Comparative study of fish populations on the north and south side of Heron Island, Queensland, Australia

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Abstract

Heron Island is a coral cay on the western end of the Great Barrier Reef. The surrounding reef hosts over 1,500 different species of fish. In 1967, a large portion of the reef was excavated in order to create a harbor for the island's passenger ferry. In 1993, two sea walls were built on either side of the island. These sea walls created a current that runs along the island's south side at high tide. This study aims to determine whether the abundance of fish species differs on the north and south side of the island. Two video cameras were deployed on both the north side and south side of the island twice a day: two hours before low tide and two hours before high tide. The footage was then analyzed to identify fish species and number of individuals within each video. The footage showed a greater abundance of fish species and individuals on the south side of the island. A p-value of 0.002 shows a strong correlation between the side of island and fish species abundance. The reasoning for this difference in fish abundance on either side of the island is unclear, however it is possible that it is due to the current on the south side of the island which is created by water rushing over the sea walls. It is theorized that fish ride this current, gaining efficient access to the reef flats and increased opportunities for feeding.

Additional Keywords: fish abundance, species diversity, sea wall, coral reef biodiversity, Great Barrier Reef

Introduction:

Heron Island is a member of the Capricorn Group of islands and lies at the southern end of the Great Barrier Reef, just under the Tropic of Capricorn (Fosberg 1961). It is approximately 80 kilometers east of Gladstone, Queensland (Gourlay & Hacker 2008). The island is made up of a sheet of flat coral and is surrounded by the Great Barrier Reef Marine Park. The Great Barrier Reef is the world's largest coral reef ecosystem (Claudino-Sales 2019). It hosts over 1,500 different species of fish (Claudino-Sales 2019). The Great Barrier Reef is home to one of the most diverse groups of vertebrate species (Choat & Russell 2008).

In 1967, a boat access channel was dredged on the island's western side (Gourlay & Hacker 2008). In 1987, this channel was enlarged to create a more accessible harbor. The dredging of the sea floor here destroyed this portion of the reef environment (Ng et al. 2021). In 1993, two sea walls were constructed on each side of the harbor. The purpose of these walls was to restore pre-harbor reef conditions but they ended up creating a current at high tide as water drains over the walls and down the south side of the island (Gourlay & Hacker 2008). It is believed that some species of fish use currents to enhance their feeding efficiency and to facilitate transportation (Klimley & Kelly 2012). Considering the rich biodiversity of fish species surrounding Heron Island, it is valuable to investigate whether these organisms utilize the man-made current to their advantage and whether it influences their abundance.

Previous studies have documented differences in species abundance between ecosystems near seawalls and those in unmodified environments (Chapman & Bulleri 2003). Dredging and seawall development have historically had negative effects on sea life, including habitat destruction and sedimentation (Erftemeijer et al. 2012). A greater understanding of the impacts of human development on marine species enables the implementation of more protective measures to mitigate these consequences.

The north side of the island does not experience the current from the anthropogenic sea wall. The south side of the island experiences the current at high tide. This study aims to determine whether the distribution of fish differs between the north and south side of the island. We hypothesized that there would be a greater abundance and diversity of fish species on the south side than the north side as the south side experiences the current.

Methods and Experimental Design:

Data Collection

Data collection occurred over the course of four days. Four GoPro Hero 11s were used for recording footage. Each day, two GoPros were deployed on either side of the island at both high tide and low tide (Baker et al. 2022). The GPS coordinates were taken from each site where the camera was deployed to allow for replication. The first camera on the north side was placed at 23°26’29” S 151°54’58” E and the second camera was placed at 23°26’29” S 151°54’59” E. On the south side, the first camera was placed at 23°26’37” S 151°54’49” E and the second camera was placed at 23°26’37” S 151°54’50” E. See Figure 1 for camera placement location. Each camera was housed in waterproof casing and was attached to a weight using zipties (Harvey et al. 2013). The cameras were then attached to a buoy with a rope in order to allow them to be easily identified from shore.

