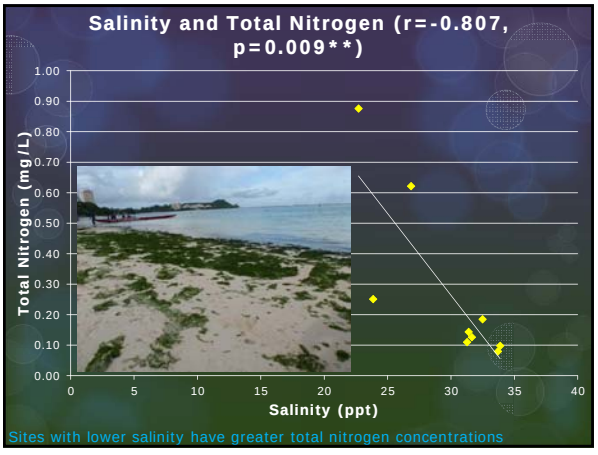


Data Analysis

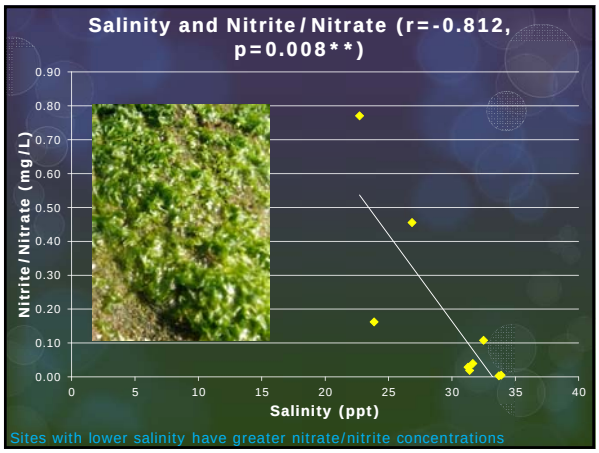
- Prior to data analysis seagrass percent cover data was converted into a ratio (seagrass/macroalgae)
- ANOVA's and Regressions were used to establish relationships within and between water quality, biology, site type, and lagoon section
- If data was normal we proceeded with an ANOVA
- If data was not normal data was ranked prior to an ANOVA
- no transformation prior to carrying out a regression
- Analyzed with SigmaPlot

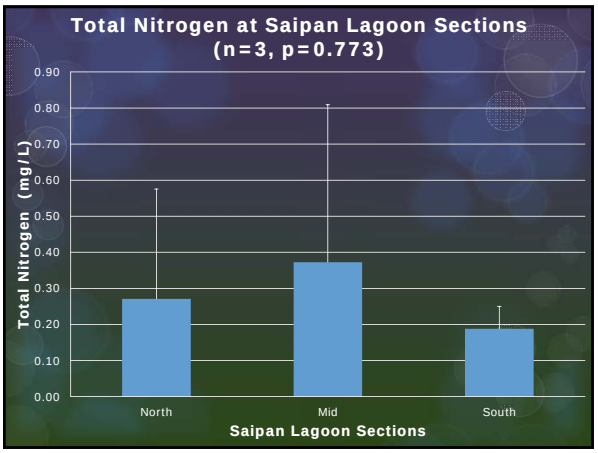


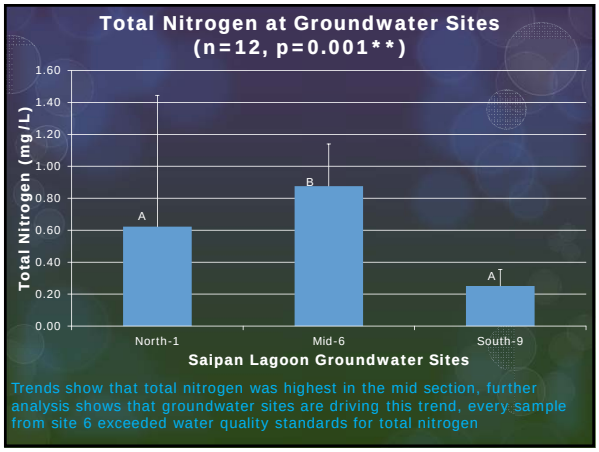
Sites of groundwater input have lower salinity than surface-water and reference sites

