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Assessing the Health of Aquatic Ecosystems in the Cook Islands: A Study of the Lagoon and Stream Water Quality

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Lagoons and Streams

- Pacific Island Countries (PICs) are heavily dependent on the blue economy, fisheries, and tourism; therefore, protecting their coastal and marine ecology is of utmost importance.
- The Cook Islands is a well-known PIC that is rapidly developing.
- In the Cook Islands, tourism is contributing to approximately 70% of GDP with visitor arrivals seeing an increase of 42% in a span of 10 years from 2005-2015.
- The main attraction to the Cook Islands are the lagoons.
- Lagoons and streams health is threatened by contamination from human population growth, urbanization, and pollutants from land-based sources.



Figure 1: Aitutaki Island, Cook Islands

Lagoons and Streams

- The lagoon monitoring program was first introduced by the Cook Islands due to Takitumu Irritant Syndrome in 2003 whereby those who had swum or spent time in Rarotonga's Titikaveka lagoon experienced throat, nose, and skin irritations and red-eye.
- Another case in Rarotonga's Muri lagoon was found to have health concerns due to bacterial spikes possibly due to sewage disposal and seaweed growth.
- This brought a bad reputation to the lagoon.

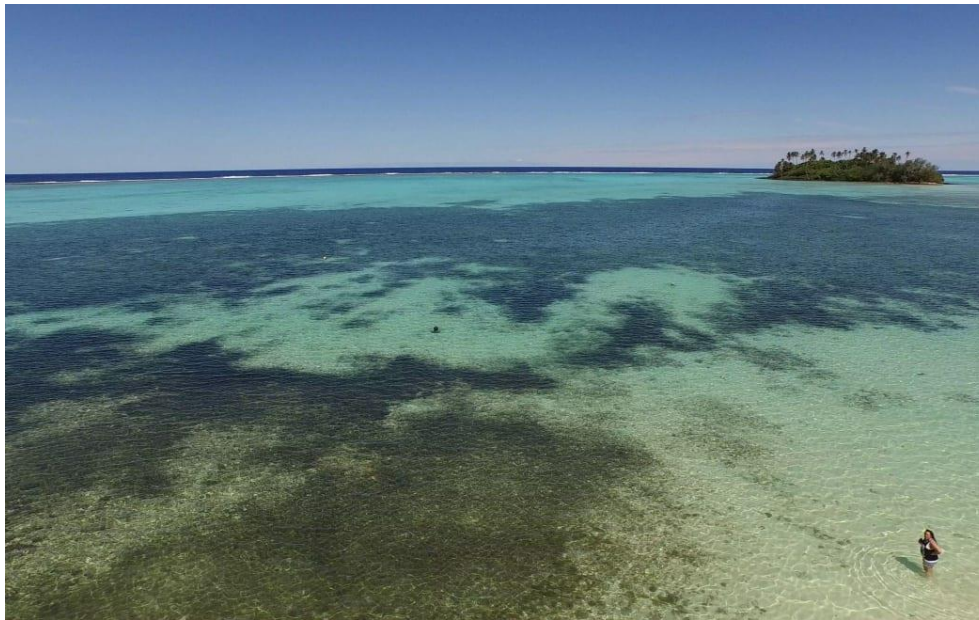


Figure 2: Algae Bloom in Muri Lagoon, Cook Islands

Lagoons and Streams

- The purpose of this study is to investigate water quality trends for both lagoons and streams in Rarotonga & Aitutaki over a three-year period (2007-2009, 2008-2010)



Figure 3: Aitutaki Lagoon

Source: <https://www.stuff.co.nz/>

Method

- Two Islands in the Cook Islands (Rarotonga & Aitutaki) twenty-nine lagoons (fourteen Rarotonga & fifteen Aitutaki) and twelve streams (eight Rarotonga & four Aitutaki) sites were sampled once every month and the findings were published yearly and from these reports were our water quality data extracted
 - The lagoon and stream data used to investigate the water quality in the Cook Islands was obtained from Cook Islands Environment Data Portal.
 - Available data for Rarotonga was taken for the period 2007-2009 and data for Aitutaki were taken between the period 2008-2010.
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Method

