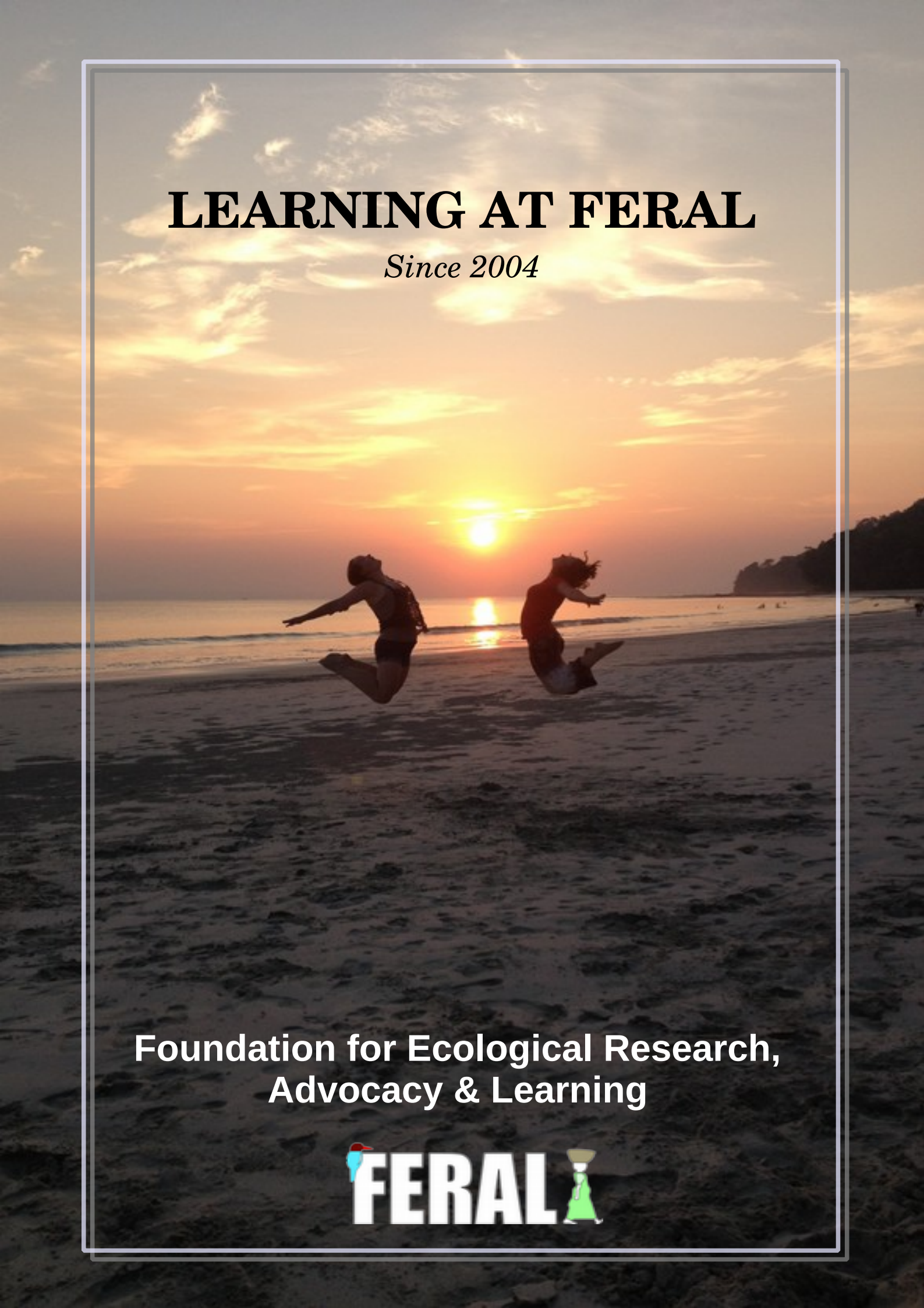


LEARNING AT FERAL

Since 2004

Foundation for Ecological Research, Advocacy & Learning

FERAL

Introduction

Learning has always been a strong core area at FERAL. This program area comprises all study abroad courses or semesters, training programs and workshops that are taught at FERAL through a variety of collaborations. Of these, the Study abroad semesters have been the longest running with atleast one semester per year. The January term or summer courses are shorter courses that can be administered independently or in combinations with other courses that go on to make an entire semester. These programs have been offered to undergraduate students from the US and therefore contribute to their degree qualification.

The most special feature of this program is it's highly flexible and adaptable nature which creates a unique experience for the student and teacher each time it is run. While few components remain constant, the program has always embraced change, continually striving to achieve academic excellence with a large emphasis on experiential learning and field exposure. This flexibility is a great advantage as students have the opportunity to design their graduate degree specific to their interests.

Dr. Neil Pelkey, who is an Associate Professor from Juniata College and also one of the early founding members of FERAL, spearheaded the Study Abroad program in 2004 and continues to do so even now. As a result, the program has been going strong for over ten years now via multiple international and local partnerships with academic and research institutions, non-profit and commercial organizations and independent professionals. Over the years, the program has seen many changes in these collaborations, constantly developing new relationships while strengthening the old ones and has therefore grown considerably from when it first began.

As the long term goal of this program is to include Indian students on the Study Abroad courses and develop Masters' courses for specific themes related to Ecology, this portfolio showcases the Learning Program at FERAL, highlighting the key elements of all courses taught on the Study Abroad semesters, short term programs and training workshops that are still on offer at FERAL.

About FERAL

"Once wild, run wild again."

The kitchen and store room on FERAL campus

FERAL is a non profit trust that was founded in 1997 and is a certified Scientific and Industrial Research Organisation (SIRO). We implement development and research projects in addition to teaching a wide range of courses in fulfillment of our mandate which is to address issues of resource management, conservation, environment and health both at the grassroots and the policy level. The bulk of our projects therefore, actively engage local communities, stakeholders and policy makers as partners in research and development through workshops, seminars and awareness campaigns. We also collaborate with several international and Indian research and academic institutions making substantial contributions in action research and education across a variety of themes that include Ecology, Wildlife Biology and Conservation, Natural Resource Management, Coastal Fisheries Ecology and Management, Remote Sensing and GIS and Community Outreach and Development. Our approach to addressing real world ecological issues is to use data driven ecological research combined with use of the latest technological advancements.

Our activities are co-ordinated from the campus close to Pondicherry and our office in Bangalore. We also have field stations located at Ariyankavu (Kerala), Saptur and Emerald (Tamil Nadu) and Sirsi (Karnataka). All of our research and field activities are coordinated and facilitated by our administration and logistics team that comprises our office manager and accountant, field staff that support the various research projects in the respective field sites and offices and finally, housekeeping staff that maintain the regular upkeep of our campus that includes thatch hut accommodation, bathrooms, kitchen, store room, training hall and an office. The team plays a significant role during the study abroad courses and practical workshops, constantly interacting with students to ensure their overall wellbeing.

About our Program Partners

Juniata College *(2004 - present)* is an independent, co-educational college of liberal arts and sciences that was founded in 1876. Located in the scenic mountains of central Pennsylvania, the beautiful 110-acre main campus is supplemented by the 365-acre Baker-Henry Nature Preserve and Baker Peace Chapel. In addition, a 365-acre Environmental Studies Field Station on nearby Raystown Lake provides one of the most distinctive opportunities in environmental science in the nation. The College has a strong reputation for excellent academics, personal attention, and state-of-the-art technological resources. Juniata students enjoy small classes, a challenging, flexible curriculum, collaborative student-faculty relationships, countless chances to learn by doing, and a lively campus offering lots to do and great new friends.

Keystone Study Away Consortium *(2011 - 2013)* was founded to develop and sustain study away programs through collaborations among institutions with similar mandates and visions for international education. This collaboration involved Chatham University (Pittsburgh), Juniata College (Huntingdon), Moravian College (Bethlehem), Susquehanna University (Selinsgrove), Washington and Jefferson College (Washington in Pennsylvania) and Drew University (Madison, New Jersey). Their programs included a spring semester program in Gambia, a new program in India, and a semester-long environmental studies program at Juniata's Raystown Field Station.

Brethren Colleges Abroad *(2009 - 2011)* is an independent, non-profit international education organization founded in 1962 by a consortium of seven colleges of the Brethren tradition. Since 1962, BCA Study Abroad has been committed to helping students understand the complexities of the contemporary world by providing challenging academic programs and cross-cultural learning in locations around the globe. From its start, BCA has focused its educational mission on engaging students with ideas that matter. As a result, students who participate in a BCA program gain a more comprehensive and precise understanding of the world.

The Semester Programs

I. Marine Science in India

Spring Semester

▲ *Cara Mayo ready to snorkel during a surface interval at Wandoor, Andaman Islands*

Here we explore the field of natural and social sciences with an emphasis on issues of sustainable development in the marine and coastal realms. Courses are designed to provide students academic and experiential learning opportunities. Students learn how to apply scientific skills in conjunction with a concern for local communities and their needs. Additionally, the rich cultural heritage of each location is explored to understand the forces that have shaped these societies.

The courses thus invite students to reflect upon the conflicting demands on society and environment. This semester takes students across the southern coasts of India, the Andaman Islands and Thailand. Students learn and observe several scientific research methods, use different equipment and conduct group and individual research projects. The several readings provided along with academic interactions at several research institutions lay the theoretical grounding in stitching together concepts and observations in the field.

The courses on this semester are Islands and Reef Ecosystems, Field Methods in Marine Science, Uplands and Estuaries, Coastal Management, Introduction to Geographical Information Systems in Marine Systems with optional courses in Culture, Class and Gender in Coastal Management & Art as Sustainable Development. Grading is a combination of class participation, individual papers and research, sections quizzes and group projects. Students are required to make a final presentation of their work at the end of the course.

◄ *Laura and Alex ready to dive with Barefoot SCUBA instructors at Havelock, Andaman Islands*

II. Cultural and Social

Fall Semester

Students at the Brihadisvara Temple, Thanjavur in Tamil Nadu (2011)

This semester takes students to several locations in southern India (along with an option to visit the Andaman Islands) giving them the opportunity to interact with people from diverse backgrounds, involved in a range of activities and who work towards making these experiences and coursework relevant to local communities. Students interact, observe, reflect and learn the concepts, challenges and opportunities in each subject area.

The overall organization of the course allows students to see for themselves some of the places and organizations that shape contemporary India's views not only in science but also on social issues. They are also provided a historical perspective and hear about current debates which will help them understand these from the larger Asian or global perspective. As students travel, learn, observe and reflect, they not only gain academic knowledge but also take home a unique personal learning experience.

Courses include Sustainable Resource Management, Heart of India, Art as Sustainable Development and Culture, Class & Gender with the optional course of Island and Reef Ecosystems. Grading is a combination of class participation, individual papers and research, sections quizzes and group projects.

About the Courses

All courses provide students opportunities to interact with researchers and practitioners in the field.

- ***Field methods in Marine Sciences***

  Locations: Andaman Islands, Phuket Thailand, Pondicherry, Pulicat lake

  This course is primarily concerned with the collection and analysis of data in Marine Science. While focus will be on field collected data, it also addresses remotely sensed data from satellites. Data collection covers a variety of biomes including terrestrial, near shore, and deep ocean methods. Scuba certification is recommended, but not required for this course. The students participate in reef, beach, estuary, and ocean monitoring of biological, chemical and geologic features of those environs. This course is integrated into the other courses as the data collection and analysis carried out for those courses overlaps with this one.

- ***Uplands and Estuaries***

  Locations: Pondicherry, Pulicat lake, Thevara Kerala, Andaman Islands

  This course will introduce coastal ecosystems connections to the continental land mass, focusing on watershed and wetland processes. Primarily covered while in Pondicherry, students visit the many estuaries in the region. Observations and data collected here are compared to observations and the literature available while visiting west coast estuaries. In addition, study of habitats such as sand dunes, mangroves and coastal forests at various locations, looks at the role played by these habitats in maintaining and influencing the health of the marine environment.

▼ *Neil & Cara learning how to profile beaches*

Students observing Chinese dip nets fishing at Fort Kochi estuary, Kerala ▼

- ***Coastal Management***

  Locations: Andaman Islands, Pondicherry, Pulicat lake, Thevara Kerala

  This course will explore the legal, institutional, and economic factors affecting coastal zone and fisheries management in India, covering the current legal status, international treaties, state and central government coastal zone management regulations, and the history and current status of conflict and the attempts to overcome that conflict in India. It also analyses the challenges faced in fisheries management - social dynamics within fisher communities, legal frameworks to promote sustainable harvests, scientific inputs, etc. Thus the course spans science, policy and law.

- ***Introduction to Geographical Information Systems in Marine Systems***

  Locations: Pondicherry, Andaman Islands

  In general, the field of GIS is perceived as an expensive, difficult to master and equipment intensive discipline. However, management of information and placing it within a spatial perspective is increasingly a requirement in almost any field of study. Many approaches have been developed to deal with issues of spatial information, its analysis and use within the ambit of the field called GIS. There have also been a slew of methods that have been adopted based on participatory and local knowledge bases. These are often spatially explicit, yet, are often seen as incompatible and being at the opposite ends of the skill/knowledge spectrum.

  This course will take students through field and lab based exercises which will give them the opportunity to work with a variety of tools. Data gathered during field surveys using compass, sight levels and GPS will provide data for use in the lab exercises. Students will also use a range of participatory mapping tools for data gathering. Comparisons between the two approaches will help students assess these approaches and their applications to different field of study. The course will be integrated with the marine methods course since much of the data collected in that course is spatial in nature and lends itself well to presentation and analysis in a GIS framework.

  The marine focus and nature of the course will make it a good introductory course for students with no GIS experience and will broaden the GIS skill set of students who have already taken an introductory GIS course. Each workshop will have an advanced topics section for students with greater experience.

➢ *Sustainable Resource Management*

Locations: Auroville, Pondicherry, Kodaikanal

Issues of sustainability have never been more in the limelight than currently with the focus on climate change, future of the environment and impacts on human population. The Auroville experiment has brought together people of many cultures and backgrounds each of who explore the challenges of sustainability in their own unique and innovative manner. A major focus of this course will be on agriculture, fisheries and ecological restoration efforts in addition to sustainable living models as implemented by various communities in Auroville. Students are encouraged to critically examine these varied systems and their viability.

Site visits will also include the Kodaikanal region in the lower ranges of the Western Ghat mountain chain. A predominantly tribal region, it was also a favourite of British colonisers escaping the heat of the plains. The culture and the agriculture in the region is still influenced by these past incursions and is today also heavily impacted by tourism. Home to many organisations and individuals working towards conserving this fragile system, student will compare and contrast the approaches on the coast with those in the hills.

This practical based course will engage students in analysing each unique approach to solving problems of resource management and conservation. The topics vary by year and student interest but some of the topics include

i. LEISA—Low External input Sustainable Agriculture

ii. Traditional Indian Organic & Modern Organic Intensive Dryland Agriculture

iii. Appropriate Irrigation Technologies—drip, mist, land management

iv. Biodynamic Techniques in Vegetables, Coffee and Tea

v. Very Low impact sustainable living cooperatives

vi. Value Added Processing and Sustainable Livelihoods

vii. Ecological Restoration of Coastal Ecosystems

▲ *Students working on biodynamic farming methods on the Sustainable Resource Management course*

◄ *Low impact community eco – living in Sadhana Forest on the Sustainable Resource Management course*

➢ *Heart of India – Historical and Cultural Perspectives*

Locations: Auroville, Pondicherry, Delhi, Agra, Jaipur, Cochin, Aleppy, Thekaddy

Culture and history in India have been inseparably intertwined through the centuries. Diversity in language, culture, and religion are among the many dimensions that form the Indian ethos, one whose engagement with the past has never ceased. This course takes students through a journey of the many conflicts and dilemmas that face Indian society today, looking through a peace and social justice lens.

▲ *Students along with the program coordinator Tara, visiting the Taj Mahal in Agra on the Heart of India course*

These dilemmas are not new; their genesis rooted in the construct of social order, religious discourse and the interpretation of these by Indian and foreign minds. Philosophers and social activists through the ages have attempted to deal with these issues with the hope of a more equitable and just society. The ideas of Gandhi, Ambedkar, and Periyar will provide the background to a deeper analysis of the organisation and functioning of Indian society and the relevance of their thoughts in a rapidly urbanising India. Additionally, various current social movements will be analysed to understand the interface of social order and resource access / use and the need for a social justice perspective.

➢ *Art as Sustainable Development*

Locations: Auroville and Pondicherry

The Auroville area in Tamil Nadu and Pondicherry has village incomes that are 3-4 times higher than surrounding areas. A large part of these incomes has been generated by small artisanal workshops in pottery, ceramics, ironwork, leather, incense, and clothing which are owned and operated by practising artists. Students visit a variety of these workshops to get a feel for the types of productions and working conditions. They then study both artistic and commercial ceramics and pottery with one of India's premier potters – Angad Vohra at Mantra Pottery.

▲ *Rachel presenting her work after the Art course at the Last School – Pyramids, Auroville*

Students also visit the Last School - Pyramids Art School where they explore various techniques in drawing, sketching, painting and sculpture. The Auroville paper factory has also hosted students for this course providing them an opportunity to work along with plenty of women from the neighbouring villages who are the artists.

➢ *Island and Reef Ecosystems*

Locations: Andaman Islands

The Andaman Islands are known for their extraordinary beauty – tropical forests, coral reefs, mangrove forests, all exist shoulder to shoulder in this island chain. Given its location, the flora and fauna have Indian, Malaysian and Burmese origins. Several indigenous tribes still inhabit many of the islands whereas initial settlers from mainland India were prisoners and indentured labour transported by the British. Today's population is a mix of several communities, mainly Bengali and Tamilian. Population growth, increasing tourist influx and associated development put huge pressure on the islands' natural systems.

This course provides the students the opportunity to gain an understanding of the ecology, anthropology and ethnography of these islands. Students will gather and interpret data on reefs and rocky marine ecosystems across a gradient of anthropogenic pressure studying the positive and negative impacts driven by ecotourism and the expanding Asian middle class alongside the challenges of conservation in this scenario. They will also focus on the various theories associated with island systems including marine, reef and coastal habitat ecology.

▲ *Students learning about rocky shore ecosystems on the inter-tidal walk in Wandoor, Andaman Islands*

▲ *Students interacting with women and children from the neighbouring village to FERAL campus called Moratandi. Many of the women from the village Morattandi are employed at FERAL and students visit the village each year to experience a day in the life of a woman from this village on the Culture, Class & Gender Course.*

➢ *Culture, Class & Gender*

Locations: All locations as this course is predominantly observational in nature.

This course explores challenging issues that have dogged the development and policy discourse for several decades – primarily the role and contribution of women within the development sector. As part of this course, students will explore cultural issues in resource management and development, particularly the culturally distinct roles for women in harvesting, production, and processing of natural resources. Issues of gender and disadvantaged groups will also be discussed alongside visits to fishing villages which are culturally distinct from upland populations.

New Courses at FERAL

In addition to courses already described, FERAL is proud to offer new January and Summer courses in

- Sustainable Development
- Tropical Coastal Ecosystems
- Research Methods, Statistics and Geographic Information Systems
- Fisheries Management and Ecology
- Culture, Class and Gender
- Scientific Communications

Some courses earlier described have now been integrated or expanded to include courses of similar or overlapping themes to provide a comprehensive field and lab course. As before, these courses can be run independently or in combinations to yield a full semester program.

➢ *Sustainable Development*

Locations: Pondicherry & Auroville, Kodaikanal

Issues of sustainability have never been more pertinent than now, following the 2030 Agenda for Sustainable Development signed by all member states of the UN, which promises to end world poverty, fight inequality and tackle climate change by the year 2030. Seventeen Sustainable development Goals (SDG) emerged from eight key goals that were the Millenium Development Goals in 2000. Eleven of these SDGs are directly concerned with sustainability across major sectors that directly affect human health and wellbeing i.e., agriculture, resource consumption and management, energy, industry, urban planning, economic growth and social justice.

This course will take students through the concepts, challenges and approaches to sustainable development via a series of lectures, field visits and group discussions. A large part of this course is derived from the Sustainable Resource Management course* that was described earlier and has expanded to include all major development concerns related to land restoration, architecture, renewable energy and sanitation. Students will have the opportunity to examine a range of issues and solutions and examine the latter in terms of relevance, replicability and efficiency.

▲ *Students learning about art as a means of sustainable development in Auroville* ▼

*Described on page 8 of this document.