On day one of collection, two cameras were deployed on the north side of the island approximately one hour before high tide. Each camera was deployed 10 meters from the shoreline and 30 meters apart. The cameras were left to record for one hour with a 15 minute adjustment period to allow the ecosystem to acclimate to the disturbance. While these cameras were being deployed, the same process was repeated on the south side of the island with the other two cameras. After the hour and 15 minute period of recording, the cameras were collected from the water and the footage was uploaded. This process was repeated an hour before low tide. Over the next three days, this process was repeated an hour before both low and high tide each day. This allowed for 31 replicates of data as one data set was disrupted and had to be removed.

Figure 1: Map of Heron Island showing the location of camera placement on both the north and south side of the island.

Data Analysis

Upon completion of footage collection, the videos were reviewed and analyzed. The fish species in each video were identified and numbers of individuals were counted and recorded. A non-metric Multidimensional Scaling (nMDS) program was used using the "vegan" package in R-Studio (Oksanen et al. 2022). This allowed for visualization of the difference in species abundance on the two sides of the island. An Analysis of Similarities (ANOSIM) test was used in order to determine if there was a statistically significant difference between fish species and abundance on the two sides of the island. Then, a PERMANOVA test was used to find significant drivers of the community compositions (Garrido-Martín et al. 2023).

Results:

On the north side of the island, fourteen fish species were identified and 238 individuals were counted over the data collection period. On the south side of the island, twenty species were identified and 1,664 individuals were counted. Of the organisms recorded on the north side, 42.44% were identified as the juvenile *Trachinotus ovatus.* Conversely, only 6.9% of the organisms on the south side of the island were juvenile *Trachinotus ovatus.* A non-metric Multidimensional scaling (nMDS) program was used using the "vegan" package in R-Studio in order to visualize the data. See Figure 2. The nMDS had a stress value of 0.1792, showing that the nMDS plot is a good fit of the data set (Kruskal 1964).

An Analysis of Similarities (ANOSIM) test was used in order to determine if there was a statistically significant difference between fish species richness and abundance on the north versus the south side of the island. The R-value obtained was 0.2329. This suggests moderate dissimilarity between the two sides of the island. The p-value obtained was 0.002. Given that this p-value is less than 0.05, we can reject the null hypothesis that there is no significant difference in species richness and abundance between the two research sites.

Lastly, a Permutational Multivariate Analysis of Variance (PERMANOVA) test was used through an ADONIS2 test to assess the proportion of variance that can be explained by the difference in site location. See appendix for code used. This test provided an r-squared value of 0.1488. Therefore, 14.88% of the variation in fish species richness and abundance can be explained by the side of the island that the data was collected from.