- **Physical Parameters**

Temperature (°C), dissolved oxygen (DO) % saturation and concentration, pH, and salinity (‰) were measured using a YSI 556 Probe

- **Nutrients**

NO₃-N was analyzed by the cadmium column reduction method (Astoria 305-A177), DRP by the molybdenum blue method (Astoria 305-A204), and NH₄-N by the indophenol blue method

- **Suspended Solids**

Total and volatile suspended solids were collected

Known volumes of samples were filtered onto GF/F filters for total and volatile suspended solids

- **Bacteria : Enterococci**

Samples were analyzed in duplicate using a membrane filtration method and placed on Enterococci agar.

Study Area : Rarotonga

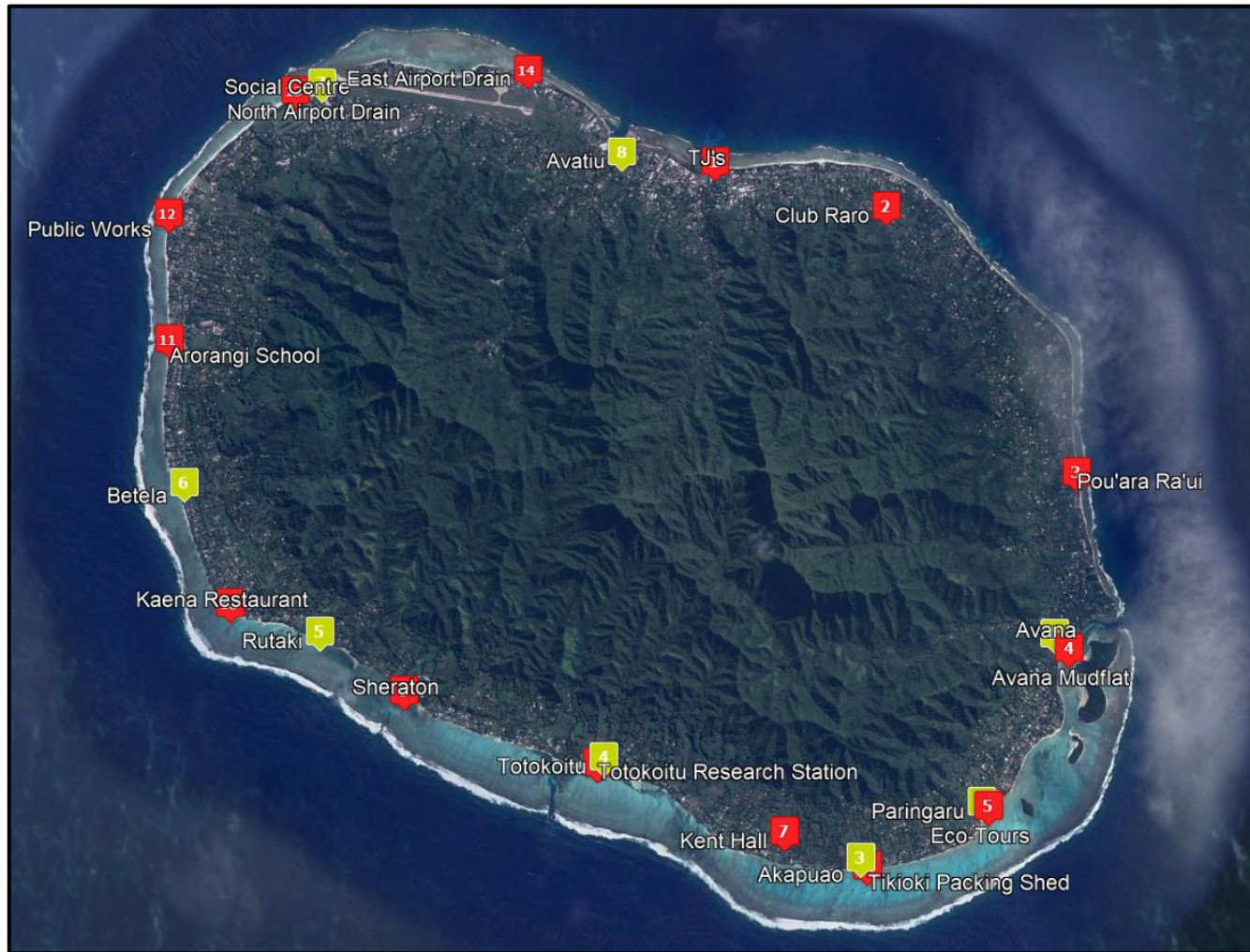


Figure 4: Location of sample sites and sample site number illustrated with red markers (for lagoon) and yellow markers (for streams) in Rarotonga.