➢ *Tropical Coastal Ecosystems*

Locations: Pondicherry/Auroville & the Andaman Islands

The course will follow a series of lectures that discusses the ecology, threats and management of a number of coastal ecosystems and their role in the maintenance of the marine environment. This is predominantly a field course with comprehensive lectures and field visits planned for a specific ecosystem each day. Human dimensions in conservation and management will form a significant portion of this course and thus, students will have the opportunity to engage with organizations and individuals actively working on major challenges across a variety of ecosystems. Students will spend one week in Pondicherry and two weeks in the Andaman Islands.

Pondicherry's coastline has plenty to offer in terms of coastal ecosystems and students will learn about wetlands, sandy beaches, estuaries and tropical dry evergreen forests. Auroville is an excellent example of successful reforestation while Kalivelli, just outside of Pondicherry is a protected wetland with incredible biodiversity. In contrast to these successes is the highly eroded coastline of Pondicherry which is an excellent example of unplanned and unregulated development.

The Andaman Islands are known for their extraordinary beauty with tropical forests, coral reefs, rocky beaches, mangrove forests, all existing shoulder to shoulder in this island chain. Large parts of these Islands are in fact protected with some portions only open to students and researchers. Students will dive/snorkel at coral reef sites in these regions and walk along rocky beaches to study the ecology and understand the threat of climate change these islands face along with human-induced pressures. They will also collect and interpret data from coral reef and rocky beach sites across a gradient of anthropogenic pressures.

➢ *Field Methods in Ecology, GIS and Data Analysis*

Locations: Pondicherry, Auroville, Kodaikanal

This course has three themes which overlap to an extent as their titles indicate and can be integrated within a semester long program as appropriate,

i. *Field methods in Ecology and Marine Sciences*
ii. *Introduction to GIS and Spatial Analysis (including Marine GIS)*
iii. *Research Methods and Statistics (predominantly a lab course)*

The main aim of this course is to prepare students for a career in research and is therefore primarily concerned with key steps in the research process. This course will encourage students to think about their own specific research interests as they are introduced to study design, field data collection techniques and subsequent data analysis. This will be a good introductory course for students with no statistical or GIS background and for those who wish to broaden existing GIS and data analysis skills, the course also includes a portion covering advanced topics.

This course will take students through field and lab based exercises which will give them the opportunity to work with a variety of tools. Data collection covers a variety of biomes including terrestrial, near shore, and deep ocean methods. For the marine methods, SCUBA certification is recommended but not compulsory. While focus will be on field collected data, it also addresses remotely sensed data from satellites. Management of information and placing it within a spatial perspective is increasingly a requirement in almost any field of study. Many approaches have been developed to deal with issues of spatial information, its analysis and use within the ambit of the field called GIS. Data gathered during field surveys using compass, sight levels and GPS will be used in lab exercises. Students will also use a range of participatory mapping tools for data gathering. Comparisons between the two approaches will help students assess these approaches and their applications across different fields of study.

For the statistical analysis portion of the course, data will be entered in excel with a brief session on cleaning and organizing data before transitioning to the R statisical programming environment. Programming skills in R are desirable and considered essential for most research and analytical jobs today which is why nearly all data analysis will be carried using the R programming software. Introductory level statistics will cover descriptive statistics, correlation and ANOVAS while the advanced statistics will include linear modelling and other regression techniques. Students will also be taught how to produce publication ready figures and maps and will be encouraged to explore other R packages in addition to those used for the course. The final portion of this course will teach students how to write the methods and results section for a scientific report or paper.

➢ *Fisheries Ecology and Management*

Locations: Pondicherry, Tamil Nadu, Kerala, Goa

Fisheries play an important role in providing food security and livelihoods to millions of people and are thus significant globally. Catch reconstructions and historical baselines clearly demonstrate that world fisheries are on the decline and are therefore in dire need of hard management decisions. The role of small scale fisheries in poverty alleviation, livelihoods and food security however, is considered to outweigh ecosystem related concerns thereby complicating the management and policy discourse considerably. The impacts of small scale fisheries is comparable to the impacts of industrial fisheries from developed nations and the lack of enforcement or acknowledgement of existing fisheries legislation promises increased degradation to coastal habitats and local extinctions of several marine species in the very near future. However, this does not suggest a lack of attempts at fisheries management in developing countries; on the contrary, fisheries management agencies such as the FAO are discussing several approaches with fishing communities from developing countries, for the purpose of fisheries management, to be able to identify a viable solution that all stakeholders are content with.

This course introduces students to fisheries ecology and management by examining the history of fisheries and establishing its significance globally. Throughout the course, students will be encouraged to draw parallels between industrial fisheries in the developed world and small scale fisheries in developing countries. Key topics will explore species based, niche and ecosystem based fisheries while discussing the importance, challenges and management of the same. Different management approaches will also be discussed in addition to the science of fisheries management i.e., identifying maximum sustainable yields versus unexploited quotas.

A large portion of this course will explore the Indian situation in terms of legal, institutional, and socio-economic factors affecting coastal and fisheries management, covering the current legal status, international treaties, state and central government coastal zone management regulations, and the history and current status of conflict and the attempts to overcome that conflict in India. The role of culture, class and gender in fisheries will also be discussed in the context of society, livelihoods and fisheries resource management. Thus the course spans science, policy and law.

➢ *Culture Class & Gender*

Locations: Pondicherry and parts of Tamil Nadu

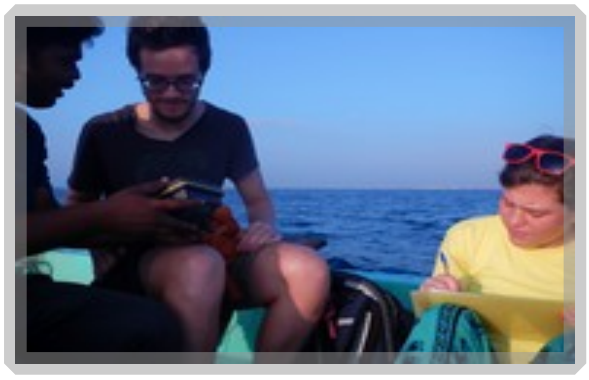
India is a land of many contradictions. A country that worships the highest number of Hindu Godessess at different times of the year, while listed in the top ten most unsafe destinations for women in the world by Forbes magazine in 2017. A country that was led by Indira Gandhi for nearly a decade and witnessed the phenomenal rise of women in politics, business and academia, yet struggles with extreme cases of misogyny on a regular basis. Gender equality is still a battle being fought, be it at home or in the workplace and this is only further compounded by issues related to caste, class and culture.

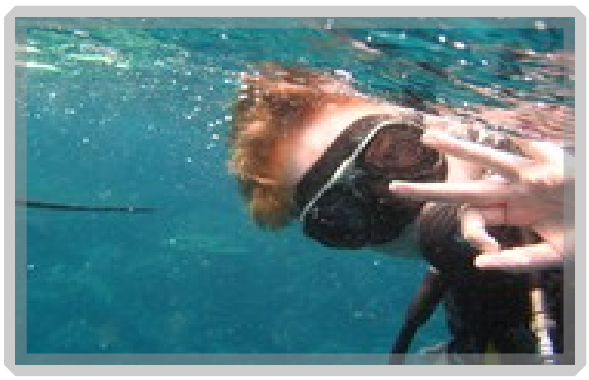
This course derives from a combination of the Culture, Class and Gender course and Heart of India course† which examines Indian culture and history and their influence on prevailing belief systems in view of the many conflicts and dilemmas that face Indian society today. While a range of social, religious and gender constructs are the root causes for many of India's past and ongoing problems, the teachings of Gandhi, Ambedkar and Periyar will provide the background to a deeper analysis of the organisation and functioning of Indian society and the relevance of their thoughts in a rapidly urbanising India. Additionally, several contemporary social movements will be analysed to understand the interface of social order and resource access / use and the need for a social justice perspective.

This course looks at the role of gender, class and caste across various facets of society and industry, from a historical and contemporary lens. Students are encouraged to draw parallels and highlight contrasts with Western society through lectures and field visits that examine the root of belief systems, current debates, progress and status. This course also explores the issues that have dogged development and policy discourse for several decades – primarily the role and contribution of women within the development sector.

The topics will be covered through a series of academic lectures, book readings, site visits cum interactions with field practitioners and activists and group discussions. Issues of gender and disadvantaged groups will be discussed, with visits to fishing villages which are culturally distinct from inland populations. Students will also explore the culturally distinct roles for women in resource harvesting, production, and processing of natural resources in addition to other professional roles. Students get the opportunity to interact with local organisations, village communities and women's groups and thereby reflect upon the processes and challenges of translating theory to action on the ground.

† Described on page 9 & 10 of this document.





➢ *Scientific Communications*

Locations: Pondicherry/ variable locations

Writing and communicating research findings form a significant part of any research or scientific career. Most of us struggle with this particular skill and develop the ability as we progress in our careers. The aim of this course is to demystify the writing process while addressing the different fora used to communicate science. A recent debate in India highlighted the silence or lack of participation of scientists, ecologists and academicians in the development versus ecosystems dialogue which has sparked an interest from the scientific community to share their research with the general public. While a large part of this course will focus on the development of a perfectly readable scientific manuscript, the course will also encourage students to go beyond peer reviewed scientific papers and develop their skills in popular writing, blogs and public speaking. One session in this course will also cover grant writing which is a fundamental skill for a successful research career. This is predominantly a lab course and can be integrated with the methods course.

Pictures (from top to bottom):
a) Students on the inter-tidal ecosystem walk in the Andamans.
b) Students collecting fishing location data on fishing surveys off the Pondicherry coast.
c) A trawl fish catch.
d) A student giving the OK sign before ascending
e) Women working in one of the Art centres in Auroville

Courses at FERAL since 2008

In addition to the courses on the Study Abroad program, FERAL also teaches regular courses which are open to graduate students, professional researchers, academicians and teachers across India. These courses are centred on developing the skills essential for quantitative research and range from basic introductory classes for beginners to advanced sessions for those who are considerably experienced. We have organized and taught a number of practical workshops covering the applications of remote sensing, GIS and statistical analysis using the R programming environment within the fields of Landscape Ecology, field Hydrology, Wildlife Biology, Fisheries Ecology and more recently Epidemiology. We also periodically teach field methods in the aforementioned disciplines including participatory methods for social and vulnerability mapping. These workshops vary in duration and are in fact, the most frequent types of events organised at FERAL and typically involve active participation from those attending.

Remote Sensing, Geographic Information Systems and Statistical Analysis using R

Locations: Pondicherry and Bangalore

Brief Overview

These topics are covered in intense hands-on workshops comprised of numerous tutorials and exercises, taught by a team with over a decade of experience in using these tools in their own research and teaching assignments. As these themes are also considerably broad, an outline of topics covered in a typical workshop has been provided which includes a brief mention of advanced topics.

At the end of each Remote Sensing and GIS course, attendees know how to

1. Import, view, edit and manage spatially explicit data in a number of vector and raster formats.
2. Manage attributes and data stored in tables.
3. Georeference maps and imageries.
4. Digitise maps.
5. Use QGIS along with GPS units and GPS enabled smartphones to collect waypoints and navigate.
6. Make publication quality maps.
7. Analyse and manipulate vector data using geo-processing routines, database features, research and spatial analysis tools *(Advanced)*.

At the end of each R course, attendees will be able to

1. Understand the basic concepts of how to use R
2. Use R as a calculator and a basic data manipulation tool
3. Understand the different data types, write data and read data into R
4. Perform basic statistical analysis by following basic programming concepts in R
5. Program in R by writing simple functions to create loops or run simulations
6. Produce summaries and descriptive graphs of data
7. Perform specific analyses by exploring relevant packages within the R programming environment grounded in a firm understanding of statistics and R.
8. Perform analyses such as Generalized Linear Modelling, Correspondence Analysis or Tree models *(Advanced)*

Final outcomes of the courses

Attendees have the ability to plan and implement relevant techniques using GIS and R that are guided by well defined scientific questions and a clear understanding that these techniques vary with research design in terms of the required data collection, entry, organization, compilation and analysis..

Participants on FERAL workshops are accommodated on campus which has modest facilities at a minimal charge.

Pictures from top to bottom:
a) & b) Thatch hut accommodation, c) kitchen, d)bunker or training hall, e) office

About faculty and expertise at FERAL

Study Abroad Program and Course Leaders

Tara Lawrence has been involved with FERAL's Learning Program for over ten years. A marine biologist by qualification, she began as a teaching assistant on the Marine Science Program, taking over the overall coordination of the Study Abroad Programs from fall 2010 to 2013. Alongside this, she completed four fisheries research projects that examined the ecological and socio-economic status of coastal fisheries along 120 km of the Coromandel Coast in India. Soon after this, she went on to complete a second Masters' degree in Marine Environmental Management and is currently developing her research with Prof. Maarten Bavinck from the University of Amsterdam for a PhD.

Her broad interests lie in the area of marine ecology, ecophysiology and environmental management. Her love for fish and anything to do with fish leaves her in charge of fish and fisheries aspects including field methods and data analysis, teaching a significant portion of related courses and some of the Culture, Class and Gender course. Additionally, she supervises all field excursions, accompanying students through all their travel and is therefore also responsible for student care and safety.

Prof. Neil Pelkey is an Associate Professor at Juniata College, Huntingdon, Pennsylvania. He is an expert in Ecology, GIS and Remote sensing and is an advisor on many of the projects and research proposals at FERAL. He is also responsible for developing the Study Abroad program via ongoing and past collaborations with Juniata College, Brethren Colleges Abroad (BCA) and the Keystone Study Away Consortium (KSAC) respectively.

He teaches a range of courses on the Study Abroad program given his broad expertise. Some of these courses are field research methods, statistical programming and data analysis, GIS, sustainable resource management and scientific communications. His presence during the first few weeks on semester long programs ensures a smooth transition for students, allaying initial fears and reassuring them such that they are comfortable and are prepped to enjoy their study abroad experience. He also has regular skype sessions with students concerning course work, assignments and projects, the latter which he closely supervises so students produce quality work.

FERAL Workshops and Course Leaders

Dr. R. S. Bhalla is a field based ecologist involved in community based management of natural resources and ecosystem services. He has a PhD in Ecology and has led a number of research projects in this area over nearly two decades. He strongly believes in the application of quantitative tools and techniques in research, development and advocacy and is proficient in the use of a range of GIS and remote sensing software and programming in R. Consequentially, he designs and teaches courses related to field research methods, data analysis and sustainable resource management on the Study Abroad Program. He also advises students on research design and sampling methods, often closely working with them on analysis.

He is also an adjunct faculty at the National Centre for Biological Sciences (NCBS) Bangalore and teaches the course on GIS and remote sensing to their M.Sc Wildlife Biology students. On the social front, he hosts plenty of barbeques and dinners which students thoroughly enjoy and look forward to.

Divya Karnad is a marine ecologist working on fisheries and threatened fish species along the west coast of India. She recently completed her PhD at the Rutgers University, USA and is studying sustainable livelihoods of fishermen and conservation of threatened marine fish species in Maharashtra, India.

Srinivas V is a wildlife biologist with particular interest in understanding changes in landscape level processes and structure and how the same affect large mammal populations and distributions. He is a guest faculty at the M.Sc course in Wildlife Biology and Conservation at National Centre for Biological Sciences, where he has been co-guiding students for their Master's thesis. His expertise is varied, ranging from using a spatial approach to understanding various ecological and environmental questions to finding innovative and practical solutions to conservation problems.

Rajat Nayak completed his Masters in Wildlife Biology and Conservation from National Centre for Biological Sciences, WCS-India Programme, Bengaluru, India. He has a special interest grassland ecosystems, both low and high altitude, semi-arid and wet. His interests are currently directed towards understanding the role played by anthropogenic fire and grazing in different habitat types, ranging from tropical seasonal forests to savannah woodlands to sub-tropical sub-alpine and alpine woodlands and grasslands. He continues studying the long-term changes in ecosystem components and processes due to anthropogenic factors in Indian forests, and contribute towards conservation of ecosystems and biodiversity.

Specific Course Contributors and Leaders

Anupama Pai has a long history of involvement with the Learning Program at FERAL, playing a pivotal role in designing and developing the courses and collaborations that made the Study Abroad program. She was also responsible for overall student care and safety while teaching the Culture, Class and Gender course and accompanying students on all field excursions. Given her vast experience with students on the program, her instructions and advice on conduct, health, Indian culture and society are invaluable to students.

She soon went on to become the Resident Director for India Study Abroad programs with Brethren Colleges Abroad where she supports American undergraduate students in various locations across India. Simultaneously, she teaches the Culture, Class and Gender course on the FERAL Study Abroad program.

Dr. Senjay Babu is a Max-Planck post doctoral fellow with an M.Phil in the History of Science and a PhD with the Centre of Historical Studies at Jawaharlal Nehru University, New Delhi on "The Culture of Science and Politics in Colonial Tamil Nadu, c. 1860 - c. 1940". His broad interests lie in social issues within vulnerable groups like fishing communities, dalits and women in villages and has worked on varied topics across the state of Tamil Nadu - from resource conflict to gender inequality. He also teaches the Culture, Class and Gender course and topics related to the role of community and women in sustainable development.

Gayathri Selvaraj is our newest member on the Study Abroad Program who is also a FERAL alum and an independent scientist with two Masters' degrees. She is currently pursuing research on characterising lizard assemblages and correlating changes in land utilisation trends with composition of these assemblages. She is also part of a project investigating the genetic diversity of gekkonids on the Andaman and Nicobar Islands in collaboration with the Center for Ecological Sciences, IISc. She is an experienced educator, having worked with graduate students and communities as part of her role as education officer for Madras Crocodile Bank Trust (MCBT). While in MCBT, she discovered her affinity towards herps and is ardently running about the country-side contributing to the understanding and preservation of these incredible animals. Apart from diligently scrambling behind reptiles, she is a qualified bioinformatician, often hired on projects for her statistical and geographical data analytical skills. She is one of the core faculty members on the Field Methods, GIS and Data Analysis in Ecology courses.

About our Course Collaborations

Collaborative learning has always been an integral part of the courses at FERAL, particularly on the Study Abroad Program. Interdisciplinary collaborations achieved through networking with reputed Indian educational institutions, research organizations, non governmental organizations and commercial establishments endeavour to build capacity of students in the program. As a direct consequence of such collaborations, students are able to understand theoretical and tactical resources in their respective fields of interest that exist outside of their own country. As the aim of the program is to equip students with a broad skill base such collaborations offer students a wide range of learning opportunities while simultaneously promoting inter-cultural understanding and recognition of individual differences.

The course curriculum was often planned around the availability of professionals to teach. Educational institutions often planned the programs based on their education calendar for that academic year as well as the availability of faculty members to teach. Visits to non-profit and research organizations was often based on the nature of projects being conducted as well as the availability of scientists and field technicians to guide students through various courses. Thus, the flexibility of the program allowed these changes resulting in each group doing something slightly if not completely different to previous or later groups. Collaborations also shifted along with key resource people who contributed significantly to the building of this program. Financial costs of the program at each location also were reasons for shifting collaborations as much as it was exploring potential and discovering newer alliances for the good of the programs.

I. Educational Institutions

Colleges and Universities offering Oceanography/Marine Biology & Aquaculture course work in India are designed in unison which explains the overlapping syllabi and often the exact curriculum followed across universities in the country. Key areas that all Universities have in common are topics related to taxonomy, fisheries, mangroves, plankton ecology and aquaculture; the latter having a stronger emphasis at some places than others. Students on the program through the years have always had these courses taught despite changes in collaborations. These courses have a strong practical and field component which students have enjoyed immensely as a result of which more time on field was a common request through the program. Students typically spend a week or two at these institutions, staying in student hostels on campus or guest houses if student accommodation is not available.

Experiencing formal education in India along with Indian students also gave students the opportunity to draw contrasts to the US education system and examine these contrasts from a cultural and gender perspective, thus adding yet another facet to their experience in Indian institutions. This, particularly was crucial for the social or cultural courses which took place in collaboration with universities/colleges with strong social work programs.

- ***Cochin University of Science and Technology (CUSAT), Kerala (2005 - 2006)***

  Established in 1971 as the University of Cochin, CUSAT has 27 departments of study offering graduate and postgraduate degrees in core areas such as Marine Microbiology, bio-prospecting of wetlands, Aquaculture, Climate Change, benthic studies, mangrove studies, Marine Botany, Biochemistry and plankton studies. The two prominent departments are:

  The School of Industrial Fisheries was established in 1976 as the Department of Industrial Fisheries under the erstwhile University of Cochin for postgraduate teaching and research on all aspects of fisheries science and technology. The School offers an M.Sc. in Industrial Fisheries and Ph.D. programme in Fisheries related disciplines like Aquaculture, Fishery Biology, fishing craft and gear technology, fish-processing technology, Fisheries Economics and Fisheries Management.