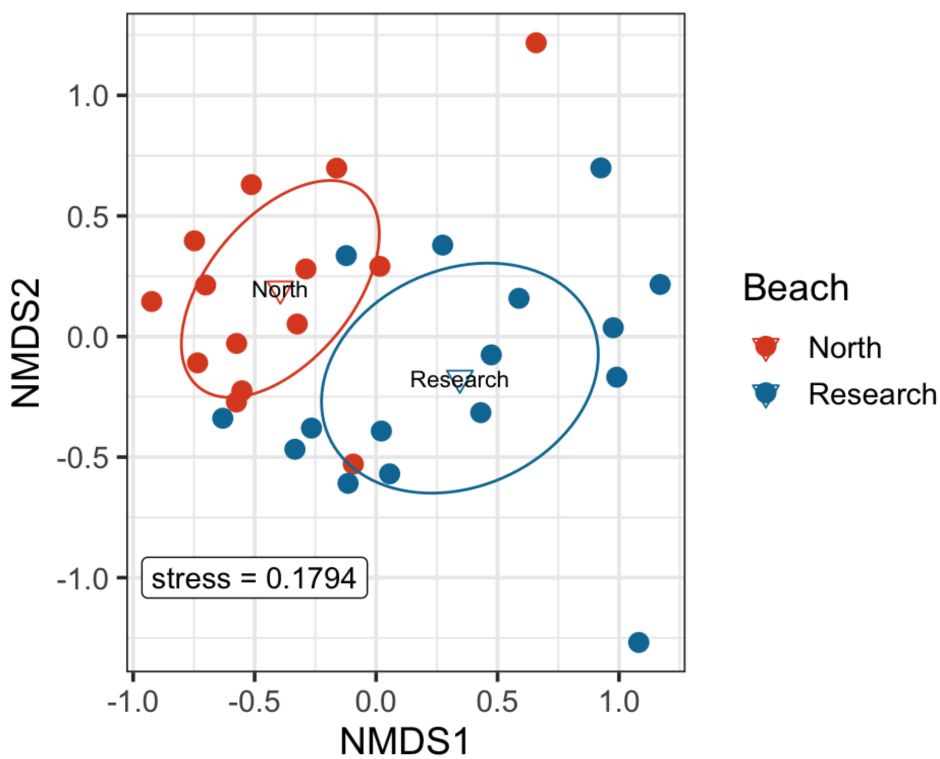

Figure 2: nMDS plot of fish species and abundance on north side and south side of Heron Island, Great Barrier Reef, Queensland. A stress value of 0.1794 indicates a significant difference in fish species and abundance between the two sides of the island.

Discussion:

Our findings indicate that fish species abundance and diversity is greater on the south side of the island than on the north side of the island. The footage from the north side of the island showed a higher repetition of species, with 42.44% of individuals identified as juvenile *Trachinotus ovatus*. On the south side, there was a greater diversity of species identified and a greater number of individuals within each species. The PERMANOVA test indicates that 14.88% of the variation in species abundance and richness between the island sides can be attributed to whether data was collected on the north or south side. This is a substantial amount of the data that is impacted by site location.

Moreover, there was a greater number of large animal species on the south side of the island, such as green sea turtles, rays, and reef sharks. Juvenile species were more common on the north side of the island. Our p-value was 0.002, which is lower than the 0.05 significance level. This allows us to accept our alternative hypothesis that the two communities are effectively different in species number and abundance.

Our findings do not prove what causes the difference in species abundance on either side of the island. We can infer, however, that the man-made channel may play a role. The current is only prevalent on the south side of the island, and this is where the higher number of fish species and individuals were observed. Therefore, it is likely that the animals here are using this current to their advantage to travel down the south side of the island.

Planktivorous fish are known to forage in currents and utilize channels to feed on zooplankton (McFarland & Levin 2002). They use currents to travel quickly towards prey in order to maximize their efficiency in capturing prey (McFarland & Levin 2002). One of the species observed frequently on the island's south side in the footage was the *Mugil cephalus,* or the Australian mullet. The mullet feeds on any small organic material it has access to, including zooplankton (Thomson 1954). It is possible that the mullet uses the current to feed on these zooplankton. It is common for predatory fish to use the current for feeding as it causes turbulence in the water which allows their prey to become disoriented and more easily hunted (Eggertsen et al. 2016). This may explain the greater abundance of larger predators on the south side of the island, such as reef sharks and rays.

The south side of the island is situated in front of the research station, while the north side of the island is in front of the island's resort. It is also possible that there are more disturbances on the north side due to the resort's presence which could impact the abundance of fish (Cowburn et al. 2018). Due to this possibility, it is not possible to definitively attribute the observed difference in species distribution to the current.

Knowing that the south side of the island hosts a greater abundance of fish species, it is important that extra protective measures are taken in this environment such as decreased tourism on the reef. The Great Barrier Reef is currently conserved as a marine protected area (Day 2017). As the south side of the island is where the research station is located, there are disturbances here due to the field work that takes place (Rinehart et al. 2023). It is important that scientists conducting research here are mindful to avoid excessive disturbance of the reef environment.

There is a need for more research on this topic in order to fully understand the reasoning behind why species abundance is greater on the island's south side. Future studies should directly investigate whether this is caused by the current. It would also be valuable to investigate potential differences in fish species abundance during peak tourism periods on Heron Island compared to the off-season. This may give insight into whether the presence of the resort plays a role in fish abundance. Increased understanding of the impact of human development on marine life will enable the implementation of more protective measures to ensure minimal disturbance, such as increased tourism regulations and climate resilience policies (Pendleton et al. 2019).

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Appendix:

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adonis2(formula = gruv_com ~ Beach, data = gruv, method = "bray")
         Df SumOfSqs      R2      F Pr(>F)    
Model     1   1.0940 0.1488 4.8949  0.001 ***
Residual 28   6.2580 0.8512                  
Total    29   7.3521 1.0000                  
```

Figure 3: ADONIS2 Test Code