Study Area : Aitutaki



Figure 5: Location of sample sites and sample site number illustrated with red markers (for lagoon) and yellow markers (for streams) in Aitutaki.

Study Area

- **Rarotonga**

Rarotonga is the main island of the Cook Islands and occupies 70% of the Cook Islands' total population and is known to generate the most economy through tourism as its main driver.

It has been identified that inadequate sanitation measures in the past have incurred a significant negative impact on the quality of the lagoons and marine life.

- **Aitutaki**

Aitutaki is the second most populated and income generator island of the Cook Islands which has substantially benefited from tourism.

Just like Rarotonga, the Island of Aitutaki is also under significant development pressure due to increasing tourism growth which calls for proper waste management so that marine reserves are maintained from pollution and contamination.

Results : Lagoons

Sites with critical Ammonia (NH₄-N) concentrations (µg/L) for the 3-year period at Aitutaki (Lagoon)

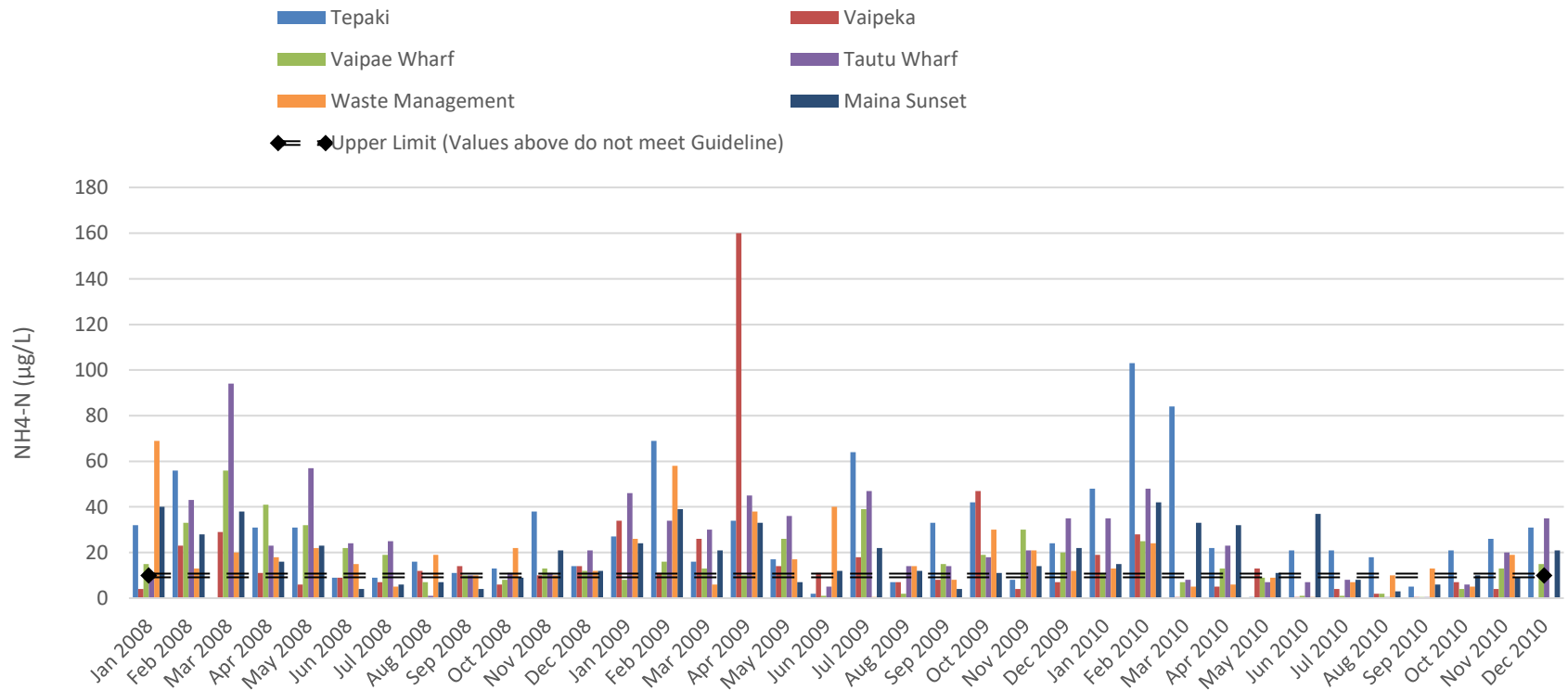


Figure 6: Lagoon Sites with critical Ammonia (NH₄-N) concentrations (µg/L) for the 3-year period at Aitutaki.

Ammonia (NH₄-N) above guideline concentrations can prove to be fatal to aquatic life as they can cause oxygen depletion. Findings suggested that the island Aitutaki has a greater amount of *Ammonia* concentration compared to Rarotonga.