  The Department of Marine Biology, Microbiology and Biochemistry is one of the first and foremost academic centres in these disciplines in the country. The Department has all the essential infrastructure for teaching, training and research in the basic and applied frontiers of these disciplines. A team of talented teachers, trained in different areas of Marine Biology, Microbiology and Biochemistry in India and abroad constitute the faculty.

Key resource person: Dr. K T Damodaran, Director

- ***College of Fisheries, Mangalore (2005 – 2008)***

  Established in 1969, College of Fisheries is a premier fisheries education and research institute in India. Now the college is part of the Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar. The college has always played a key role in fisheries education and research in the country and has spearheaded consultancy projects in post-harvest fisheries, fishery engineering and electronics, environmental pollution monitoring and ecosystem study, geospatial hydrology and remote sensing. The college offers M.Sc. and Ph.D. programs in aquaculture, fishery microbiology, fish processing technology, fisheries resource and management and fisheries environment and ecology.

Key resource person: Dr.Keshavnath Perar, Dean

- ***Centre for Advanced Study (CAS) in Marine Biology, Annamalai University, Porto Novo (2005 – 2009)***

  CAS, established in 1975 is modelled along the lines of Marine Biological Station, Woods Hole, USA. The institute has gained national and international recognition as a pioneer in marine research and has published over 1000 research papers. The institute is equipped with major analytical instruments, cell and tissue culture capacity, sea water circulation facility, marine botany research facility, plankton identification and culture facility, aquaculture demo ponds, gene bank of rare mangroves sps., physical oceanographic field equipment display and reference collection of authentically identified specimens of flora and fauna of the area collected over a period of 40 years.

Key resource person: Dr. T Balasubramanian, Director

- ***National Instititute of Oceanography, Goa (2006- 2011)***

  The National Institute of Oceanography (NIO), was established in 1966 and is an internationally renowned oceanographic research laboratory with it's headquarters in Dona Paula, Goa. The institute's research is focussed on observing and understanding the spatial oceanographic features of the North Indian basin. Their four core research areas include biological, chemical, geological/geophysical, and physical oceanography. This institute has over 200 scientists and is well equipped with laboratories, research vessels, and a library that contains the largest collection of printed literature on ocean sciences in the country. They also conduct applied research including oceanographic data collection, environmental impact assessment, and modeling to predict environmental impact. NIO also provides advanced educational services in ocean sciences and provides a spectacular facility for doctoral research. NIO has many Junior and Senior Research Fellows pursuing their doctoral studies and over 240 undergraduate and postgraduate students pursuing project research every year. They have a large international guest house which provides a comfortable living space for all guests, students, and researchers which visit or work at NIO.

Key resource person: Dr. Virupaxa K. Banakar, Head HRD-SAC

- ***Post Graduate Marine Biology Department, Karwar, Karnatak University (2009 – 2011)***

  The post graduate centre for Marine Biology is located at Karwar which about 175 km away from the main campus. Their mission was to prepare competent scientific manpower for exploration, utilization and rational management of marine resources of the sea around us. The centre has a laboratory with facilities for near shore research.

Key resource person: Dr. U. G Bhat, Chairman& Dr. Radhakrishnan, Professor

- ***SDMRI: Suganthi Devadason Marine Research Institute, Tuticorin (2007 – 2011)***

  The Suganthi Devadason Trust established SDMRI in 1998 in Tuticorin, Tamil Nadu, India for the purpose of Marine Research and Higher Education with the intention to improve the socio economic conditions of coastal folk and increase higher education among women. The institution's main focus is to research marine and coastal ecosystems based on India's current needs leading many research projects that focus on conservation and management.

  Some of the projects address integrated coastal and disaster management, ecosystem restoration and monitoring, coral and seagrass monitoring, fish spawning aggregations, and many more. Their social work comprises activities with coastal fisher folk with a particular focus on bringing better education to women. SDMRI also has an M.Sc, M.Phil, and Ph.D program to increase higher education in the Marine Sciences.

Key resource person: Dr. J. K Patterson, Director

- ***Madras Christian College, Estuarine Biological Laboratory, Pulicat Lake (2011-2012)***

  Madras Christian College is a private institution that was founded in 1837 in Chennai. It is one of the top ten Arts and Sciences colleges in India. The Department of Zoology established an off campus Estuarine Biological Laboratory on Pulicat Lake, Pulicat town about 35 miles from the city of Chennai. The total area of this campus is 3.5 acres including the water front. There is a full fledged laboratory for classes and research in the fields of Zoology, Estuarine Biology and Marine Science. The postgraduate students of Marine Studies and Coastal Resource Management, carry out their field and laboratory work at this centre. The lab holds a class room, a mini museum of marine organisms available at Pulicat, a kitchen, staff quarters and a store room where chemicals, instruments, life jackets and boat engines are housed. A dormitory that can house upto 30 students was added to existing facilities in 2009.

  The centre has produced over 15 PhDs and has had several international students participate in research activities that involved popularizing eco-friendly methods of fishing, sanitation and health awareness, awareness programs on resource management, non destructive fishing gears. The centre also forms a resource centre where the fisher folk and others can understand the wealth and resources around Pulicat Lake. As the lake is all set to attain the "Ramsar" status for wetlands, the Madras Christian College leads the way for many other institutions for conservation and restoration of the Pulicat Lake which is the second largest brackish water in India.

Key resource people: Dr. R.W. Alexander Jesudasan, Principal and Dr.Moses Inbaraj, Director (Estuarine Biological Laboratory), Pulicat lake

- ***Rajagiri College of Social Sciences, Kerala (2005 – present)***

  Rajagiri College of Social Sciences (Rajagiri) was established as a result of the indefatigable industry and foresight of the Carmelites of Mary Immaculate (CMI) which was the first indigenous religious congregation for men in India. The School of Social Work was one of the pioneering institutions in South India, establishing programmes and setting standards for the field. Rajagiri has successfully established and maintained the apt ambience for learning and the highest level of academic performance by providing state-of-the-art infrastructure and facilities. International partnerships with reputed Management and Social Work institutions across the globe allows the College, the faculty and students to stay abreast of the constant changes occurring as Rajagiri is becoming truly global, with its graduates being placed and working around the world.

Key resource person: Fr. Jose Alex, Provincial Manager, CMI Congregation

- ***Sacred Heart College, Kerala (2013 - present)***

  Sacred Heart College, Kochi, is a premier institution of higher education affiliated to the Mahatma Gandhi University, Kerala. Established in 1944 by the Carmelites of Mary Immaculate (CMI), a catholic religious order for men, the college aims at the fashioning of an enlightened society founded on a relentless pursuit of excellence and a secular outlook. Over the years, the college has established itself a frontrunner in the quest for excellence, both in academic and co-curricular fields. In the year 2000, the college was accredited five stars by the National Accreditation and Assessment Council (NAAC) and in 2013 it was reaccredited at the A level. With 14 undergraduate and 14 postgraduate programmes including a range of diploma and certificate courses, the college has been in a quest to stay abreast of the ever expanding academic frontiers.

Key resource person: Dr.J. Prasant Palakkappillil, Principal

- ***The Last Scool : Pyramids Art Center, Auroville (2012 – present)***

  At places like the Pyramids Art Center, art is recognized as a means to develop the personality rather than as an end in itself. Children from all Auroville schools are invited to develop their aesthetic sense and their concentration, as well as train their endurance to manifest an idea, all through art. Students have the opportunity to learn and explore techniques in drawing, sketching, painting, sculpture and also work with small structures which require a certain deft and nimble technique that students acquire over a period of time. During their course here, students also visit other studios and interact with several artists along with immersing themselves in their own creativity. The very interiors are decorated with student works of art and encourage a freedom of expression through art.

Key resource people: Michelle & Veronique

◄ *Students on a purse seine fishing boat off the coast of Karwar. Students get to see how the net is operated, the kind of manpower it involves and the implications on ecological and social aspects of fisheries in India.*

Students visit fishing villages using Chinese dip nets which are only found in Kerala. Students also visit the backwaters to see shrimp farms, salt resistant paddy and other types of fishing gears ►

◄ *Becca Students enjoying a cultural performance of a traditional dance form called Theyyam, Kerala.*

Becca and Corinne working on their art in one of the art studios of The Last School ►

II. Research Organizations/ Non-profit Organisations

These collaborations offer the program more diversity and flexibility than Universities or colleges do. As alot of these organizations are driven by strong research programmes along with education, the diversity in research activities offers students a range of opportunities to choose from. These can be in the form of field assistance leading to a research paper or a full fledged internship. Each group experiences or learns something different as research projects are often time bound and conducted by different researchers and scientists. Students not only have the opportunity to participate in projects of their interest but also attend talks on specific topics related to these research projects and interact with the respective experts. These collaborations present an informal and less structured environment encouraging students to explore their own research interests with strong emphasis on data driven research.

■ *Andaman and Nicobar Islands Environmental Team (ANET) (2005 – present)*

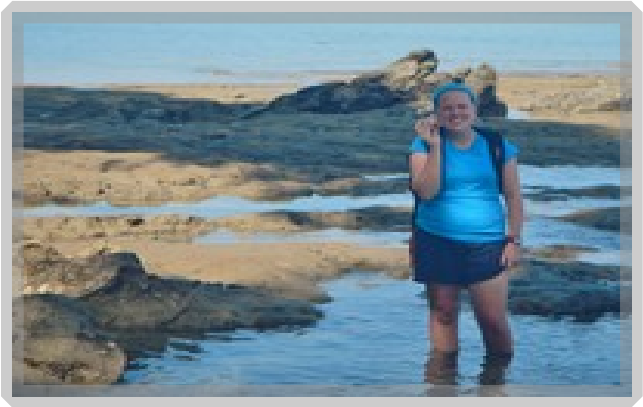
ANET was set up in 1990 at Wandoor and since its formation, ANET has undertaken several extensive research projects studying the islands' flora, terrestrial and marine reptiles, small mammals, resource and land use, coral reefs, and socioeconomic factors affecting them. The team has been responsible for the discovery of eight new species as well as several records throughout the region. Turtle nesting dynamics are also monitored by the team through seasonal field camps that are located within the archipelago. In collaboration with the Forest Department, ANET also aids in providing safe management plans for Protected Areas. The organization runs a strong environmental education program as well, working closely with the Center for Environmental Education.

▲ *Thatch accommodation at ANET*

The facility itself consists of a kitchen/ dining area, capsules for housing staff and visitors, and a large hall-like building with a small library and workspaces located upstairs. Right in the backyard is a patch of restored mangroves and rich inter-tidal ecosystems.

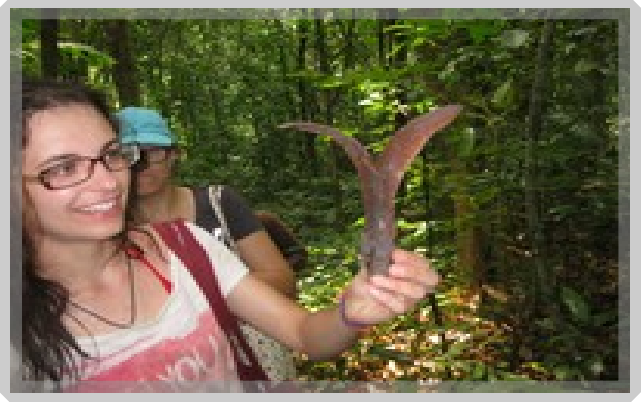
Students spend a fair amount of time observing these ecosystems during both high and low tides and discussing its functions. Students also take a boat to a nearby mangrove patch that is part of the Loha Barrack Crocodile Sanctuary, looking for saltwater crocodiles that occupy the shallow channels. The portion of the crocodile sanctuary in the opposite direction is a rocky intertidal area offering an excellent classroom for studying tidal zones and the organisms that occupy each of them. Limpets, chitins, and gastropods can be seen inhabiting boulders during low tide, and tide pools can be found containing crabs, snails, and mudskippers. A few days at the station is dedicated to research methods, in which the students are given the opportunity to conduct their own small ecological experiments within these mangro ve and inter-tidal areas. The students are given several lectures by ANET staff as well as visiting friends and collaborators of the organization. Topics covered included dugongs, sea turtles, mangrove ecosystems, and the islands' indigenous tribes; all of which encompassed the current state and conservation efforts behind each.

Key resource person: Tasneem Khan, Assistant Director



▲ *Becca listening to a sea shell during the rocky shore exploration.*

▲ *Students visiting a remote village on Rutland Island, home to the cook at ANET. The village does not have electricity or running water.*



▲ *Ashley fascinated by a size of a seed on their forest walk.*

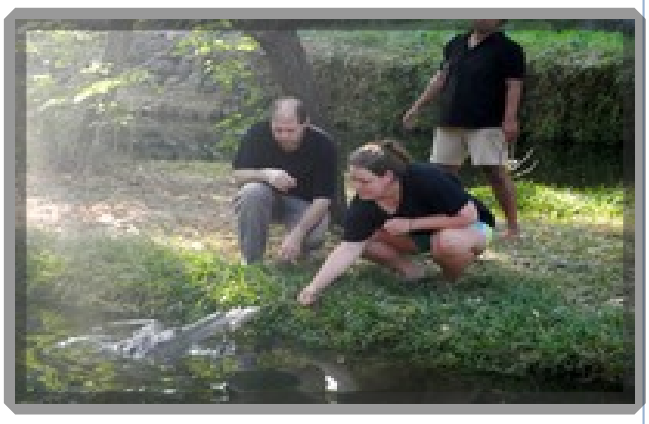
Students enjoying a tea-break with Tasneem during the inter-tidal walk

■ *Madras Crocodile Bank Trust and Centre for Herpetology, Chennai (MCBT) (2005 – 2013)*

MCBT was established in 1976 by Rom and Zai Whitaker and the first Centre for Herpetology in Asia. MCBT is a reptile park that houses crocodilians, turtles, tortoises, snakes and lizards. The park focuses on conservation and captive breeding of endangered species and scientific research on reptiles and amphibians. MCBT regularly hosts students from universities, both within and outside the country, as part of their curriculum. Students are involved in cleaning animals pens, helping with food preparation and feeding reptiles, attending presentations on the various reptile taxa by the in-house experts, curatorial activities such as measuring and weighing young crocodilians, snakes and chelonians. MCBT also organises bird watching trails, night trails and snake walk with members of the Irula tribe.

Key resource person: Gowri Mallapur, Assistant Director

▲ *Students cleaning a crocodile pen under the watchful eyes of the attenders and handlers.*



▲ *Colin, the Director of MCBT guiding Rachel on how to feed Robin, the gharial who broke his snout in a fight with another male gharial.*

Visiting organic farms in Bahoor,Tamil Nadu

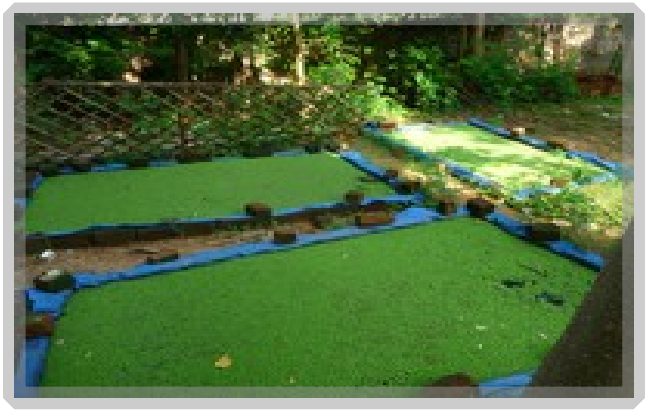
■ *Centre of Ecology & Rural Development (CERD) (2005 - 2012)*

An organisation that is part of the Pondicherry Science Forum which was exclusively formed for taking up meaningful interventions in Health, Sanitation, Natural Resource Management, Energy, Watershed management and ICT for development. CERD was set up in the year 1994 jointly by the Pondicherry Science Forum and Tamilnadu Science Forum to take up S&T based development initiatives improving the rural livelihoods of weaker sections. The earlier works included interventions in sericulture, vegetable leather tanning and fish aggregation devices amid several local initiatives.

CERD has a field station at Bahoor called the Kalanjiyam (meaning Granary in Tamil) which acts has a hub of agriculture and technology options for the surrounding area. CERD has a full-time manpower structure with a committed team of scientists working on a variety of areas ranging from women's technology, science communication, continuing education, participatory irrigation management through local democratic people's institutions, women's micro credit networks etc.

Students are exposed to a range of topics relevant to sustainable development, sustainable agriculture and gender studies.

Key resource person: Dr.Raghu Menon, Director



An Azolla pond growing a bio-fertilizer for paddy cultivation ►

▲ *Parts of Bodhi Zendo's Zen garden* ▼

▲ *Views from Bodhi Zendo and other places at higher elevations in Kodaikanal.*

■ *Bodhi Zendo: Zen center in India, Kodaikanal (2005 - 2012)*

Bodhi Zendo is a Zen training center in South India's Perumal Hills, which also serves as the center for Bodhi Sangha, an international community of followers of Zen-Master P. AMA Samy.

Bodhi Zendo is open to all who practice Zen, or who wish to experience it. Students typically spend only half a day here but usually people spend some days or weeks in silence and meditation and experience the brotherhood of the Sangha. At Bodhi Zendo visitors will find a beautiful Zen garden with wonderful panoramic views of the surrounding mountains and valleys. There is also a considerable library, with literature on Zen, Buddhism, Christianity, Philosophy, other religions and other subjects.

■ *PROWESS (2005 - 2012)*

An innovative non-profit development program for underprivileged women in South India. It aims to inspire self-determination and empowerment through awareness-raising and income generation.

The women in the program produce a wide array of toys, puppets, furnishings and accessories, most of which are made with 100% cotton or silk fabrics. Polyester fiber filling is used for the toys and furnishings.

Key resource person: Beulah Kolhatkar, Director India Educational Tours

III. Communities in Auroville

These collaborations change based on key topics covered on the respective courses. Students typically spend atleast a week with each of these communities, immersing themselves in the community, participating in all the activities and learning throughout. These communities offer students the opportunity to experience sustainable living first hand, and students often request for extending their time with these communities. Students also conduct their research projects across different communities for comparisons in adopted practices.

- ***Evergreen (2011 – present)***

"Experiential Environmental Programs for an Emerging World"

Convergence is an innovative environmental education center in the South East of India offering experiential environmental programs. People from different social and cultural backgrounds in a working dialogue are engaged, to enable deep observation and awareness of the self, society and the surrounding natural world. They explore world views through workshops, field work and community outreach, living in the midst of an evolving forest, with time to relax and have fun and explore the desire to create change. Their programs go through the process of creating a picture of the world you want to live in and then help focus your energies into building it. They offer information, experiences, resources and a general understanding about the global environmental context, the combination of which is an essential part of all their programs with an opportunity for introspection and self-discovery.

The programs include working hands-on in areas such as organic food production, renewable energy, sustainable building, reforestation and water management. Most importantly they provide the experience of living as a community, exploring both global and local issues and solutions. The power of people is in their ability to create change in their daily actions and innovations, which over time, create our collective reality.

Key resource person: David Storey

- ***Pebble Garden (2012 - present)***

Pebble Garden was started in 1994 on 6 acres of severely eroded land. Today it is a vibrant forest of indigenous Tropical Dry Evergreen Forest (TDEF) trees, eleven water bodies, a fruit tree area and a garden of 1000 square meters. Pebble Garden is cultivating about 90 hardy vegetable varieties ideal for home gardening. It has been created without any bio-inputs from outside, just with biomass grown in situ, no animal manure, no purchased soil or compost, no hired labour and only with small voluntary donations from individuals.

Key resource people: Bernard and Deepika

- ***Sadhana Forest (2012 – present)***

  The founders, Yorit and Aviram Rozin, envisioned transforming 70 acres of severely eroded, arid land on the outskirts of Auroville. In a spirit of human unity, they aimed to introduce a growing number of people to sustainable living, food security through ecological transformation, wasteland reclamation, and veganism. Their energy and resources are focused on the creation of a vibrant, indigenous Tropical Dry Evergreen Forest (TDEF).

  The aim of this ecological project is to support the local rural villages mainly:

  i. By retaining water and filling the aquifer. Sadhana Forest India allows the villagers to cultivate their food and prevents exodus towards nearby city slums.
  ii. By planting the indigenous plants that constitute TDEF, an ecosystem unique to this region, and one that is currently endangered.
  iii. By providing Environmental education for all.

  As many children and young people are involved in the process of ecological revival and sustainable living. Their aim is to encourage them to share and propagate the vision of an ecologically responsible and sustainable way of living, and for them to help take urgent actions that are necessary for the future of their environment. Children and young people from nearby villages take an enthusiastic and active part in this project. For most, it is their first 'hands-on' experience in sustainable living, an exciting and transformative experience for them. Students spend a week here immersing themselves in their way of life. They not only learn about sustainable living but meet and interact with people from all over the world who share similar thoughts and beliefs.