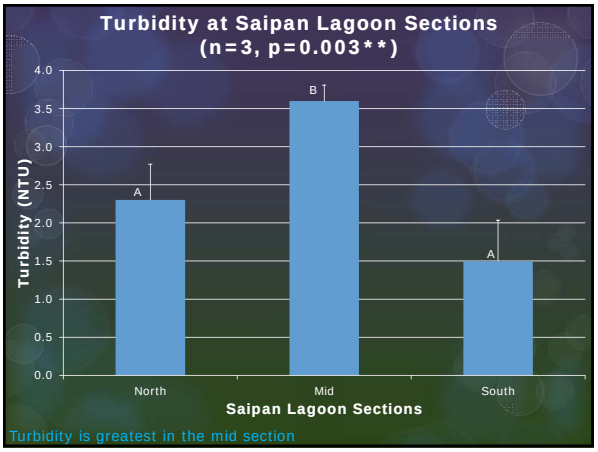


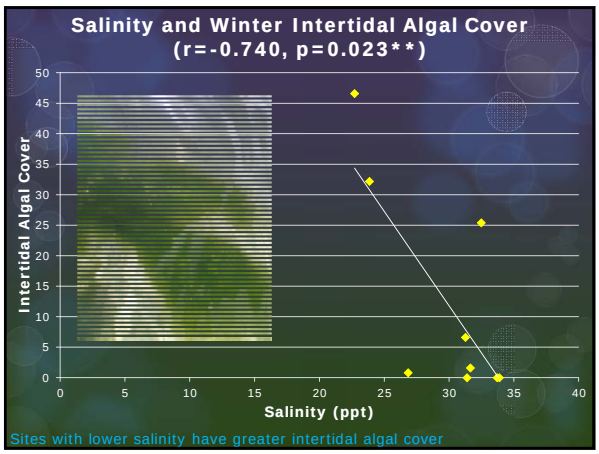
Sites with lower salinity have greater total nitrogen concentrations

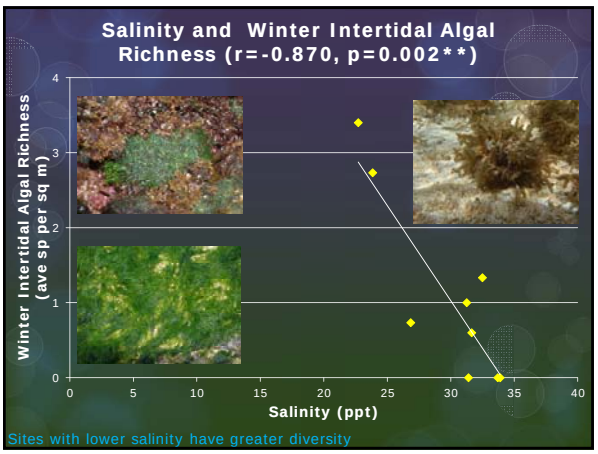

Salinity and Nitrite/Nitrate (r=-0.812, p=0.008**)
Nitrite/Nitrate (mg/L)
Salinity (ppt)
Sites with lower salinity have greater nitrate/nitrite concentrations

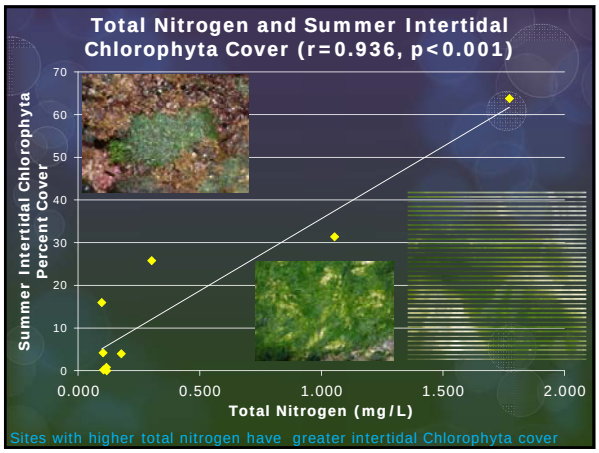

Total Nitrogen at Saipan Lagoon Sections (n=3, p=0.773)
Total Nitrogen (mg/L)
North
Mid
South
Saipan Lagoon Sections

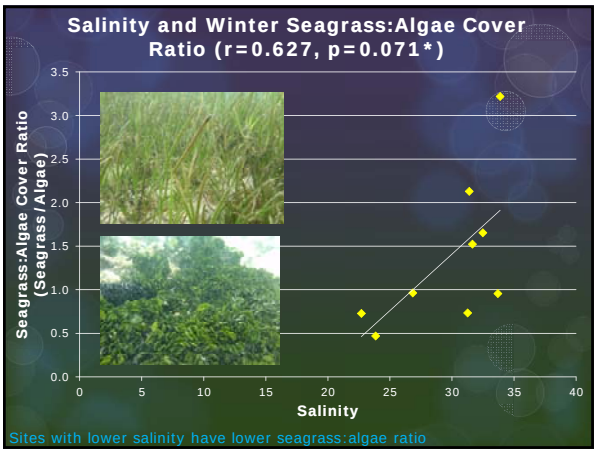

Total Nitrogen at Groundwater Sites (n=12, p=0.001**)
Total Nitrogen (mg/L)
A
B
A
North-1
Mid-6
South-9
Saipan Lagoon Groundwater Sites
Trends show that total nitrogen was highest in the mid section, further analysis shows that groundwater sites are driving this trend, every sample from site 6 exceeded water quality standards for total nitrogen