Results : Lagoons

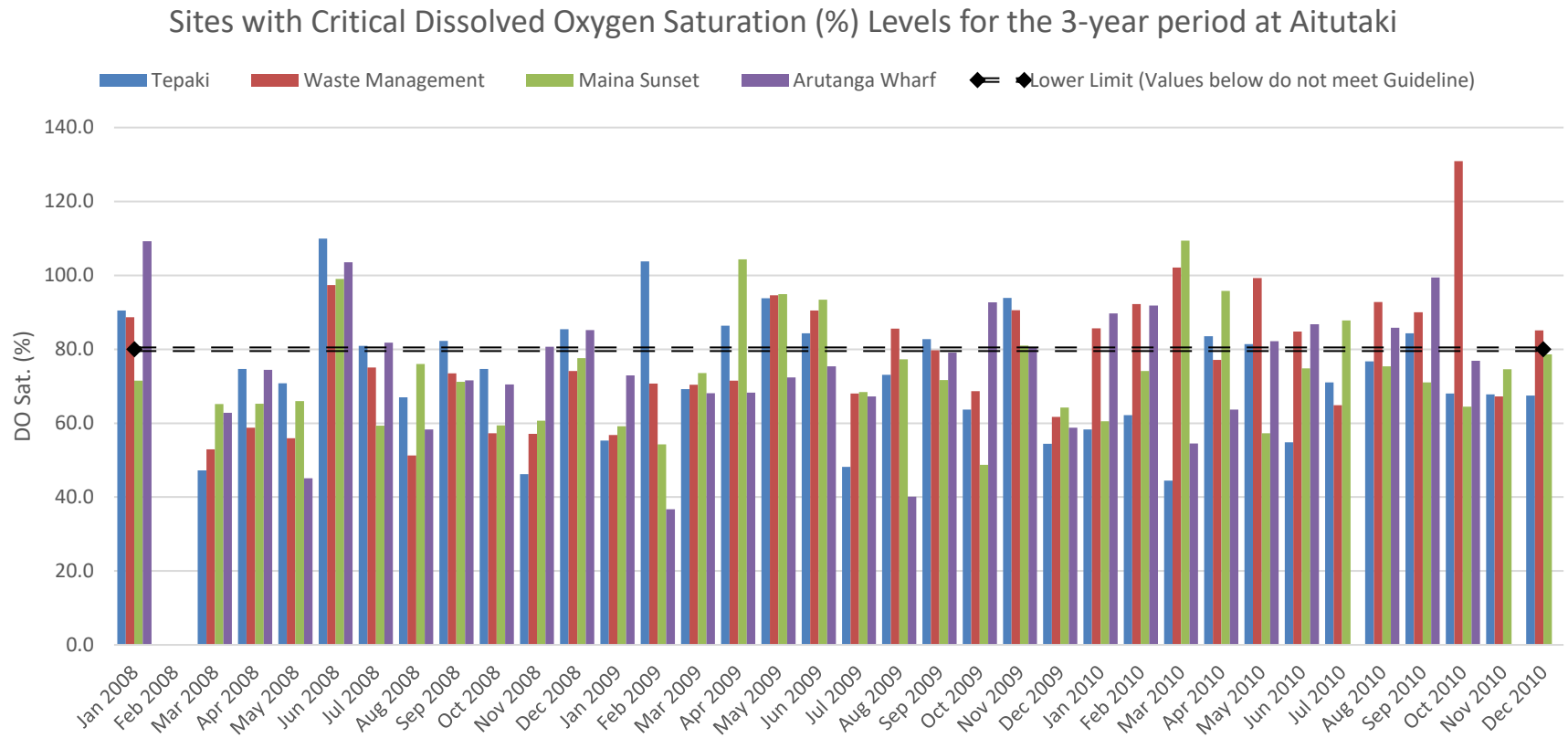


Figure 7: Lagoon Sites with critical Dissolved Oxygen Saturation (D.O %) Levels for the 3-year period at Aitutaki.

For the *D.O Saturated (%)* for Aitutaki Island, approximately 35.71% of the monthly sampled readings were below the lower limit of 80% (D.O Sat %), going extensively below the lower limit will cause adverse effects on aquatic organisms.

Bacteria Guideline for Enterococci

Intestinal enterococci (95th percentile value per 100 mL [rounded values])	Basis of derivation	Estimated risk per exposure
≤40 A	<p>This range is below the NOAEL in most epidemiological studies.</p> <p>Low risk or low probability of adverse effects.</p>	<ul style="list-style-type: none"> • <1% GI illness risk. • <0.3% AFRI risk. • The upper 95th percentile value relates to an average probability of less than 1 case of gastroenteritis in every 100 exposures. The AFRI burden would be negligible.
41–200 B	<p>The 200/100 mL value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or LOAEL for GI illness and AFRI.</p>	<ul style="list-style-type: none"> • 1–5% GI illness risk. • 0.3–1.9% AFRI risk. • The upper 95th percentile value relates to an average probability of 1 case of gastroenteritis in 20 exposures. The AFRI illness rate at this upper value would be less than 19 per 1000 exposures, or less than approximately 1 in 50 exposures.