Key resource people: Aviram & Yorit

▲*Tree planting every morning is part of the daily schedule and tasks are assigned to community members so each person has a role to play.*

Inside the community hall at Sadanah. Community members dine together in this hall. A variety of performances from people across the globe also take place here ▼

IV. Commercial Establishments

These are regular business centers where the program and students sometimes pay for a course or the activity and explore their research interests or creativity as required. Atleast two weeks are spent at each of these establishments.

- ***Barefoot Scuba Dive Resort (2004 – present), Andaman Islands***

Located on Beach No.3 and is the leading dive resort on Havelock Island. Barefoot is a PADI five star instructor development dive facility. It has top of the line equipment, several boats, and various dive locations available. Barefoot is also concerned with environment conservation and education. They work with local schools to increase awareness of how fragile the environment is and what humans do that impacts the environment. Barefoot has a hope in expanding their conservation efforts by hiring marine biologists in the coming years to study butterfly fish as well as coral reef ecosystems.

At Barefoot, classes for students consist of Island Biogeography lectures, an introduction to Geographic Information Systems, marine science videos, scuba diving, intertidal walks, and follow up discussions on the day's activities.

▲ *Neil and Cara standing outside their A-frame hut at Barefoot*

▲ *Student group picture with the team at Barefoot*

- ***Rumblefish Adventure, Phuket, Thailand (2013)***

A PADI 5 Star Instructor Development Dive Resort and a private company located in the serene Kata Beach in Phuket. Modest yet one of the friendliest dive centers in Asia, Rumblefish Adventure has all that is required for diving; from quality PADI dive courses, a full service equipment retail shop, to a range of options for daily dive trips to rich dive sites in the waters off Phuket. Opportunities in Phuket are yet to be explored as there is plenty of potential to tap into for both the semester programmes. Topics covered while diving in Phuket overlapp with those conducted at Barefoot Scuba and ANET.

- ***Temple Adventures, Pondicherry (2012 -2013)***

  India's first and only East Coast Diving Center based in idyllic Pondicherry. They currently dive at more than 20 sites ranging from 5m to 40m depth, with average ocean temperatures of 28 C and visibility up to 40M. 30 years of diving in Pondicherry has led to the discovery of some amazing dive sites here. Most have been discovered, marked, and mapped more recently with the use of modern equipment such as GPS and Sonar. It is a pleasure to dive on sites found by the pioneers of diving in Pondicherry. It is also special to find something new, previously never before seen by human eyes. All their sites are excellent in both marine life and topography. They train alot of people to Open Water, prior to their trips overseas, to the Andaman Islands, or for mainland diving which some of the students have been a part of. Students and faculty have also completed their refresher PADI courses with them before heading off to the Islands for research dives.

- ***Mantra Pottery (2004 - 2011)***

  Angad Vohra, who started Mantra pottery has been a potter since 1976, established this unit in 1994. Mantra makes high fired stoneware using a wood fired natural draft kiln. The pots are made on kick wheels and the clay is prepared by hand and so the process provides a viable alternate technology that is very relevant to rural India and in particular to the context of the Auroville project located in South India. Generating employment in good working conditions is a priority along with making high quality pots and tiles. The pots are safe for use with food and the tiles, also of stoneware, are very durable. There is no tradition of stoneware pottery in India although pottery (mostly terracotta) has been around since a long time.

  Students typically make 8 pieces of their choice on the course, only paying extra for the materials used to make more.

Pictures from top to bottom:
a) Alex at the potter's wheel, b) an elephant teapot, c) Students designing and making tiles

V. INDEPENDENT EXPERTS/PROFESSIONALS

Some of the experts who have taught on the program have been introduced below. While some are independent professionals, most are involved in research projects with multiple collaborations and therefore teach on the program as and when schedules permit them. Their time on the program sometimes spans from an hour to a couple of days. Their area of expertise is indicative of the courses they contributed to.

Dr. Rohan Arthur, NCF

Nature Conservation Foundation

Rohan's research interests concern issues of conservation, particularly the implications of climate change for marine ecosystems, the rational management of marine systems and fisheries in India, and the interface between policy, traditional practices, and ecosystem management. He is one of NCF's founder-trustees, and directs its reef program.

Paul Blanchflower,

Auroville Botanical Gardens

Paul has over twenty years of experience in forestry and landscaping. He arrived in Auroville in 1991 from Scotland after graduating in Forestry and Ecology at Edinburgh University. He founded the Auroville Botanical Gardens in 2000 that offers a variety of services for land management and landscaping. He is currently engaged in developing the gardens with emphasis on environmental education for the local school children.

Dr. Naveen Namboothri,

Dakshin Foundation

Naveen's interests lie in marine ecosystems and in applied aspects that would assist in conserving and better managing resources. He is interested in understanding vital processes and functions of ecosystems that are essential in maintaining its health. He is one of the founding trustees and is currently the Director of Dakshin. He also heads the Biodiversity and Resource Monitoring Programme and Environmental Education Programme.

Benjamin Larroquette, UNDP

United Nations Development

Programme

Benjamin was the Managing Director of FERAL (2010 – 2012) and is currently a Regional Technical Specialist for UNDP in Africa on Green Climate Fund projects, providing oversight and technical support to 15 African countries on implementing Climate Information and Early Warning Systems Strengthening Livelihoods (CIRDA), Disaster Risk Reduction and adaptation to Climate Change.

Aurofilio Schiavina,

PondyCAN

Aurofilio was born and brought up in Pondicherry of Italian parentage, completing his education at the Sri Aurobindo International Centre of Education. An avid swimmer, diver, surfer, and wind-surfer, he decided to combine this love for the sea with his higher education and received a masters in Tropical Coastal management at Newcastle University. Ever since he began witnessing Pondicherry's beautiful beach disappear, with large rocks dumped into its place, he has been engaging with the Puducherry Government for the restoration of the Pondicherry coast.

David Storey,

Convergence & Evergreen

Dave majored in Tropical Soil Science and Plant Ecology at Newcastle-Upon-Tyne university in the UK and completed his Masters at Wageningen in the Netherlands in Ecological Agriculture. He has worked with several non-profits and United Nations organizations like FAO and UNDP leading teams through all stages of the participatory project cycle. He is an experienced manager and negotiator, providing technical assistance in projects related to food security and livelihoods in addition to the development and implementation of participatory learning and community development projects. In Auroville, Dave works with Convergence, an educational platform for sustainability.

Dr. Dipani Sutaria,

James Cook University

Dipani has a doctorate degree from James Cook University, Australia and is one of the few people researching marine and fresh water mammals in Indian waters. She worked as academic advisor on the Marine Science semester Spring 2011 semester. Her role was to supervise student research projects and interface with the students and college faculty specifically leading discussions on topics covered during formal classes. She is involved in ecological research, specifically in the marine environment also mentoring students interested in similar aspects.

Dr. Lucas Dengel,

AuroAnnam & Eco-Pro

Lucas is a doctor trained in medicine at the University of Mainz, Germany. He has over fourteen years experience in the field of public hygiene with a focus on public health related to the environment. He coordinated a UNICEF program addressing water management in Tamil Nadu schools and has produced a number of educational materials about sanitation and water management. He founded AuroAnnam, a business unit of Auroville in 2000 to promote organic farming and ecological sanitation. He is also the founder of Eco-Pro, a business unit specializing in EM (Effective Microorganisms) technology.

Dr. N. Parthasarathy, Pondicherry University, Department of Ecology and Environmental Sciences

His area of specialization is Biodiversity and Conservation, Forest Ecology, Diversity and Ecology of lianas, Forest dynamics, Medicinal plant resources and Conservation. He is currently working on the Biodiversity, Ecology and Bio-resources conservation of Western Ghats, Eastern Ghats and Coromandel Coast Tropical dry evergreen forests of Peninsular India. He has established Long-term Ecological research (LTER) plots in tropical wet evergreen forest of Anamalais, Western Ghats; Kolli hills in Eastern Ghats and in 12 site of tropical dry evergreen Forest of Peninsular India. In a collaborative Liana research programme at NCEAS, University of California, Santa Barbara, he is building a large Asian data set of lianas, pooled for global generalization and furthering research on liana communities.

David Hogg, Naandi

David Hogg is one of India’s premier experts & practitioners of Biodynamic farming. He shepherded the Biodynamic movement in India, under the aegis of the Biodynamic Association of India (BDAI) as Founder and Secretary for many years. David currently heads the sustainable livelihoods project at Naandi foundation where he has successfully helped thousands of tribal families convert to a sustainable way of living and farming. He is a gifted teacher particularly unrivaled in his knowledge of farming & nutrition.

Beulah Kolhatkar, India Educational Tours

Beulah Kolhatkar taught at Kodaikanal International School for 9 years on topics focussed on Social Experience, Indian Literature and Health. During this period, she formulated the curriculum for "The Social Experience" which is a Social Awareness course, consisting of "Seminars" during which students discuss various ethical and social issues. As part of this curriculum, students did practical work in the community, which gained them "CAS" - Creativity, Action and Service - credits required by the International Baccalaureate Organization.She also initiated various field trips, which, apart from helping students gain "CAS" credits, were also deeply moving experiences: students have had their career choices - and subsequently their lives - altered by what they have seen on such field trips. She now brings this wide experience with teenagers to India Educational Tours, and has drawn on her extensive contacts to formulate many new field trips.

About Faculty Programmes

These visits were usually organized along with the semester program and since the Marine Science semester has been the most regular, faculty members had the opportunity to participate in course related activities that students engage in during the semester. However as these visits are only a week long, the schedules often are hectic with plenty packed in over a very short duration. This allows faculty members to share in the study abroad experience with students and take the same back to their colleges in the US where they engage with students about the program. Feedback provided has contributed to the overall growth of the program over the years.

- ***BCA 2010***

  Organized by BCA, this visit was for about ten days of which 4 days were organized by FERAL in Pondicherry followed by Mahabalipuram. A visit to the Andamans followed with the students after which the Social work faculty continued with the BCA Social Work program in Mangalore. The joint sessions with students mainly involved discussions on topics related to coastal erosion and fisheries management. CCG topics were also briefly discussed as issues relating to culture, class and gender are too obvious to ignore. The faculty members along with their areas of expertise has been listed below:

  i. Catherine Schaeff, Marine Sciences
  ii. Julia K.Moen, Social Work
  iii. Sharon K Davis, Social Work
  iv. Marian Mattison, Social Work

- ***KSAC 2013***

  A week long program for seven KSAC faculty members was run simultaneously with the Spring Marine Science semester. The purpose of their visit was to explore potential for further collaborations particularly with Sacred Heart College, Thevara and Madras Christian College, Chennai as well as share in some of the student experiences on the India program. The group divided their time between Pondicherry and Sacred Heart College resulting in a very hectic schedule. They visited a few places ie., Sadhana forest and Discipline farm which students usually visit or intern with on the program. Also part of this experience was a boat tour along the coast led by Aurofilio from PondyCAN followed by field visits to two sites severely affected by beach erosion with a concluding lecture on Coastal Zone management. Interactions in Kerala with Fr.Prasant and faculty gave the group a glimpse of the student experience on related courses.

The last day included a visit to Madras Christian College with a brief interaction with the BCA resident director, Ms.Anupama Pai followed by a few hours at MCBT with subsequent visits to the temples in Mahabalipuram. The program received positive feedback from the faculty members whose names and expertise is as below:

i. Leah Hamilton, Social Work
ii. Susan E Prill, Religious Studies Sikhism
iii. John Unger, Chemistry
iv. Rosalie Rodriguez, Cultural Diversity
v. Robert M East, Environmental Studies
vi. Celia Cook-Huffman, Peace Studies
vii. Kati Csoman, International office

▲ *Faculty members Celia and Rosalie interacting with Laxmi, the temple elephant at the Arulmigu Manakula Vinayagar Temple in Pondicherry*

The Students

MARINE SCIENCE IN INDIA

Collaboration with Juniata College

2005

Holly Gabries
Steve Beck
Scott
Alex Craun
Mariel Marlow
Lynn
Gaia

2006

John Vargo
Zachary Laubach
Sara Lombardi
Nicole

2007

Brosi A Bradley
Caitlan G Eger
Thomas M Evans
Joshua M Hatch
Genna M Huston
Zachary M Kupchinsky
Laura E Waters

Teaching Assistant: Tanvi Vaidyanathan

2008

Nicole Cappuccio
Amanda L Fabias
Elise K Hagenberger
Erin V Satterthwaite

Collaboration with BCA

2009

Jason Fischel
Caitlin Stormont
Elizabeth Roberts
Franklin Hockenbrocht
Danielle Stump
Christopher Smith
Takako Yamamoto
Whittier Henke

Teaching Assistant: Tara Lawrence

2010

J-term : Islands and Reefs

Lucas Messick
Sadie Wunders

2011

Andrea Burton
Christine Woodard
Sara Nason
Dale Rubury
Bradley Wells
David Hopkins
Grant Robison
Nicole Lundberg
Zachary Bordner
Eleanor Provias
Lindsay Partymiller

Collaboration with KSAC

2012

Corinne Dorais
Neil Neigenfind
Rachel Walman
Cara Mayo
Rebecca Strohm

2013

Ashley Fersch
Emily Layman
Taylor Cox
Samantha Michelle Rock
Lydia Susanna Bridi
Lauren Bauernschmidt
Kelsey Kohrs

Teaching Assistant: CJ Smith
(Marine Science student – 2009)

CULTURE CLASS & GENDER

Collaboration with Juniata College
2005
Brent
2007
Adam Vachon
Charlie Foster
Karina Gonzalez
Kathleen Tavenner
Elisabeth Rattenborg
Sarah Svigals
Sarah Kotora
Teaching Assistant: Sara Lombardi (Marine Science student 2006)
2009
Daniel E Kraft

Collaboration with BCA
2010
Sarah Ledrach
Tamara Condry

SUSTAINABLE AGRICULTURE

Collaboration with Juniata College
2006
Sarah Bay
Sarah
Brittany Moyer
2007
Eben
Coleen

WILDLIFE BIOLOGY

Collaboration with Juniata College
2008
Laura E. Weber
Carolyn M. Romako
Ariana R. Keyser

PEACE & SOCIAL JUSTICE/ ENVIRONMENTAL CONFLICT STUDIES

Collaboration with Juniata College
2008
Elizabeth M Heiny
Lily Kruglak
Accompanying faculty: Dr.Celia Cook-Huffman
2009
Troy Carl
Hannah Everhart
Jennifer Loving
Sara Beth Stoltzfus
Marcin Jaroszewicz
Juliette Garlow
2011
Ellen Bechtel
Julia Cramer
Danielle Marie Fulmer
Megan Lopez
Jennifer Loving
William McGrew
Andrew Savadkin
Teaching Assistant: Lily Kruglak (Peace student 2008)
Accompanying faculty: Dr.Celia Cook-Huffman

SUSTAINABLE DEVELOPMENT IN INDIA

Collaboration with KSAC
2011
Christian Wilkens
Joshua Graybeal
Alexandra Witter
Laura Mclaughlin
Leah Tester

STUDENTS WITH INTERNSHIPS IN INDIA

Laura E. Weber (2008): Worked on a zoo keeping internship with Madras Crocodile Bank Trust

Carolyn M. Romako (2008): Worked on a zoo keeping internship with Madras Crocodile Bank Trust

Takako Yamamoto (2009): Worked on chemical oceanography with National Institution of Oceanography, Goa

Juliet Garlow (2009): Wastelands Fodder Fertigation Project

Marcin Jaroszewicz (2009): Wastelands Fodder Fertigation Project

Troy Carl (2009): Worked on the UNH water and sanitation project with FERAL

Jennifer Loving (2009): Worked on children's development efforts with Rajagiri College, Kalamassery.

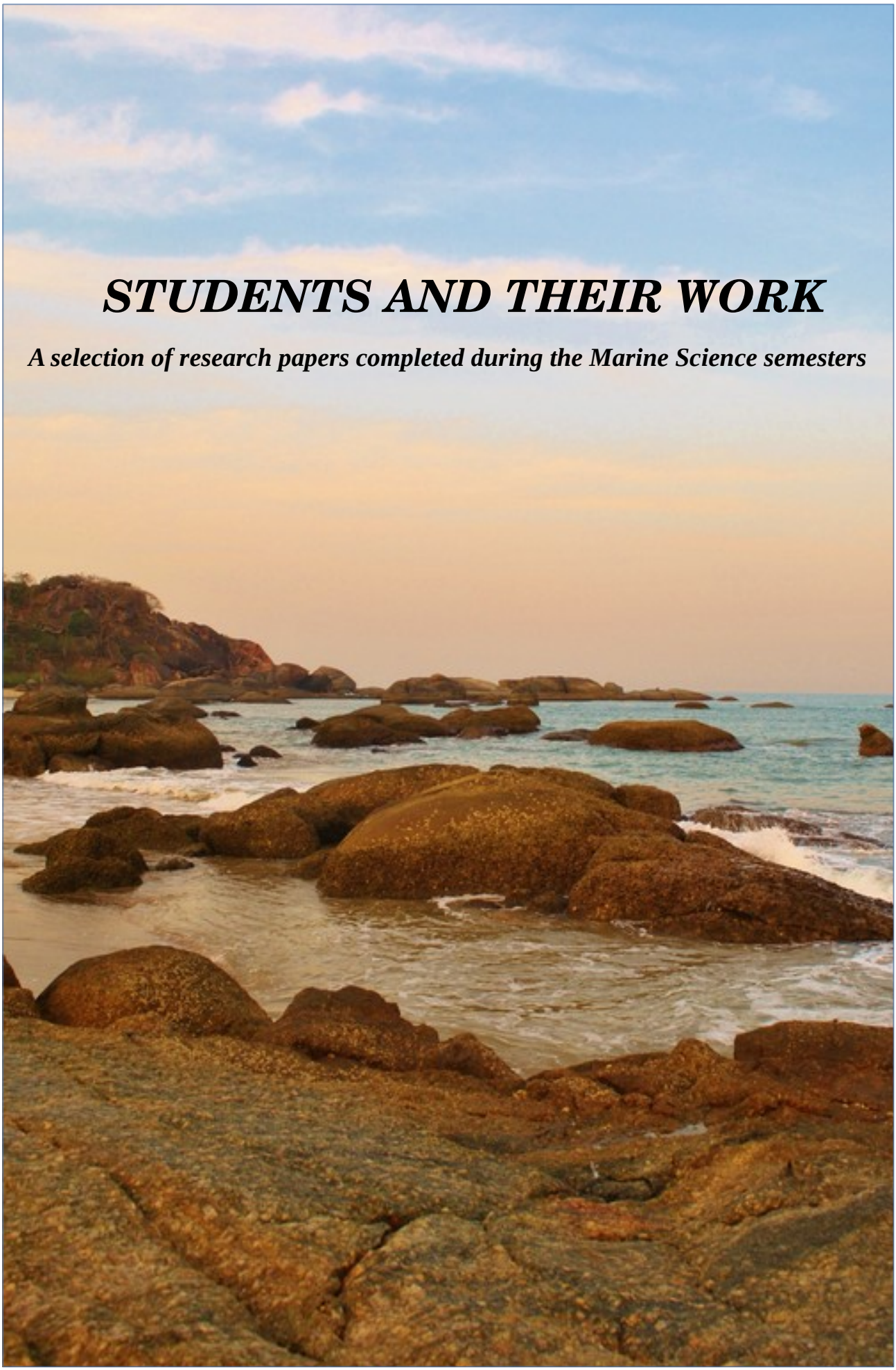
Kathleen Tavenner (2010): on the UNH water and sanitation project with FERAL

Eleanor Provias (2010): Wastelands Fodder Fertigation Project

Christian Wilkens (2012): Worked on animal care internship with Madras Crocodile Bank Trust

Christopher Smith (2013): Worked on a reasearch assistantship on the fisheries project with FERAL

Pictures from top to bottom:
a) Marine Science batch 2011 on their final presentation day with (from the left) Anu & Dipani & Tara (sitting)
b) Sustainable Development batch 2011 taking a break on their trek through Periyar Tiger Reserve
c) Marine Science batch 2011 at the farewell dinner with Tara (from far left), Alok, Elke, Anu and Ravi (from left below) and Raji (far right).
d) Marine Science batch 2013 celebrating Holi – the festival of colors on FERAL campus.