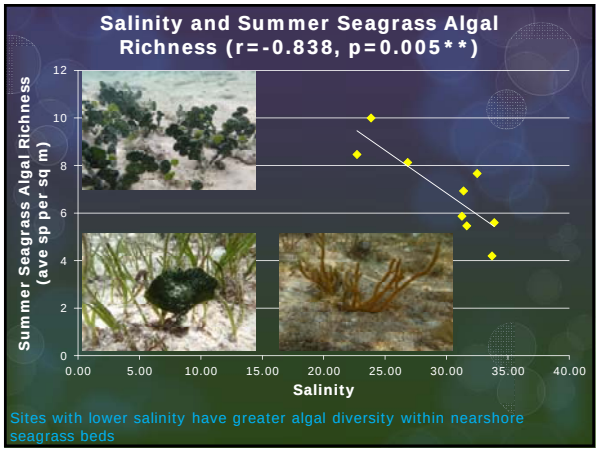

Turbidity at Saipan Lagoon Sections (n=3, p=0.003**)
Turbidity (NTU)
A
B
A
North
Mid
South
Saipan Lagoon Sections
Turbidity is greatest in the mid section

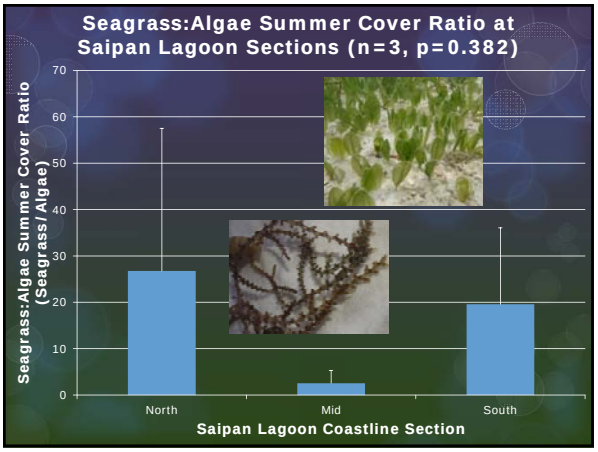

Salinity and Winter Intertidal Algal Cover (r=-0.740, p=0.023**)
Intertidal Algal Cover
Salinity (ppt)
Sites with lower salinity have greater intertidal algal cover

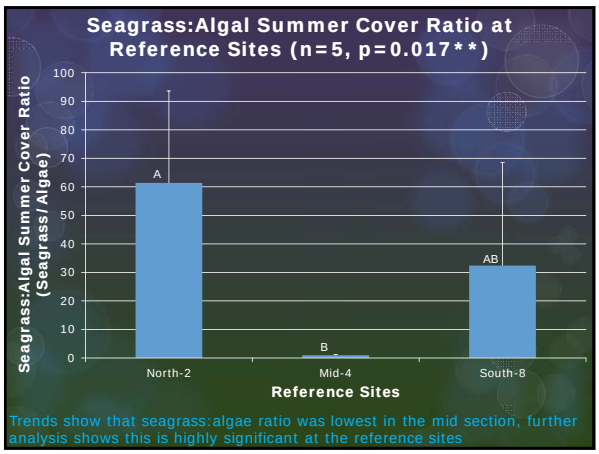

Salinity and Winter Intertidal Algal Richness (r=-0.870, p=0.002**)
Winter Intertidal Algal Richness (ave sp per sq m)
Salinity (ppt)
Sites with lower salinity have greater diversity

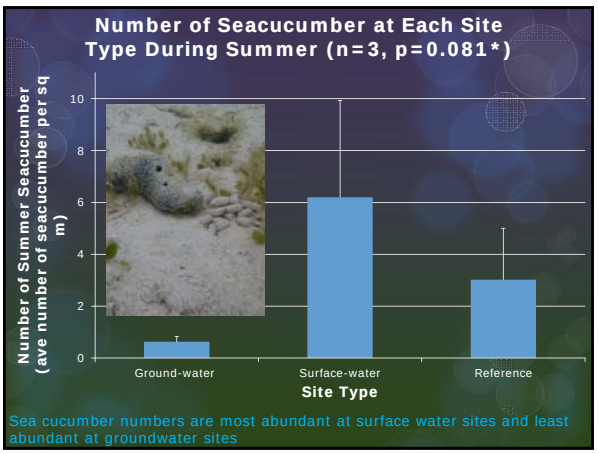

Total Nitrogen and Summer Intertidal Chlorophyta Cover (r=0.936, p<0.001)
Summer Intertidal Chlorophyta Percent Cover
0
10
20
30
40
50
60
70
0.000
0.500
1.000
1.500
2.000
Total Nitrogen (mg/L)
Sites with higher total nitrogen have greater intertidal Chlorophyta cover