201–500 C	<p>This range represents a substantial elevation in the probability of all adverse health outcomes for which dose–response data are available.</p>	<ul style="list-style-type: none"> • 5–10% GI illness risk. • 1.9–3.9% AFRI risk. • This range of 95th percentiles represents a probability of 1 in 10 to 1 in 20 of gastroenteritis for a single exposure. Exposures in this category also suggest a risk of AFRI of 19–39 per 1000 exposures, or approximately 1 in 50 to 1 in 25 exposures.
>500 D	<p>Above this level, there may be significant risk of high levels of minor illness transmission.</p>	<ul style="list-style-type: none"> • >10% GI illness risk. • >3.9% AFRI risk. • There is a greater than 10% chance of gastroenteritis per single exposure. The AFRI illness rate at the 95th percentile value of >500/100 mL would be greater than 39 per 1000 exposures, or greater than approximately 1 in 25 exposures.

Figure 8: Guideline values for microbial quality of coastal and freshwater recreational waters (WHO, 2021)

Results : Streams (Rarotonga)

Location	Site Number	Date	DO Sat (%)	NH4-N (µg/L)	Enterococci (Count/100ml)
Avana	1	2007	94.8	6.0	4241.9
		2008	107.7	8.4	3272.1
		2009	97.6	8.4	1618.9
Paringaru	2	2007	67.6	30.7	10833.3
		2008	84.5	43.2	3681.3
		2009	91.8	45.2	1285.7
Akapuao	3	2007	33.7	430.9	17201.3
		2008	48.3	145.4	7734.4
		2009	45.2	262.7	7852.7
Totokoitu	4	2007	90.2	13.1	3285.8
		2008	98.8	14.7	3457.5
		2009	87.6	14.8	1843.5
Rutaki	5	2007	98.3	6.3	2294.8
		2008	96.0	6.4	4697.9
		2009	53.4	14.3	3125.0
Betela	6	2007	88.5	10.2	2513.8
		2008	79.4	11.3	5124.3
		2009	65.3	13.9	3654.0
North Airport Drain	7	2007	123.5	27.5	440.9
		2008	145.6	18.4	620.7
		2009	112.7	8.5	741.3
Avatiu	8	2007	123.1	5.4	5454.1
		2008	105.5	13.3	3592.5
		2009	88.3	8.8	1365.8

Table 1: Physical, Chemical & Bacterial results for all the stream sampled sites in Rarotonga.