STUDENTS AND THEIR WORK
A selection of research papers completed during the Marine Science semesters

Using Specific Characteristics of Fish Morphology to Make Predictions on Diet and Use of Habitat

Zachary Kupchinsky

Abstract. Specific characteristics of fishes morphology can reflect the diet and use of habitat. The study of a species' habit to assemble in a common ecological niche in terms of morphological differences is known as "ecomophology." Assumptions can be made on diet and habitat use based on visual observations and dissection examinations of the mouth, length of intestines, and gill rakers. In this study, predictions were made on diet and habitat use of four species of fish landed at the Pondicherry Fishing Harbor. Mouth position, presence of gill rakers, and gut length were observed and recorded on Russell's snapper (*Lutjanus russelli*), Pink perch (*Nemipterus japonicus*), Indian mackerel (*Rastrelliger kanagurta*), and one species of sardine (*Sardinella sp.*). Using FishBase and other reliable sources, these predictions were compared with actual accounts of diet and habitat. Results show that while abundance of gill rakers and long intestines are easily identifiable for herbivorous species of fish; habit use on the other hand was hard to determine. This study, along with a similar study in ecomorphological assumptions by Shoup and Hill, shows that assumptions should not be assumed accurate without testing to confirm the relevance of the morphological ability/constraint to the organism under the conditions in its specific environment.

Introduction

The feeding ecology, swimming mode and even habitat use of fish can often be inferred by examining its morphology (Adite 1997). Specific morphological characteristics are directly related to these behaviors and assemblages of fish inside their ecological niche. "Ecomorphological" studies explain ecological patterns in terms of morphological differences and consequences of such differences for physiological function and resource utilization (Gilmore 1998). Ecomorphology can be simplified to form and function, where the form of the animal speaks on its function and vice versa. Traits that are related to form and function include adaptations that exist in both the internal and external anatomy. A comparative anatomy approach was used to discuss two major morphological traits during Shri S.R. Somashekar's laboratory practical on form and function of fish morphology (Mangalore Fisheries College). These were differences in the internal digestive system between carnivorous and herbivorous (plankton feeding) fish and also the presence and size of gill rakers between the afore mentioned feeding strategies.

As is common with other herbivores, herbivorous species of fish have more surface area in their intestines than carnivores of similar size. Herbivores ingest food items that are often morphologically and chemically defended, encased in largely indigestible fibrous cell walls, and that are considered nutrient poor. The longer digestive tracts are thought to increase the volume of food that can be ingested and increase the digestive forces enacted upon the food (German 2006). The longer intestine also allows more time for absorption of nutrients to occur during digestion. Two other common differences in the digestive tract are (1) differences in the stomach and (2) presence or absence of pyloric caeca, which are finger-like projections that aid in absorption of food. Shorter digestive tracts, as observed in carnivores, present a greater number of villi and pyloric cacea, which amplify many fold and compensate for relatively short intestines (Rios et al 2004).

Another example of morphological relationships in diet, is the size, shape, and location of the mouth. Again, form and shape of the mouth is related to their feeding habits and assemblages. The difference between the inferior and superior mouth orientation is how the upper or lower jaw extends past the opposite jaw. Superior mouths have the lower jaw extended farther forward than the upper jaw which aids in surface feeding. Inferior mouths allow the upper jaw to extend farther forward than the lower jaw which aids in bottom feeding. The mouth shape often found on column feeding

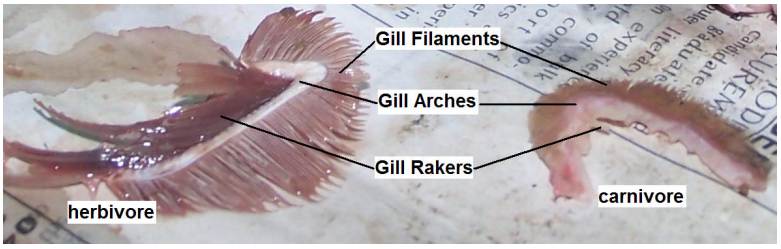


Figure 1 The gill rakers on the herbivore species (*Rastrelliger kanagurta*) are more defined and more abundant than that of the few and stubby gill rakers of the carnivore species (*Lutjanus russelli*).

fish is the terminal mouth, where both the upper and lower jaw are the same distance forward. The mount represents an obvious linkage of form and function, but the gill rakers located with the mouth cavity are also an excellent example.

The gills present in fish are used for gas exchange during respiration. For their survival in their environment, it is essential that the gills are protected and detritus is not allowed to damage the gill filaments. The presence of stiff bony projections, known as gill rakers, have the ability to sieve particles that can damage the gills and the number and size of gill rakers also serve as an indicator of the organisms' feeding habits. Fish that feed exclusively by filter feeding have longer and more abundant gill rakers compared to carnivorous species which tend to have fewer and smaller gill rakers (Munshi 1984).

Ecomorphology can be useful in aquaculture, especially in polyculture as seen with Indian carps: Catla (*Catla catla*), Rohu (*Labeo rohita*), and Mrigal (*Cirrhinus mrigala*). The underlying goal of polyculture involves increasing productivity by more efficient utilization of ecological resources within an aquatic environment (Lutz 2003). These carps used in composite fish culture have mutually compatible and complimentary food habits (FAO). According to Dr. P. Keshavanath, Dean of Fisheries College, polyculture is only productive when the species of stocked fish feed at different ecological niches. Stocking two or more complementary species can increase the maximum standing crop of a pond by allowing a wider range of available foods and pond volume to be utilized (Lutz 2003).

Figure 2 Notice the three mouth positions on the three different species of carp used in polyculture. (a) *Catla catla*, (b) *Labeo rohita*, and (c) *Cirrhinus mrigala*.

Within the three species of carp, the morphological differences in their mouth positions indicate three feeding habits. The superior mouth represented by the *Catla catla* indicates that it is an omnivorous surface feeder eating plankton and terrestrial/aquatic insects that skim the surface of the water (FishBase). The column feeder fish, *Labeo rohita*, has a terminal mouth and an abundance of gill rakers indicating that it filter feeds on plankton, algae and other types of submerged sea grass (FAO). Along with the flat ventral side of the *Cirrhinus mrigala*, its inferior mouth indicates that it is a bottom dwelling species that feeds on tube worms in bottom biota (FAO). All three species are able to survive in the same environment because they all feed on three different types of food.

Materials and Methods

With just visual observations of morphological structures, assumptions can be made of habitat and diet. As a research topic, Zachary Kupchinsky used knowledge about form and function to predict diet and habitat assessment of species of fish landed at the Pondicherry Fishing Harbor. Without previous investigation of these species, comparing actual data from FishBase and other reliable sources with predictions made of the species will show if assumptions of morphological structures are an accurate way of determining ecological niches.

Observations with external anatomy and also dissection of internal anatomy were made to make predictions on species: Russell's snapper (*Lutjanus russelli*), Pink perch (*Nemipterus japonicus*), Indian mackerel (*Rastrelliger kanagurta*), and one species of sardine (*Sardinella sp.*).

Results

Predictions of *Lutjanus russselli* are that it is a carnivorous fish due to its large stomach and short intestines. Also the few amounts of gill rakers hinders the chances of this species feeding on plankton. The superior mouth suggests that it does most of

Fish	Mouth Position	Presence of Gill Rakers	Gut Length/Total Length Ratio	Predictions
Lutjanus russelli	Superior	few/short/ stubby	12.5cm/ 21.0cm	surface feeder/ carnivore
Nemipterus japonicus	Terminal	few/short/ stubby	10.0cm/ 15.0cm	column feeder/ carnivore
Rastrelliger kanagurta	Terminal	numerous/ long/thin	28.5cm/ 20.5cm	column feeder/ herbivore
***Sardinella* spp**	Terminal	few/long/thick	8.5cm/14cm	column feeder/ carnivore

Table 1 Predictions made on observations during analysis of fish.

its feeding at the surface. According to FishBase, *Lutjanus russelli* lives on the sea floor and feeds on benthic invertebrates and fish.

The short gut length and absence of gill rakers on *Nemipterus japonicus* suggests that it is not a filter feeder, but a carnivore. A possible habitat may be the water column due to its terminal mouth. According to Fishbase the pink perch feeds on small fish and crustaceans on sandy and muddy sea floors.

The Indian mackerel was the only species where predictions matched actual accounts from Fishbase. With the abundance of long and thin gill rakers and long intestines, it was predicted and confirmed that the mackerel is an herbivore that feeds on phytoplankton in the water column.

Although most sardines feed on zooplankton and phytoplankon, some species are known to feed on crustacean and mollusc larva. The species observed during investigation had a small intestine and very few gill rakers, leading to the assumption that it is a carnivorous species.

Discussion

Some assumptions based on morphology of the species were not entirely accurate. While gut size and presence or absence of gill rakers provide reliable information regarding diet, it does not provide stable accounts for habitat. Shoup and Hill with the strong support of similar researchers argue that although functional morphology often does correlate with an animal's potential resource use, they should not be assumed accurate without testing to confirm the relevance of the morphological ability/constraint to the organism under the conditions in its specific environment. They concluded that evidence to suggest that ecomorphology diet predictions were not accurate for the environments they were studying. Caution should therefore be used when making untested predictions about the trophic ecology of an organism based on its functional morphology. Depending on specific conditions found in certain environments, like if fish could not find their prey at desired depth of choice, ecomorphology predictions could lead to erroneous conclusion about the ecology of an organism in some situations (Shoup 1997).

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Shoup, Daniel E. Hill, Loren G. “Ecomorphological diet predictions: an assessment using inland silverside (*Menidia beryllina*) and longear sunfish (*Lepomis megalotis*) from Lake Texoma.” Hydrobiologia 350: 89-98 (1997).

Three commonly captured species of crab along the Indian Coast (*Charybdis feriatus*, *Portunus pelagicus*, and *P. sanguinolentus*) and possible fishery considerations

Thomas Evans, 2007

Abstract. Indian fisheries rely heavily on poorly understood and categorized species. This study attempted to gather some basic physiological data on three species of crab (*Charybdis feriatus, Portunus pelagicus, P. sanguionolentus*). Length to width ratios were y = 0.5579x + 0.9077 for *C. feriatus males* and y = 0.6936x - 1.274 for females. Ratios for *P. pelagicus* and *P. sanguinolentus* were y = 0.4568x - 0.125 and y = 0.4481x + 0.0491 respectively. During the study many females of *C. feriatus* and *P. sanguinolentus* were observed to be gravid and for these species gametic somatic indices (GSI) were calculated. GSI's were defined by y = 0.1116x + 0.5848 and y = 17.525Ln(x) - 56.287 respectively. Even such a limited amount of data could help improve the fisheries, by providing any data on these important species.

Introduction

Along the Indian coast three species of marine crab are often caught for consumption: 1)*Portunus pelagicus*, 2) *P. sanguinolentus*, and 3) *Scylla serrata* (Islam 2003). However, *Charybdis feriatus* is also an important crab species and is also caught for consumption (Wu and Shin 1998). All of these species have been studied extensively for aquaculture and their life histories, as adults, are well known (Marshall et al 2005, Sarada 1998, Williams and Primivera 2001). All three species of crabs (*C. feriatus*, *P. pelagicus*, and *P. sanguinolentus*) are closely related (Xu et al). The large amount of information on life histories also parallels the lack of information on these fisheries.

India's interest in the growth of its economy does not favor environmental conservation. As a result there is little interest by the government in the state of these fisheries, which thankfully do not appear to be in danger of collapse. However, without a clearer picture of how harvesting is affecting populations of crabs this fishery could eventually damage stocks.

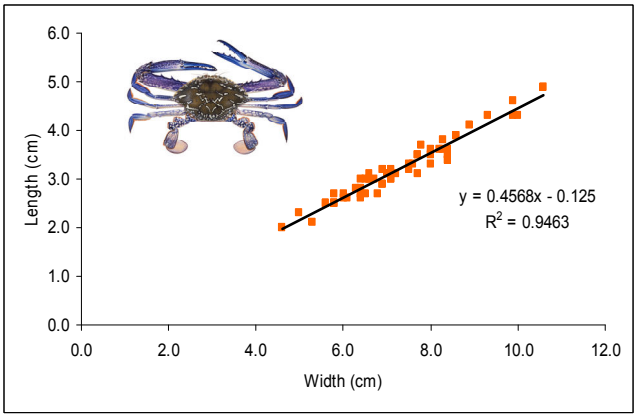

Figure 10 Carapace measurements of width to length in *Portunus pelagicus*. Males and females were not determined to be significantly different.

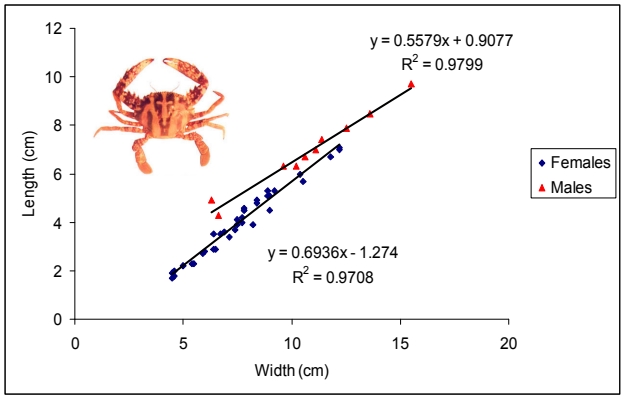

Figure 11 *Charybdis feriata* comparison of carapace width to length. Males and females were found to be significantly different with reference to both width and length and were separated for comparison.

Studies have been done with similar goals to this research, but they are not readily available online (Sukumaran and Neelakantan 1997, Sukumaran and Neelakantan 1998). In this study width to length ratios and length to mass ratios were determined for all species, excluding *S. serrata*, which was not collected. In addition, many female crabs of *C. feriatus* and *P. sanguinolentus* were observed to be laden with eggs during the study period (February-March) (T. Evans, personal observation). Therefore gametic somatic indices (GSI) for both species were determined to allow for a prediction of the ecology of the species and potential threats to stocks. If simple management strategies were put in place many more larvae could be produced in the

region, which could potentially increase stocks of these species.

Materials and Methods

Specimens of *Charybdis feriatus* were collected from fishing jetties on 2 February 2007. Some were collected on the 5 February 2007 by bottom trawl at 25m between 12º52'13"N, 74º 41'87"E and 12º49'51"N, 72º43'22"E. All measurements were made on the day of collection or the day after. More specimens were collected from the fish jetty in Mangalore on February 6, 2007 and measurements were made on the same day. All specimens collected on fish jetties were purchased from fishermen.

Collections of *Portunus pelagicus* were made using two bottom trawls on the 5 February 2007, 1) 25m between 12º52'13"N, 74º 41'87"E and 12º49'51"N, 72º43'22"E and 2) 12m between 12º49'61"N, 74º 47'69"E and 12º51'15"N, 74º46'90"E. All specimens were measured on the day of the collection.

P. sanguinolentus was purchased from the Pondicherry fish jetty on the 5 March 2007 and frozen until measurements were taken on the 11 March 2007.

Specimens missing claws were still included in both the width to length measurements and the length to mass ratios. Any specimens with damaged carapaces were discarded if damages appeared to remove over 5mm of carapace. Measurements of both carapace and width were done to maximize both.

Results

For all species of crabs a width to length ratio was calculated, and where it was significantly different as determined by NCSS 2000 male and female length to width ratios were calculated separately (only in the case of *Charybdis feriatus*). The length to width ratio of the *C. feriatus* males was y = 0.5579x + 0.9077 (R^2 = 0.9799), and for females it was defined by y = 0.6936x - 1.274 (R^2 = 0.9708) (Figure 1). The length to width ratios of *Portunus pelagicus* and *P. sanguinolentus* were defined by y = 0.4568x - 0.125 (R^2 = 0.9463) (Figure 2) and y = 0.4481x + 0.0491 (R^2 = 0.9327) (Figure 3) respectively.

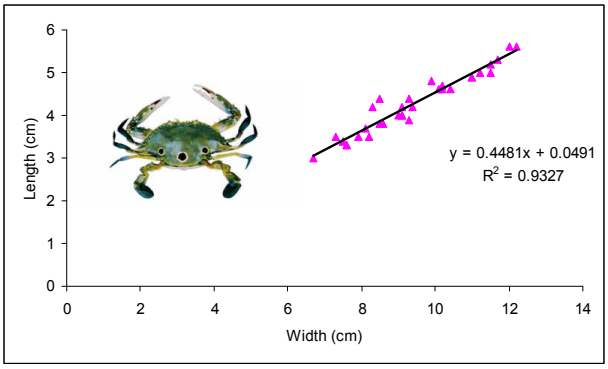

Figure 12 A comparison of carapace width to length in *Portunus sanguinolentus*. Female to male comparisons were not made because they were not found to be significantly different.

Mass to width ratios were also calculated for all species. In species where male and female widths were determined not to be significantly different (*P. pelagicus* and *P. sanguinolentus*) the mass and width was compared between all crabs regardless of sex. The mass and width in *C. feriatus* was compared by sex because only females were massed. In *P. pelagicus* and *P. sanguinolentus* the width to mass ratios were determined to be $y = 0.6631e^{0.4383x}$ (R^2 = 0.902) and $y = 1.9072e^{0.3404x}$ (R^2 = 0.906) respectively. The mass to width ratio of *C. feriatus* of females was defined by $y = 1.5784e^{0.5054x}$ (R^2 = 0.9495). The mass to width ratio for males was not able to be calculated because their masses were not taken (See Appendix).

The gametic and somatic masses were compared for all females observed carrying eggs in *C. feriatus* (44% of all females) and *P. sanguinolentus* (40% of all females). Females of *P. pelagicus* were never observed to be carrying eggs either at the dock or in the collected specimens. In *C. feriatus* a comparison of gametic to somatic masses was defined by the y = 0.1116x + 0.5848 (R^2 = 0.953) (Figure 4). The line of best fit for *P. sanguinolentus* was defined by y = 17.525Ln(x) - 56.287 (R^2 = 0.8365) (Figure 5).

Discussion

Previous studies have found a width to length ratio for all the crabs chosen for this study, but their results contrast with numbers published in this paper (Sarada 1998). This contrast may simply be due to

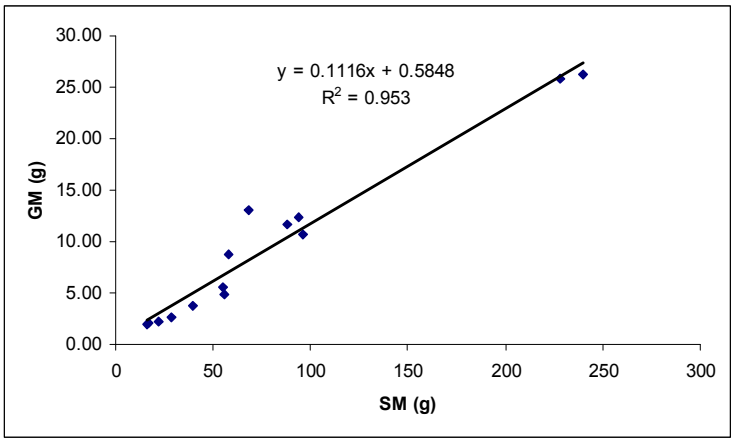

Figure 4 Using Gametic mass (GM) and Somatic mass (SM), a Gametic Somatic Index (GSI) can be determined graphically for *Charybdis feriatus*. Females show an increase in fecundity with body size, a relationship seen in other species such as barnacles and polychaetes (Barnes and Hughes). Unfortunately the data is greatly lacking for crabs between 100g and 225g.

low sample sizes (n = 41 for *C. feriatus*, n = 28 for *P. pelagicus* and n = 25 for *P. sanguionolentus*). The study was also affected by limited sampling area, since crabs were only collected from a jetty in one location. More studies would be required to determine if changes had occurred in populations, and if changes had occurred if they were natural fluctuations or related to anthropogenic forces.

The establishment of a width to length ratio allows for a comparison in future years to hypothesize that fishing is affecting this easily measurable ratio. Fishing may affect this ratio by selecting for individuals who mature faster and grow differently from populations of unfished crabs. If fishing was very high populations should probably be characterized by crabs with different width to length ratios. The author assumes that width would continue to increase faster than length to allow for female crabs to produce more eggs at a younger size. However, this is entirely speculative and should in no way be taken as the logical progression of heavily fished populations. More research is required to determine if this hypothesis is correct.

Mass to width ratios are also important to establish for the same reason that width to length ratios are so critical. The insignificance of sex in *P. pelagicus* and *P. sanguinolentus* may again be the result of low sample size (n = 28 and n = 25 respectively). If not this may suggest that sexual dimorphism with reference to body mass and size is not present for a number of reasons. Color difference did exist between the sexes, males were far more blue and females were more golden (T. Evans, personal observation). Also populations under high levels of fishing should experience smaller absolute body sizes, because large individuals are taken preferentially. However, in India where there is very little selection during fishing, almost all edible products were returned to port, this may not be true. Information on fishermen numbers and gear types is crucial for a more informed discussion on selective forces on crabs. Indeed, if fishing gear is capturing all crabs from the earliest settlement size to aged adults, the absolute body size should not shift much if it all.