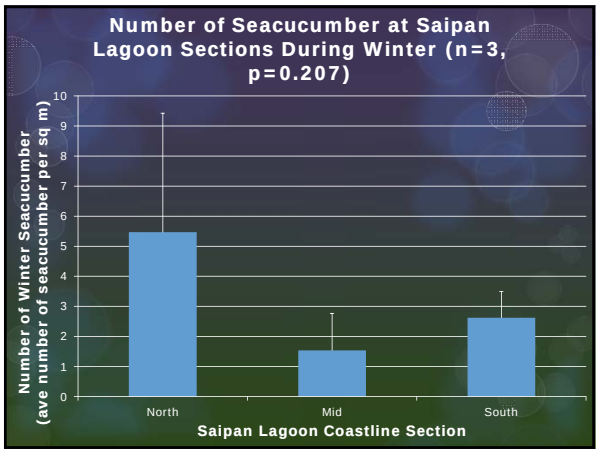

Salinity and Winter Seagrass:Algae Cover Ratio (r=0.627, p=0.071*)
Seagrass:Algae Cover Ratio (Seagrass/Algae)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
5
10
15
20
25
30
35
40
Salinity
Sites with lower salinity have lower seagrass:algae ratio

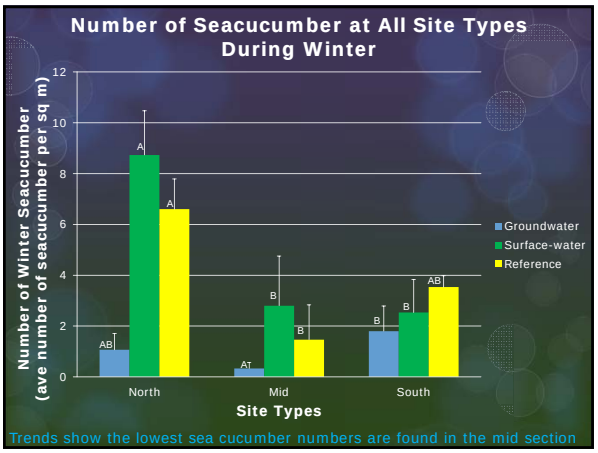

Salinity and Summer Seagrass Algal Richness (r=-0.838, p=0.005**)
Summer Seagrass Algal Richness (ave sp per sq m)
0
2
4
6
8
10
12
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Salinity
Sites with lower salinity have greater algal diversity within nearshore seagrass beds


Seagrass:Algae Summer Cover Ratio at Saipan Lagoon Sections (n=3, p=0.382)
Seagrass:Algae Summer Cover Ratio (Seagrass/Algae)
0
10
20
30
40
50
60
70
North
Mid
South
Saipan Lagoon Coastline Section


Seagrass:Algal Summer Cover Ratio at Reference Sites (n=5, p=0.017**)
Seagrass:Algal Summer Cover Ratio (Seagrass/Algae)
0
10
20
30
40
50
60
70
80
90
100
A
B
AB
North-2
Mid-4
South-8
Reference Sites
Trends show that seagrass:algae ratio was lowest in the mid section, further analysis shows this is highly significant at the reference sites

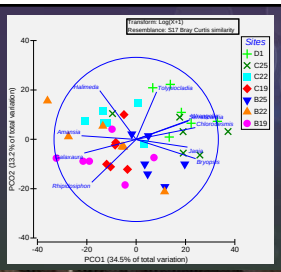

Number of Seacucumber at Each Site Type During Summer (n=3, p=0.081*)
Number of Summer Seacucumber (ave number of seacucumber per sq m)
0
2
4
6
8
10
Ground-water
Surface-water
Reference
Site Type
Sea cucumber numbers are most abundant at surface water sites and least abundant at groundwater sites





Recommendations

- Assess the influence of season
- PRIMER
- N-isotope, QPCR, or other means of tracing sources of total nitrogen and nitrate/nitrite
- Influence of groundwater on other factors should be assessed (seagrass growth rate, fish counts, etc)
- Greater attention to groundwater for management action



Conclusion

- This study shows that groundwater has a greater influence on nearshore biological communities than surface water within Saipan Lagoon.
- This study shows the influence of groundwater results in compromised water quality and nearshore biological communities within Saipan Lagoon.
- The mid section has the poorest water quality relative to the north or south sections.

Mahalo

- NOAA Coral Reef Conservation Program
- UOG Water and Environmental Resources Institute
- BECQ Water Quality Surveillance / Non-point Source Branch, Laboratory Branch, and Marine Monitoring Team
- CRI Interns – Austin Piteg, Mary Fem Urena, and Julius Reyes