Results : Streams (Aitutaki)

Location	Site Number	Date	DO Sat (%)	NH4-N (µg/L)	Enterococci (Count/100ml)
Vaitiare	1	2008	78.0	32.3	981.7
		2009	26.1	104.5	8559.8
		2010	46.8	112.0	3091.1
Vaipae	2	2008	77.2	41.6	994.1
		2009	65.3	34.6	3695.3
		2010	79.5	13.5	1556.4
Pāta	3	2008	22.5	59.6	302.0
		2009	14.2	84.6	3919.4
		2010	14.9	64.7	4912.1
Arutanga Wharf	4	2008	92.0	5.6	2150.5
		2009	78.6	9.7	3875.1
		2010	87.4	4.9	5843.2

Table 2: Physical, Chemical & Bacterial results for all the stream sampled sites in Aitutaki.

The values indicated are mean of each year for the individual sites. Values in red font have exceeded the guidelines whereas values in yellow font indicate concentration levels that need to be monitored but are still accepted by the established guideline.

Enterococci counts have exceeded almost all the sampled years indicating the urgent need for containment.

Discussion

- Oxygen depletion can be due to discharges from nearby waste plants using dissolved oxygen.
 - It can also be due to decay in organic matter which is quite prevalent due to the vast forestry.
 - It was identified that there were certain periods with huge bacterial spikes in lagoons.
 - Ammonia levels may exceed and can threaten the lagoons.
 - Both of these could be possibly due to improper sewage disposal.
 - Increase in nutrient levels can be a side effect of agricultural activities such as fertilizer runoff and the sizeable amount of fertilizer used on the islands to increase crops.
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Discussion

- Rapid developments lead to a demand for agricultural goods and to meet these demands, poor farming practices pollute nearby streams.
 - The use of animal manure and inorganic fertilizer is a cause of exceeding nutrient levels.
 - Rapid development can cause unplanned movements and improper human and animal sewage disposal.
 - It has been well-identified that poor stream and lagoon water quality is not natural but rather anthropogenic.
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Recommendations & Conclusion

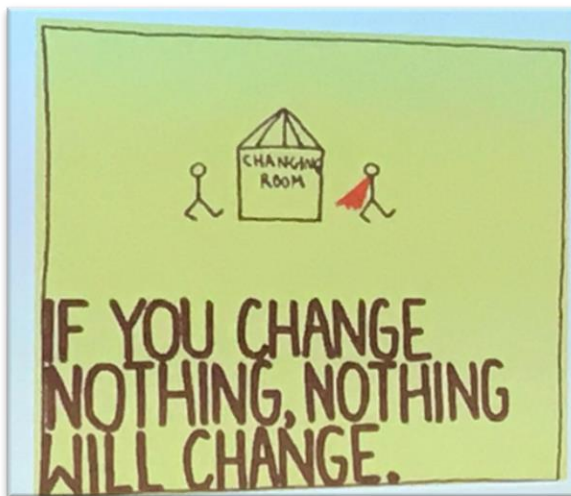
- The preliminary results indicate that lagoon water quality did meet the requirements for recreational use for most of the period studies.
 - The improper sewage discharge from nearby resorts affects their lagoons and in term is costlier to them.
 - Unplanned movements cause improper human and animal sewage disposal again polluting streams.
 - With more demand for vegetation with increasing urbanization, a healthier approach to farming needs to be incorporated.
 - Innovative measures of wastewater treatment can also be implemented in resorts to reduce bacterial levels in lagoons.
 - It can only be recommended to further allow more investigation and monitoring in PICs.
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Future Work

- Missing data does play a crucial role in acquiring the correct trend for water quality data.
 - If more recent data would be available and accessible, further studies would look at how data trends are after a decade period, how lagoon and stream water quality are impacted within that period as well as how climatic factors affect changes in lagoon temperatures, salinity, and associate parameters.
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Take home message

- Lagoons and streams are crucial for Pacific island countries.
- Conserving and managing island lagoons and streams requires a multidisciplinary and collaborative approach that balances ecological integrity, sustainable resource use, and community involvement.
- By adopting these principles, we can ensure the long-term health and resilience of these unique and valuable ecosystems.