The best fit line in *C. feriatus* females of somatic mass to gametic mass produced a line displaying a predictable linear relationship. This is not uncommon and many species exhibit this behavior (Barnes and Hughes 2000). The best fit line for *P. sanguinolentus* was more unusual since it showed that larger females did not continue to produce as high a ratio of gametic mass to somatic mass as smaller females. This maybe the result of a few reasons: 1) females are unable to swim effectively with large amounts of eggs regardless of body mass, 2) the ratio of gametic to somatic mass goes down, but the quality of eggs improves, 3) too few females of this species were sampled to understand the breeding ecology of this species, 4) all the aforementioned is working in concert on this species.

With a simple understanding of physiology of the three studied crab species better management methods can be put in place. Although it appears that these crabs are abundant now, it is not clear if they were more abundant or more widely distributed in the past. It is critical to perform and categorize the basic morphology of the species before it is subjected to more fishing pressure. It seems advisable that if the crabs are found to be over fished, that basic management be emplaced and enforced immediately. Admittedly management enforcement is difficult to do in India, and it

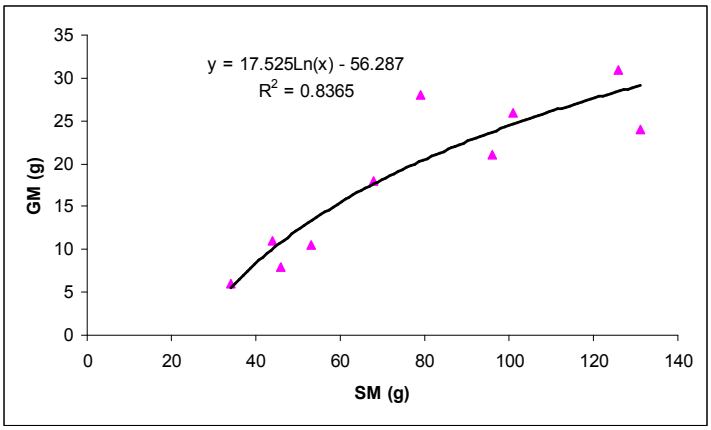

Figure 5 In *Portunus sanguinolentus* females showed an unexpected result, such that larger females did not carry larger a higher proportion of eggs than smaller females. This may mean that these females are constrained by selective forces, and can only produce clutches of a limited size. Females may also produce larger eggs instead of more eggs as gametic mass increases.

is less clear how that should be done. Potentially local fishermen could be educated and encouraged to enforce the laws autonomously. Even if crabs are not found to be overfished, studies need to be done to find if maximum sustainable yield is being reached. Simply releasing females, especially those gravid, and a maximum and minimum size, could potentially produce extremely vigorous stocks. Already fishing is halted for ~6 months out of the year when seas become too high and a ban on trawling is enforced (Shivaprakash 2007). India's fish stocks have the potential to be sustainably harvested especially if good management is enforced before the fleet becomes more modernized.

Suggestions for Next Year

This study provides a large amount of data which can allow for many statistical tests. Students interested in learning more about statistics could easily acquire large amounts of data with a similar study. Even though much data was collected, more data would have been valuable, masses of all crabs (male and female) and all length to width measurements would have been helpful. Focusing on one species may allow students a more complete view of their importance in fisheries. However, using multiple species allows for comparison between species which can be interesting. In addition mantis shrimp (Stomatopods) would also be an interesting study organism that could easily fit into a similar study.

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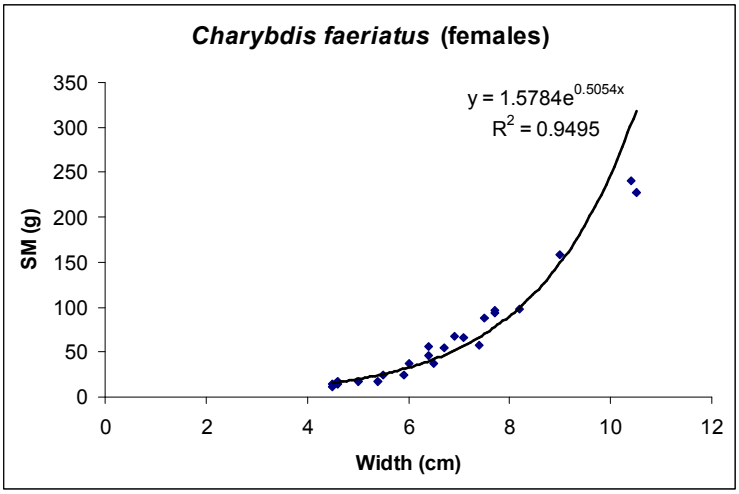
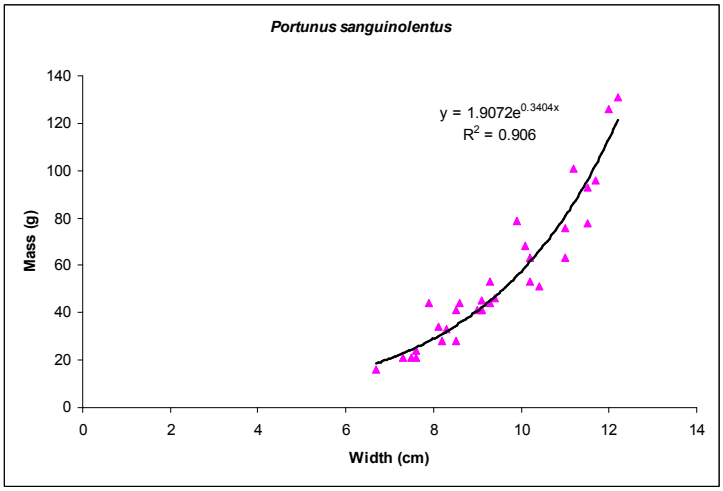
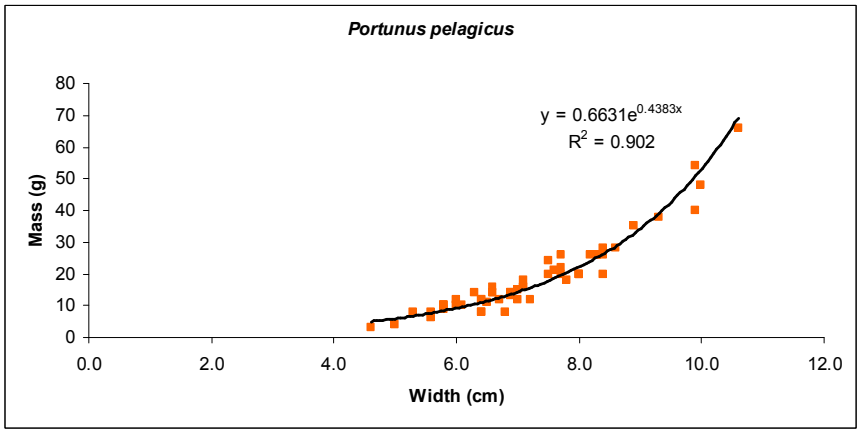
Appendix


Charybdis faeriatus (females)
y = 1.5784e^0.5054x
R^2 = 0.9495
SM (g)
Width (cm)
0
50
100
150
200
250
300
350
0
2
4
6
8
10
12


Portunus sanguinolentus
y = 1.9072e^0.3404x
R^2 = 0.906
Mass (g)
Width (cm)
0
20
40
60
80
100
120
140
0
2
4
6
8
10
12
14


Portunus pelagicus
y = 0.6631e^0.4383x
R^2 = 0.902
Mass (g)
Width (cm)
0
10
20
30
40
50
60
70
80
0.0
2.0
4.0
6.0
8.0
10.0
12.0

WATER CHARACTERISTICS AND ECOLOGICAL SURVEY OF THE BENTHIC FAUNAL DIVERSITY OF THE CHUNNAMBAR ESTUARY

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Brethren Colleges Abroad, Juniata College, FERAL, INDIA

Abstract. Estuaries represent the transitional zone between freshwater and marine environments. They are unique chemically, in terms of factors such as pH and salinity. Biologically, only euryhaline organisms are able to tolerate the varying salinities. Ten data points, sampling salinity, pH, and benthic species diversity, were recorded at low tide from the Chunnambar Estuary outside of Pondicherry, Tamil Nadu. A total of eleven species were identified within the estuary. Salinity and pH displayed a positive liner trend due to the freshwater and saline water mixing. Species richness graphed against salinity and pH, exhibited a negative correlation. Overall, *Cerithidea cingulata* was found to be the most tolerant species of dessication, and *Terebralia* was the superior competitor of Chunnambar. Inconclusive results were obtained due to limited number of samples. Minimal research has been conducted on the Chunnambar estuary, therefore this study provides rough baseline research for which future studies can be based.

INTRODUCTION

An estuary is a unique and essential system in the marine environment. It is a semi-enclosed body of water between freshwater riverine systems and the saline marine environment, acting as a transition zone. This brackish water environment is one of the most dynamic ecosystems worldwide (Edgar 1999). Salinity fluctuations occur from marine tidal influxes along with changes in freshwater inflow from the river. These changes can occur both daily and seasonally.

An estuarine system represents a unique chemical environment due to the dramatic daily alterations in such factors as pH and salinity. The measurement of pH is a key component to the chemical properties of an aquatic system. While freshwater systems are slightly acidic, marine systems tend to be slightly alkaline. Estuaries represent the pH gradient between these two systems.

Salinity is another important water characteristic, which varies between 7-35ppt. All organisms living in a saline environment must perform osmoregulation, the maintenance of a constant osmotic pressure between the organisms' body fluid and the surrounding saline water. There are a select number of species which can osmoregulate effectively to thrive in broad range salinities, these are known as euryhaline (Gunter 1961). Most species can only withstand a narrow range of salinities, known as stenohaline organisms, which are only found in freshwater or oceanic systems. This illustrates the reason why salinity is the limiting factor of distribution and diversity of organisms (Attrill 2002).

Little is know about most estuaries in India due to the limited amount of data published. The Chunnambar estuary has no information available making it an ideal location to study. This paper analyzes the ecological diversity and distribution of the benthic fauna in relation to salinity and pH of the Chunnambar estuarine system.

METHODS

Ten points of data were colleted over three nonconsecutive days at varied distances along the south Chunnambar river bank in Pondicherry, India starting at the Chunnambar Bridge, 2600 m

from the mouth of the estuary, and proceeding toward the ocean. Samples were collected within two hours of low tide, at accessible areas along the bank, which included 120 m, 240 m, 640 m, 1200 m, 1500 m, 1770 m, 2070 m, 2450 m, 2550 m, and 2600 m from the bridge. Samples were taken to assess species diversity at the edge of the water and 1.5 m from the bank into the water. A 25cm^2 quadrate was used to sample the substrate surface to a depth of 5 cm. The sediment sample was sifted in a 1.7 mm sieve and the remaining species were collected in a labeled container. The species were then identified, counted, and recorded. Sampling was limited to species, which could be accessed from the bank and using scoops. Therefore, our focus was on the benthic species in the upper layer of the substrata.

Water chemistry was measured with five water samples from each location, measuring pH and salinity. Readings were taken on the site using Eutech instruments pH and salinity meters. Due to skepticism of instrumental readings, two of the sites readings were taken back to the laboratory for further consideration. At these two sites six samples were taken using small plastic containers and reading were recorded after re-calibration of instruments was carried out. Data was analyzed using Microsoft Excel in a test of linear regression with species richness and abundance in relation to pH and salinity.

RESULTS

With regards to water quality, pH and salinity are directly correlated and have a positive linear trend (Fig.1 & 2). The pH readings started at 7.0 at the Chunnambar Bridge and concluded at 8.4 at the beach. From 120 meters past the bridge to 1500 meters past the bridge, the pH ranged from

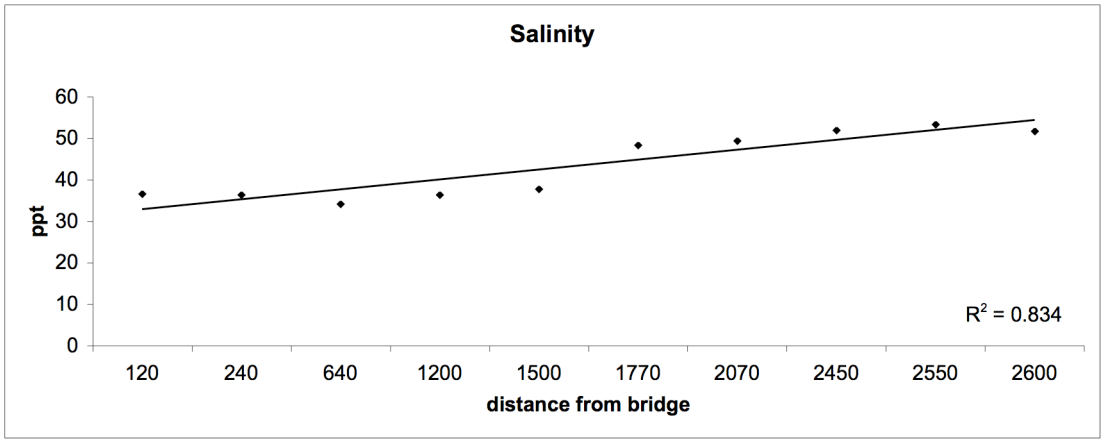

Fig. 1 Salinity measured in ppt in relation to distance from the Chunnambar Bridge to the ocean

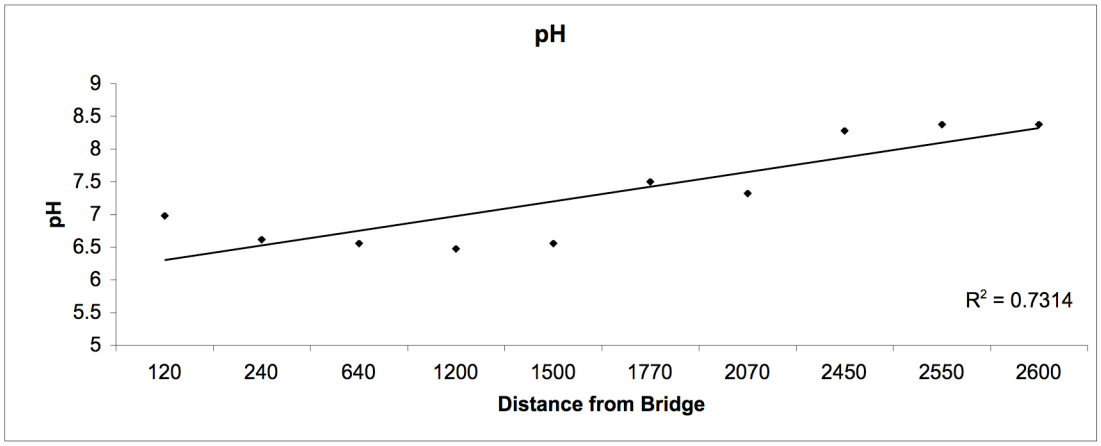

Fig. 2 pH measured in relation to distance from the Chunnambar Bridge to the ocean.

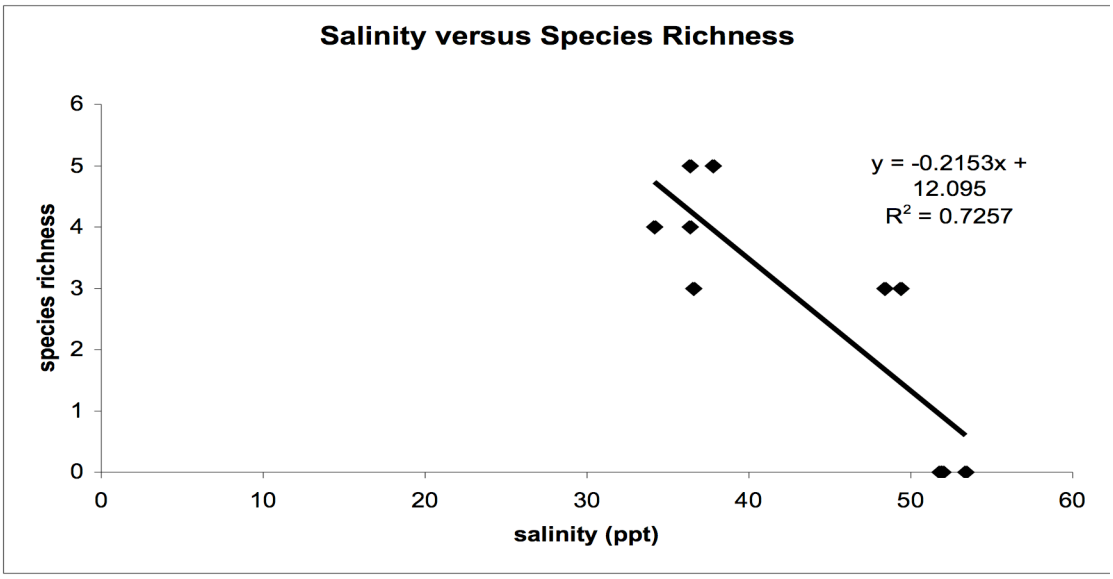

Fig. 3 Species richness of the Chunnambar River compared to increasing salinity.

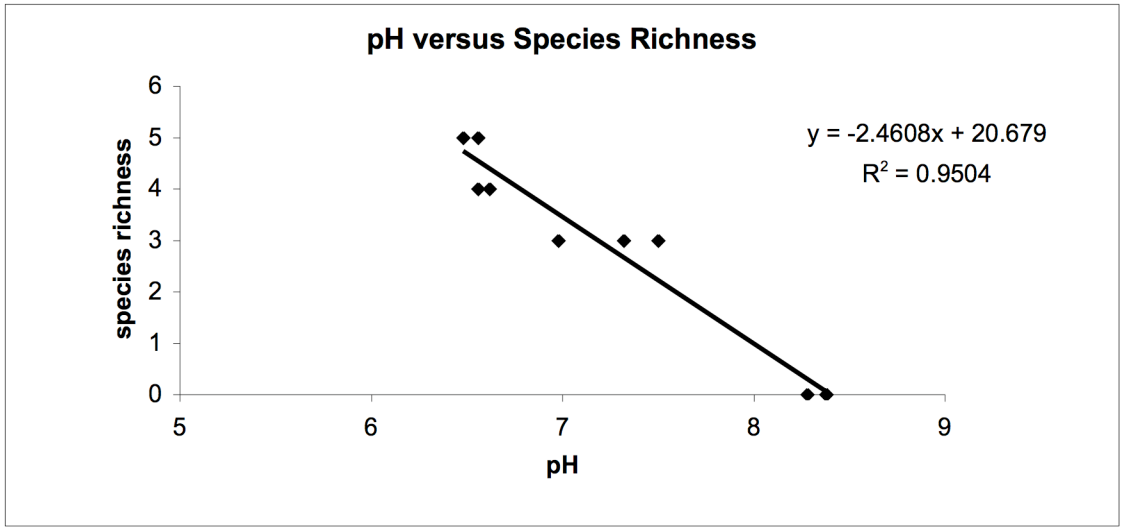

Fig. 4 Species richness of the Chunnambar River compared to increasing pH.

7.0 to 6.5, and from 1770 meters through 2600 meters past the bridge, the pH ranged from 7.3 to 8.4. Salinity readings began at 16.6 ppt and continued to 33.8 ppt; the salinity trend was linear and had no major dips. Both pH and salinity readings leveled off at 2070 meters from the bridge. The R^2 value for the pH data was 0.731, and the R^2 value for salinity was 0.834.

When species richness was graphed in relation to pH and salinity, an inversely proportional trend was observed (Fig 3 & 4). The R^2 value for the pH regression line was 0.950, the R^2 value for the salinity was 0.726.

As for the benthic species found, land and water species were analyzed separately. Eleven total species were found among land and water. *Cerithidea cingulata* was the dominant species throughout, and *Terebralia* was found in the greatest abundance up to 1500 meters from the

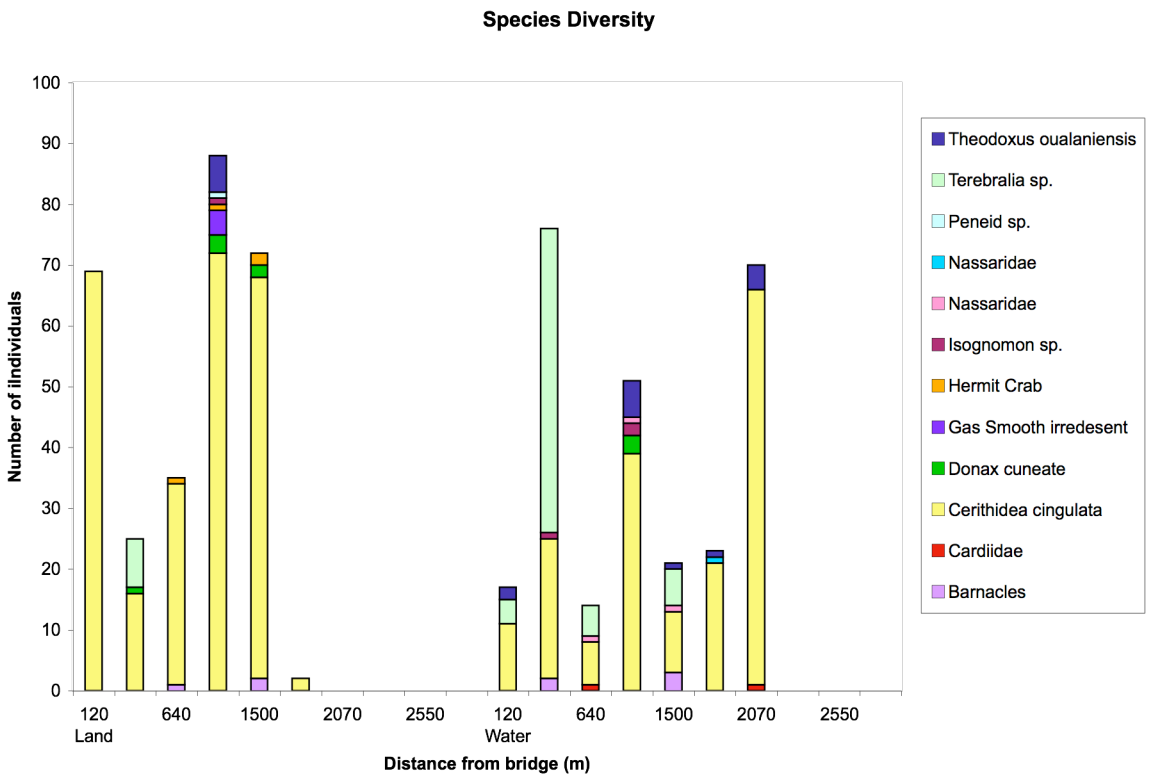

Fig. 5 Species diversity found in the land and water samples in comparison to distance.

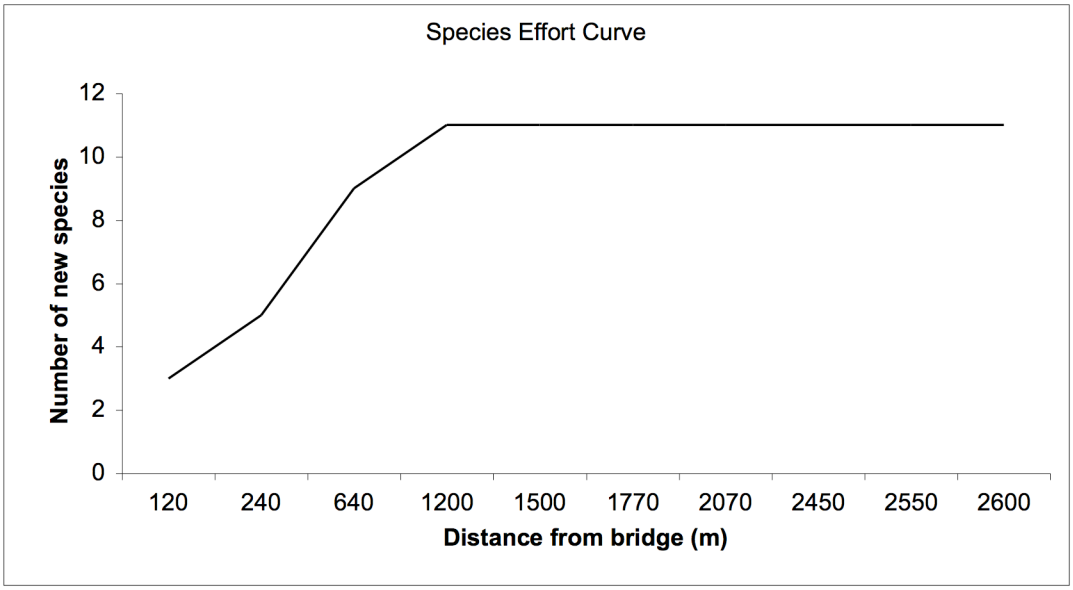

Fig. 6 Species effort curve showing the number of new species found at each distance from the bridge.

bridge in the water. Where *Terebralia* was present, *C. cingulata* appeared in lower abundance. No other overall trends in species abundance appeared in either land or water species. The largest species richness, seven different species, occurred at 1200 meters from the Chunnambar Bridge in both the land and water samples. When the species richness was graphed in correlation, there was a bell curve trend with a peak in species richness with five different species at 1200 meters from the bridge (Fig. 5).

A species-effort curve was graphed for total number of new species observed at each sampling site which increased continuously from 120 m until 1200 m, where the data leveled off at eleven new species (Fig. 6).

DISCUSSION

Salinity and pH were directly correlated and displayed a positive linear trend toward the mouth of the river. This trend is due to the nature of an estuarine system with open access to the ocean, which allows for an inflow of salt water to mix with the freshwater of the river. Thus, the salinity and pH observed exhibit natural fluctuations, which arise from varying mixing patterns of fresh and salt water.

The salinity of an estuary is the key component of the benthic species abundance and richness directly (Attrill 2002). Land data was taken only for the purpose of assessing species richness, therefore the land and water data for benthic species were analyzed separately. The land data has no correlation with that of the water quality data. When species richness of the water was graphed in comparison with pH and salinity, it was found to have a negative linear correlation. This negative linear correlation could show that species may have a high tolerance for large fluctuations in a low salinity range and a lower tolerance for high salinity with less severe fluctuations. In order to conclusively determine that this could be a potential hypothesis, further testing should be conducted on the conditions at varied tidal levels, halocline properties, and mixing patterns. In addition, the organisms present in the range of 120 m to 2070 m may not be able to tolerate long term turbidity that is characteristic nearer to the ocean. This hypothesis was strengthened by the observation that no organisms were found in the area closest to the mouth, which was noticeably affected by wave action.

Species richness and abundance were graphed against distance from the bridge to the mouth of the river. Species abundance did not have a definite trend that could be observed, probably because the individual number of organisms is highly variable due to the fact that individuals migrate and move on a regular basis. Though, a trend was observed for species richness in relation to distance from the bridge. A skewed bell curve was detected for the benthic faunal richness in both land and water. The bell curve was skewed, favoring the upstream data, with a peak at 1200 m, and decreasing in richness to the mouth where no species were found. This could have been caused by the change in benthic substrate characteristics and associated food resources. We noted that the peak of species richness, 1200 m, was in an area with sea grass which allows for more sources of food, hiding locations, and accumulation of detritus. This sea grass bed was a habitat for *Peneid* shrimp and hermit crabs, both of which are detritivores, further strengthening this hypothesis. Also, the region closest to the mouth of the estuary consisted of a sandy bottom. This would not be ideal for the mud flat species which we identified throughout our research. This hypothesis could be strengthened with analysis of benthic characteristics, along with floral and plankton diversity in the Chunnambar estuary.

Species richness analyses do not allow for a complete understanding of the characteristics and trends of individual species. Therefore, species trends were examined and findings concluded *Cerithidea cingulata* was the main species found in the mudflat environment. This species was found throughout the estuary in both the land and water. This could be due to the fact that *C. cingulata* can tolerate a wide range of varying environmental conditions such as desiccation and oscillating salinity. *Terebralia* was only found in significant numbers in the water, which demonstrates its preference or low tolerance to fluctuating environmental factors. At 240 m there

was the greatest abundance of *Terebralia* in the water sample, which correlated to the only occurrence of *Terebralia* in the corresponding 240 m land sample. This could be attributed to spatial and food availability constraints. When *Terebralia* was present in the water, *Cerithidea cingulata* was found in low abundance. This could be associated to the fact that *Terebralia* are a superior competitor in the water, as this taxa is known to destablilize sediments and create intense competitions for food (Carlin and Olafsson 2002).

The species-effort curve provides insight into the number of samples necessary to plot the diversity of the lower region of the Chunnambar estuary. This shows that approximately four data collection points are needed within a 1200 m range to collect the total species richness of the estuary from the Chunnambar Bridge to the mouth. Although these results are only based on one data collection, they provide a rough baseline on the amount of sampling points and time that needs to be invested in order to obtain a given number of species. This information can be used as background information for future research on the Chunnambar estuary.

Overall, both human and instrument error could have played a role in our results. Salinity results were not accurate but they were precisely off by a consistent 20 ppt, therefore it did not affect the trend in salinity. The error was recognized due to the fact the results of the salinity measurements appears to be far out of range of any known brackish water body. This was confirmed by testing the salinity instrument with known salinity solutions. Also, the pH appeared to be giving false readings at 2450 m, 2550 m, and 2600m. As a result of this skepticism, six total samples were collected from the three sites and taken back to the lab for further analysis. The doubt was due to the fact that the salinity readings were accurate and should have coincided with the pH reading. The reading given for these sample sites was 7.4, far below the range in which it should have been in regards to the salinity level. Once the instrument was re-calibrated and samples re-tested, accurate readings were obtained.

Limitations to our study include time constraints and limited accessibility, thus restricting consistency of data. Hence, the large gaps in the days when samples were taken, limited access to equal distances between sampling points, and one collection of data per sampling point. Limited number of data points may give a false correlation between information, therefore hypotheses are speculatory and cannot be definitively stated.

Results could be strengthened with more replicates at each distance and samples at varying tidal levels. Observations in tidal characteristics could further strengthen results obtained from this study.

CONCLUSION

Salinity and pH measurements followed a positive linear trend along the estuary. When species richness was correlated with distance, a skewed bell shaped curve was observed, yet a negative linear correlation was detected when species richness was plotted against redcorded salinity and pH data. Definitive results are inconclusive from the lack of replicates from each sampling location.

Further research could test additional water characteristics such as temperature, dissolved oxygen, phosphorous, and nitrogen corresponding to the species richness and abundance of the estuary. Also, testing could be carried out by transects at designated intervals perpendicular to the estuary. Bottom sampling at various depths could give a more complete picture of the estuarine species diversity and substrate type.

ACKNOWLEDGEMENTS

The authors would like to thank Anupama Pai, Ganesh, Raji, Vankatesh, Ravi Bhalla, and the FERAL staff for their support and assistance in this study. Also, much appreciation goes to the capitan of the fishing boat which helped in transportation to the river mouth for data collection.

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AN OBSERVATIONAL STUDY ON BUTTERFLYFISH SPECIES RICHNESS AT TWO CORAL LOCATIONS ON HAVELOCK ISLAND, ANDAMAN AND NICOBAR ISLANDS

Nicole E. Cappuccio, Amanda L. Fabis, Elise K. Hagenberger, Erin V. Satterthwaite
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INTRODUCTION

Chaetodontidae, is a class comprised of various species of butterflyfishes which are found throughout the world in tropical regions. They exhibit the greatest overall species richness and abundance in the area between the Australian Great Barrier Reef and Southern Japan. All species inhabit coral reefs and feed extensively on benthic fauna and floral although some may feed exclusively on coral polyps. They can serve as indicators of coral health. Based on work done with the Great Barrier Reef in Australia, the greatest limiting factor on coral-reef fishes is space (Findley and Findley 1985). Although butterflyfish are not territorial, they seek space for hiding places, particularly at night.

A majority of butterflyfishes are specialty corallivores, respond to declines in coral health by behavioral and spatial adjustments. This makes them an ideal group of species for use in assessment of coral reef health. Various studies have observed the relationship between butterflyfishes and corals, and have found that they attach to a specific site and live for many years. Therefore, even gradual changes in the ecosystem will affect the same individuals (Crosby and Reese 1996).

This study examines butterflyfish species richness in relation to depth at two different coral reef locations in the Andaman and Nicobar Islands. It focuses on Elephant Beach and Lighthouse Point located on Havelock Island. Lighthouse point is relatively sheltered reef area with a few, concentrated exposure to anthropogenic impacts.

METHODS

On January 9th, 2008 data was collected from two coral sites, Lighthouse point and Elephant beach, off the west coast of Havelock Island. Sampling sites were chosen at random within a 30 m radius around the boat. Species were identified and rank abundance measurements were recorded with an underwater slate at depths of 4 m, 5 m, 6 m, 8 m, 10 m, and 12 m, over 5 minute intervals. Rank abundance was categorized based on the rank abundance scale (Table 1). Results were analyzed using Microsoft excel for average species richness and the statistical software, R.

Scale	Number of Individuals
0	0
1	1-2
2	3-4
3	5-6
4	7-8
5	>9

Table 1: Abundance rank scale determination based on number of individuals

RESULTS

The depths were divided into the two criteria of shallow, 4-6 m, and deep, 8-12 m. At Elephant beach the average species richness of the deep region was significantly greater, 2.17 species with standard error 0.38, than the average species richness in the shallow zone, 1.2 species with standard error 0.22. Lighthouse point did not have a significant difference between the average species richness in the shallow and deep regions. Between the two sites, Lighthouse point had a larger average species richness, 1.4 species, than Elephant beach, 1.2 species, in the shallow region. Yet, Elephant beach had a greater average species richness, 2.16 species, than Lighthouse point, 1.8 species, in the deep region (Fig.1). Oval butterflyfish were sighted on average the most in all of the test sites, with a significantly larger mean of 3.1 sightings (Fig. 2).

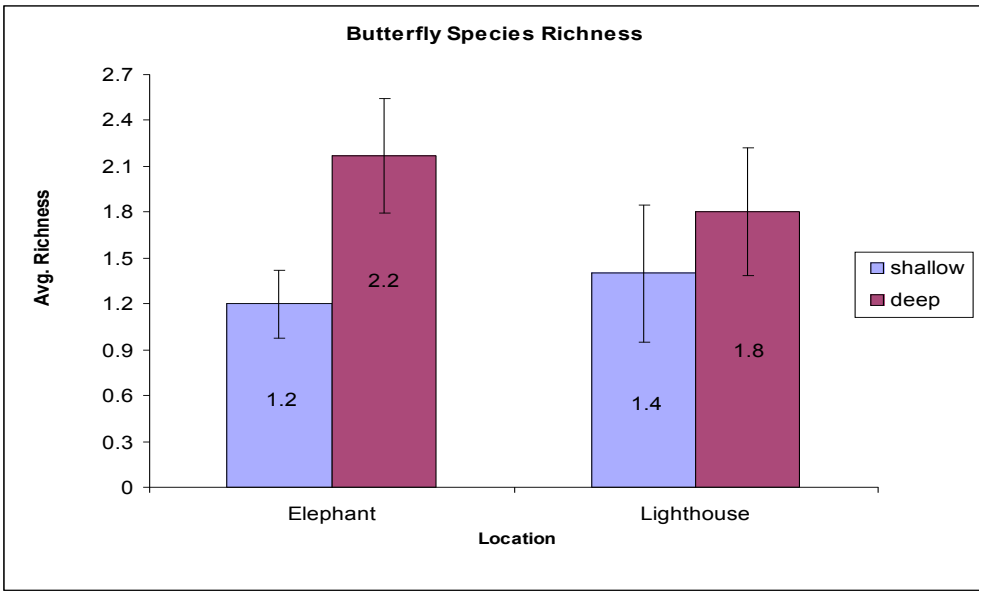

Fig. 1 Average Richness among shallow and deep regions at each site

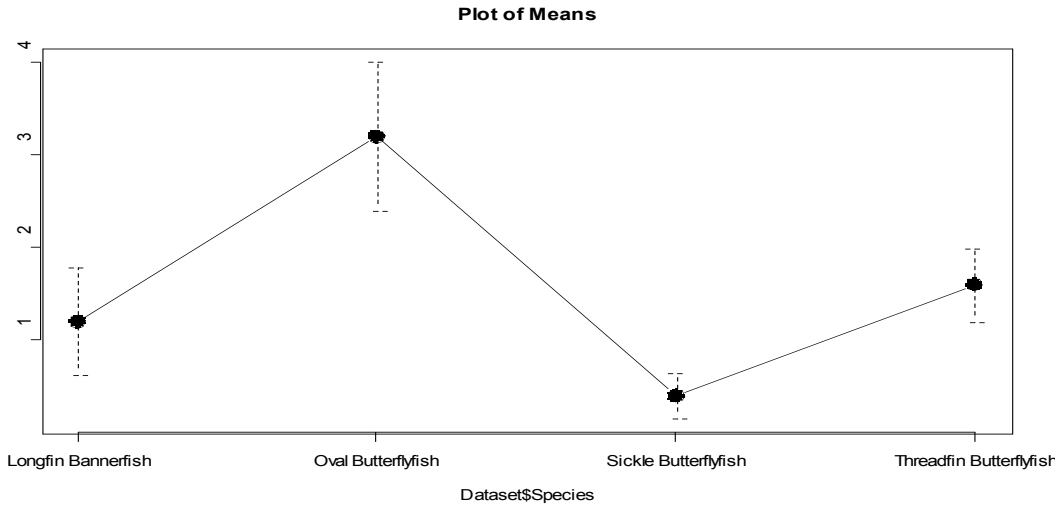

Fig. 2 Average number of sightings according to different butterflyfish species

CONCLUSION

One hypothesis for the significant difference in average species richness between Elephant beach and Lighthouse point considers anthropogenic influences and effects on coral health. Elephant beach is a location which is easily accessible to snorkelers, many of whom are inexperienced. This increases the risk of harming coral by destructive practices, such as breaking coral and disturbing sediment. Observations from a study by Findley and Findley prove that butterflyfish species richness increases on a local scale in relation to live coral cover (2001). Therefore, the species of butterflyfish who cannot tolerate such disturbances and harm to the

coral would be restricted to the deeper zone. These species would include those who feed strictly on coral polyps, or coral surface scrapers. This strengthens the notion that butterflyfish are important indicators of coral health.

Also, the difference between species richness in the shallow and deep regions among the two sites could be attributed to the open ocean exposure, contributing to greater planktonic food sources. Open ocean exposure has been shown to increase butterfly species richness (Findley and Findley 2001). The shallow region at Elephant beach appeared to be more sheltered and may not be as greatly influenced by open ocean processes. Yet, at Lighthouse point the ocean's influence on the shallow versus deep regions appeared to be similar. Consequently, planktivorous and benthivores would be found in both the deep and shallow regions of Lighthouse point, contributing to a more even species richness over the two sites.

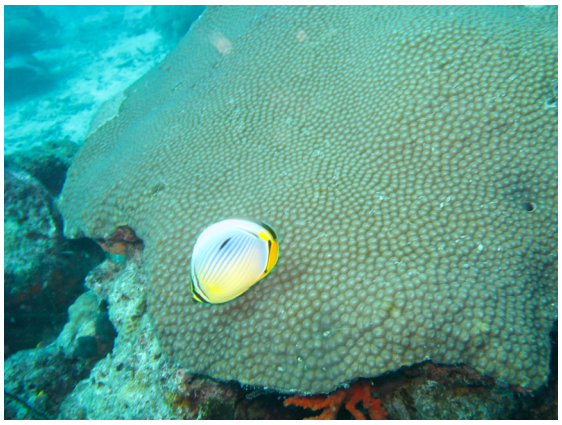

Fig. 3 *Chaetodon lunulatus* on the coral reef, Andaman and Nicobar Islands

The Oval Butterflyfish, *Chaetodon lunulatus*, was sighted significantly more times than any of the other species at both locations. This could be attributed to the fact that *C. lunulatus* may be a superior competitor over other butterflyfishes. This hypothesis is supported by Yubata 2000, who observed that *C. lunulatus* will defend their territory against other butterflyfish species, with territorial behaviors which can escalate to severe attacks.

These hypothesies are highly plausible, yet inconclusive, because more data must be obtained to form definitive results. This study could have been improved with a more standardized measurement scheme. Transects could have been used to more accurately sample specified sample points at each site. Also, communication is difficult underwater, so prior preparation is essential. Hand signals and alternate modes of communication must be established, to ensure that sampling is consistent among researchers. Future research could include more data on the health of the coral and the influx of tourists to each area. Also, GPS points would be useful to plot for exact locations to assess the influence of oceanic processes on each site.