Thank You!

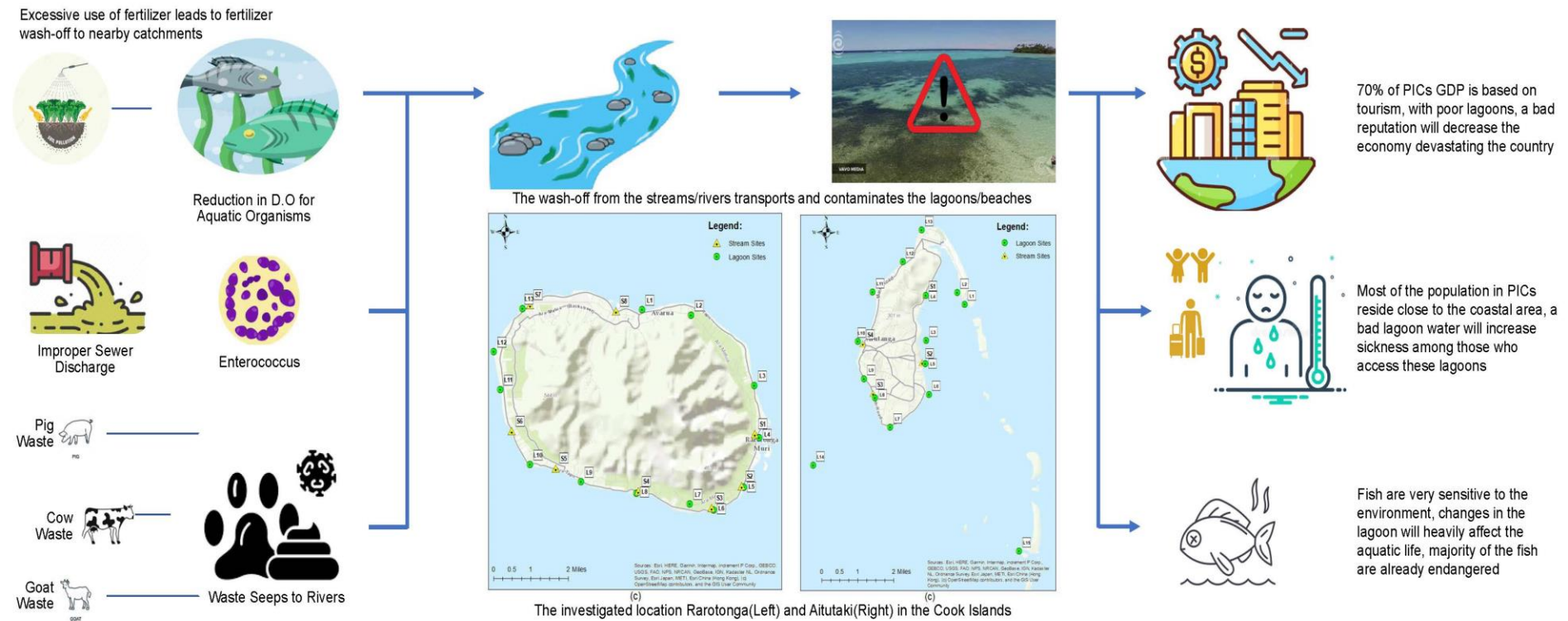
Questions & Suggestions?

Water Quality Monitoring for lagoons and streams in Pacific Island countries

Parameters affecting stream & lagoon water quality

Effects and Findings

Effects on Economy, Human Health and Aquatic Health



Source: Personal Abstract Image