ACKNOWLEDGEMENTS

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Analysis of Discard Catch from Trawl and Gill Nets Found in Pondicherry

Andrea Burton

ABSTRACT

Bycatch has always been a large problem in the fishing industry. Sadly, there is very little that is known about the bycatch produced by small-scale fisheries such as those in India. Along the Indian coast, there are many fish landings where local fishers make a living on a single day's catch (Kurup, 2005). At these landing sites, the problem is not bycatch, but the large quantities of fish that are just thrown away. This discard catch is extremely wasteful and can be detrimental to the marine ecosystem (Kelleher, 2005). Two trawl nets and three gill nets were analyzed to better understand the discard catch. The maximum length at which a fish is considered discard catch was found to be 86.41 mm. Trawl nets have a much higher percentage of discard than gill nets, but both methods discard more than 40 percent of their total catch. There is a large diversity of fish species seen within the trawl nets, further demonstrating that trawl nets are an extremely wasteful way to obtain target catch.

INTRODUCTION

The Indian fishing industry began to grow in the early 1950s (Bhathal and Pauly, 2008), and fishery production reached its peak in the 1970s with about 2.7 million fish being sold and distributed (Devaraj and Vivekanandan, 1999). However, since 1997, fishery production has been declining (Lobo 2010), and with this sharp decline, the fishing industry has reached the point where the economic value of fish caught is less than the cost of bringing them to markets. Additionally, due to the decline or total loss of targeted species, fishermen have been forced to target smaller fish lower on the food web (Bhathal and

Pauly, 2008). The depletion of large fish populations now threatens coral reef ecosystems since such fish are the top predators of these ecosystems.

Due to of the over-exploitation of its fisheries, the fishing industry in India is on the verge of collapse (Devaraj and Vivekanandan, 1999). Such a collapse would be extremely detrimental for the local coastal communities that rely heavily on fish for food and income. One study done on 8,129 fishing villages, found that 45 percent of the population had 1 million individuals working full-time within the fishing industry, but only 11.5 percent of these villages' fishing production was exported for trade (Devaraj and Vivekanandan, 1999).

There are many different artisanal and mechanical methods used for fishing in India including cast nets, gill nets, traps, longlines, bottom-set nets and explosives (Hoon, 2010). The most ecologically detrimental fishing method in India is the use of trawlers. About 50 percent of the catches in India are from fish trawls (Sathianandan and Srinath, 1995). The ecological threat posed by trawling stems from its lack of specificity. Any organism that is larger than the size of a net's mesh will be swiped up by the trawl, including species that are not targeted. In order to catch prawns -- a popular target species for trawls (Newman and Williams, 1995) -- the mesh sizes of most trawl nets need to be small with a mesh size of about 15 mm (Kumar and Deepthi, 2005). In 1998, there were 30,979 trawlers operating along the Indian coast with net sizes ranging from 9 to 17 mm in length (Vivekanandan, 2003).

A fishery's catch can fall into one of four categories: target catch, trash fish, discards, and bycatch. Target catch is what a fishermen want to capture for production. Traditionally, Indian fisheries targeted larger fish, which included mostly predators and a few herbivorous fish. However, due to carnivorous fishes being a small percentage of the ecosystems (Letourneur, 1996), their numbers have declined and fisheries have targeted smaller fish as a result. Prawn and squid are also major target species for trawl fisheries (Jaquemet, Potier, and Ménard, 2010). Trash fish are smaller fish species that are too

small for consumption but can be used for fish-meal (Funge-Smith, Lindebo, and Staples, 2005) or as dried catch. Discards are individuals that are thrown away either at sea or on the beach (Kelleher, 2005). Bycatch is captured nontarget species that are not discarded at sea. The two subcategorizations of bycatch are commercial bycatch, which is captured non-target species that are still sold at local markets but not used for export, and trash fish bycatch, which is captured non-target species that are discarded (Lobo et al., 2010).

Two fish landings were studied; Pudukuppam and Pillaichavadi in Tamil Nadu. At these sites, local fisherman sort through their catch and discard piles before sending it to the market. Pudukuppam has many modified trawl nets, which are gill nets attached with two weights on the bottom in order to drag the net along the substrate, targeting shrimp. Pillaichavadi fishers use gill nets that target large fish. The objective of this study is to determine the maximum length at which a fish can be caught and be considered discard catch. Additionally, estimates to the overall composition of the catch were made in order to understand how much of the catch is discarded. The diversity of the fish found in the discard piles was also assessed.

METHODS

At both Pudukuppam and Pillaichavadi, the discard pile that was organized on the beach was taken. Two modified trawl net discard piles were taken from Pudukuppam, and three gill net discard piles from Pillaichavadi. Pictures were taken of the target and bycatch piles that would be sold at the market. These pictures were used to estimate the mass of the piles in kilograms, This was used to determine what percentage of catch was discarded.

The discard pile was separated into phylums: Arthropods, Chordates (not including fish), Cniderians, Echonoderms, Molluscs, and fish. When target shrimp were found in the trawl discard pile,

they were separated into a separate pile as well. These piles were then weighed. Using Microsoft Excel, the respective percentages of phylum, bycatch, and target catch were determined.

All of the fish from the discard pile were photographed. Using ImageJ, the fish were measured in order to determine the maximum length at which fish are considered discard catch. Each fish was identified to the species level using fishbase and identification charts (Bruin, Russell and Bogusch, 1994). Using R Commander, species abundance, richness, and lengths were analyzed. A Shapiro-Wilk test was used to test for normality in the number of fish species for the trawl nets. A nonparametric test was run as well for the two trawl nets. No statistical test was run for the gill nets because there was an insufficient number of fish found to run statistical analysis. Biodiversity R was used to look at the species richness within trawl nets. A species accumulation curve, Diversity indices, and graphs using R were plotted.

RESULTS

Microsoft Excel was used to calculate the percent composition of trawl 1, trawl 2, gill 1, gill 2, and gill 3. R Commander was used for statistical analysis and to determine the distribution of fish lengths.

Length of fish

Fish lengths from trawl 1 ranged from 25.06 mm to 91.85 mm. This range includes values from puffer fish, *Lagocephalus lunaris*, which are considered discard catch regardless of size. With *L. lunaris* taken out, the maximum length of the fish discarded is 76.66 mm. This range of fish lengths is not due to chance as seen from the p-values less than .0005957 shown in Table 1.

Trawl 2 had a fish size range from 24.23 mm to 122.13 mm as seen in Figure 2.This figure includes the species *L. lunaris* and *Himantura imbricatus*. *H. imbricatus* is a sting ray that is normally sold at the market, but due to its small size, these individuals were considered discard catch. The range of

H. imbricatus is 96.65 mm to 122.13 mm in length. Removing these two species, the largest individual found in the discard pile of trawl 2 was 86.41 mm.

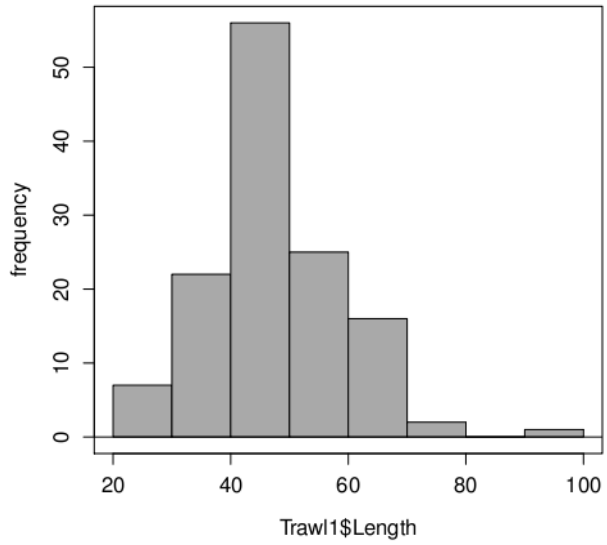

Figure 1. Histogram plot of the length of fish within trawl 1. Measurement of sizes are in millimeters

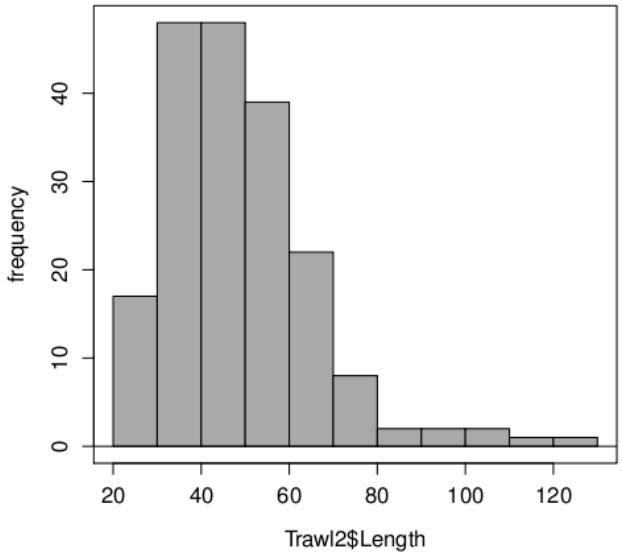

Figure 2.: Histogram plot of the length of fish within trawl 2. Measurement of sizes are in millimeters

Composition of catch

The overall composition of catch from both trawl and gill nets shows a large percentage of bycatch and discards as seen in Figures 3-7. Gill 2 had a very high percentage of target catch, as seen in figure 4. In trawl 1, there was a lot of variety within the catch. Based on the mass of the pile, only 14 percent was the target catch of shrimp. Additionally, 19 percent was bycatch that was sold at the market, leaving 66 percent of the catch from trawl 1 discarded as waste. Within the discard pile, 0.47 percent was the target catch shrimp.

Trawl 2 had a much bigger catch, with a larger discard pile. The target catch was 13 percent, and the bycatch was 18 percent, which can be seen in Figure 2. The remaining 69 percent of the catch was discarded (including 3 percent being discarded target shrimp). Thrown away fish made up 5 percent of the catch. Trawl 2 also included individuals from the phylum chordata; three sea crates that were thrown away.

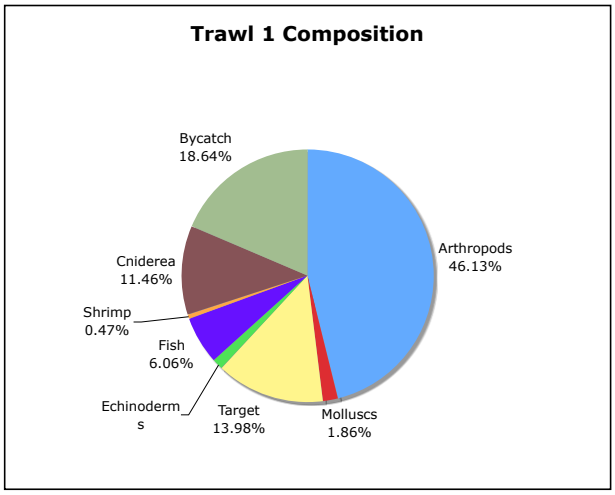

Figure 3. Chart showing percentage of overall catch composition based on weight from first trawl net

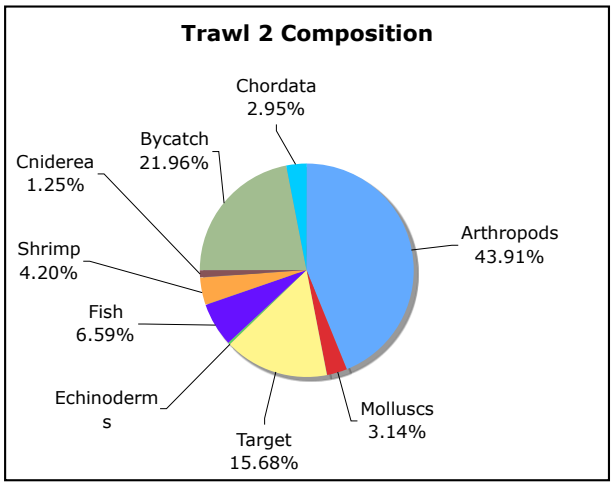

Figure 4. Chart showing percentage of overall catch composition based on weight from second trawl net

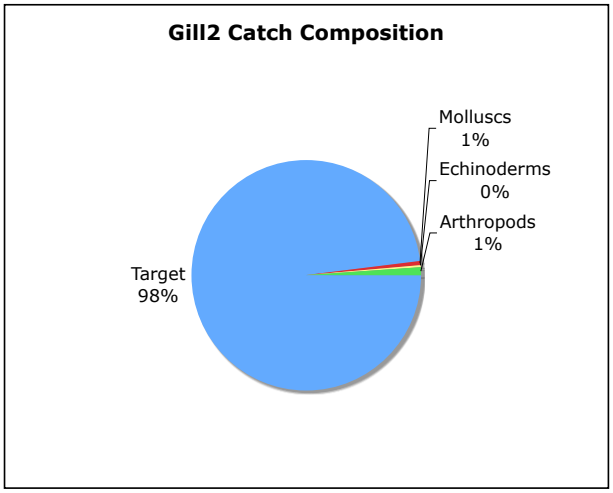

Figure 5. Chart showing percentage of overall catch composition based on weight from first gill net.

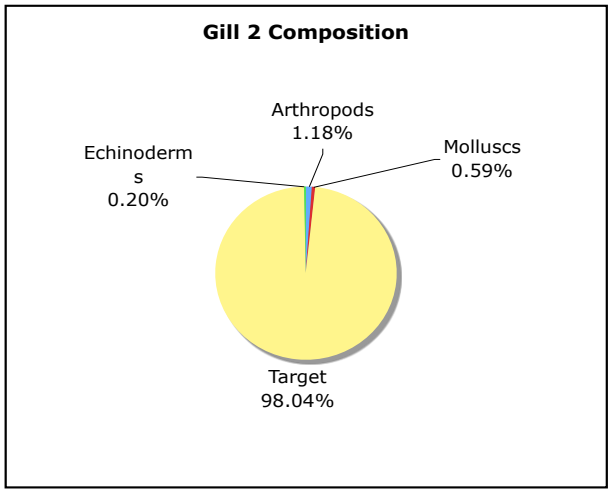

Figure 6. Chart showing percentage of overall catch composition based on weight from second gill net

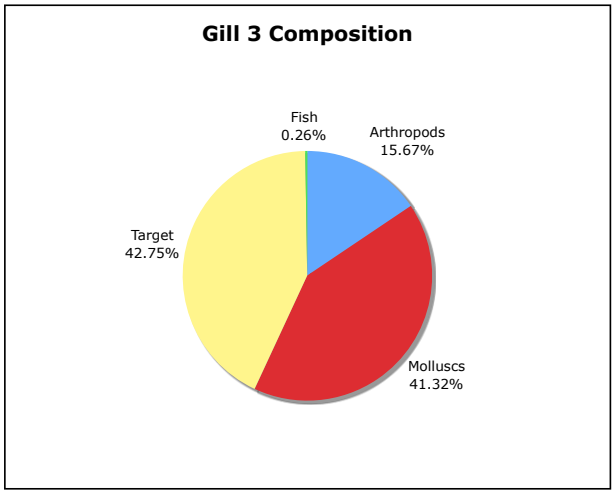

Figure 7. Chart showing percentage of overall catch composition based on weight from third gill net.

Fish diversity

Fish diversity was graphed and statistically tested using BiodiversityR in R Commander. For gill 1, gill 2, and gill 3, the diversity was very low. The number of fish found in these discard piles where less than four, as seen in Figure 9. One fish was found in gill 1, no fish were found in gill 2, and three were found in gill 3. Figure 8 indicates that the standard deviation is low in the three gill nets, which can be attributed to the low sample size.

When looking at the diversity ranking of fish, trawl 1 had a large diversity (Figure 9). However, there are a lot of repeated species within the same discard pile (Figure 8). The large standard deviation from the first plot of Figure 8 shows that the diversity within trawl 1 has a low accumulation rate. From the p-value seen in Table 1, the null hypothesis can be rejected. This indicates that the diversity of fish caught is normally distributed. A nonparametric chi-squared test indicated that the fish diversity is not due to chance (Table 1).

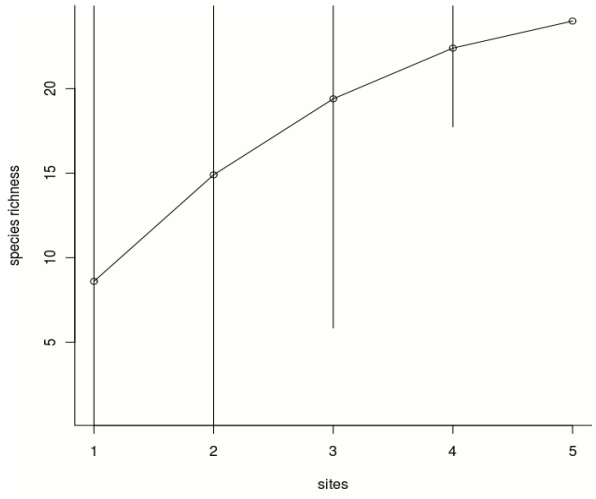

Figure 8. Species accumulation curve for the different five nets based on number of species. 1 is trawl 1, 2 is trawl 2, 3 is gill 1, 4 is fill 2, and 5 is gill 3

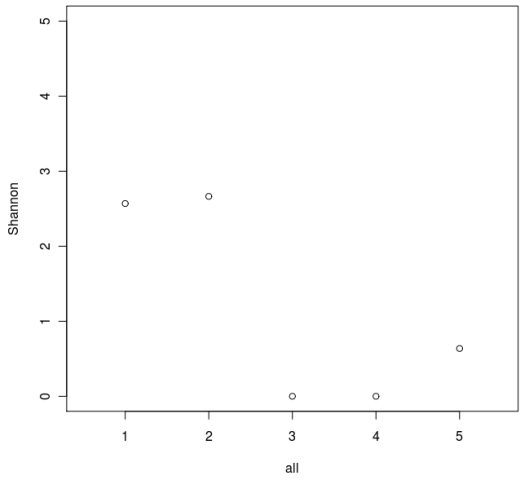

Figure 9. Species Diversity Graph showing diversity ranking between the 5 nets. 1 is trawl 1, 2 is trawl 2, 3 is gill 1, 4 is gill 2, and 5 is gill 5

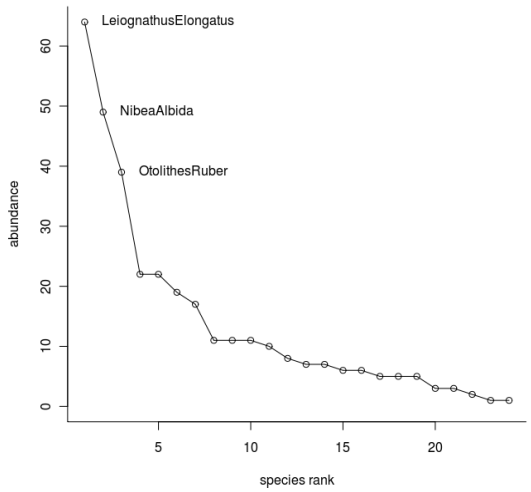

Figure 10. The abundance of fish species from all nets ranked from highest to lowest

	Shapiro-Wilk (p-value)	Chi-square	Nonparametric (p-value)
Trawl 1: fish	0.0002781	118	<2.23-16
Trawl 1: lengt	0.0005956	77.3	2.5443e-9
Trawl 2: fish	9.05e-6	116	3.45e-15
Trawl 2: length	2.326e-10	134	<2.2e-16
All nets	2.73e-13	207	<2.2e-26

Table1. Statistical analysis of trawl 1, and trawl 2 using Shapiro-Wilk test, and nonparametric tests (chi-squared and p-value). Values were determined through R commander.

DISCUSSION

Length of fish

After removing *L. lunaris* and *H. imbricatus* from the data the maximum length of fish in the discard was determined. *L. lunaris* was removed due to this species being poisonous for consumption; thus it is disposed of regardless of length. Compared to the bony fish caught, *H. imbricatus* is large, resulting in higher standards for market. Further research is necessary to assesses the impacts of fishing on *H. imbricatus* and other shark species due to their standards being higher from those of bony fish. These species reside on the top of the food web and have been heavily affected by fishing and are important for the ecosystem. Thus it is important to help preserve these organisms by conducting research on their discard rate.

The normal distribution seen within the lengths of fish indicates that there is not a clear cut off length. If there was a definite maximum length that fish were considered discard catch, there should not be a bell-shaped curve. This could be due to poor sorting by fisherman. Additionally, each species of fish may have its own size requirements to be considered marketable.

Composition of catch

The high percentage of target catch in gill 2 is most likely due to the possibility that the fishermen had begun sorting their catch on the catamaran before reaching the beach. Also, their discard piles were thrown on already existing discard piles from the week's previous catches. Collecting this data would have shown a strong bias towards discard catch being most of the net composition. Excluding gill net two for this reason, it can be seen that all other net types have a large percentage of discard piles.

In the overall composition of the discard piles, arthropods make up the majority of the catch (Figures 3-7). The arthropods caught included crabs, mantis shrimp, and hermit crabs. The large percentage of arthropods may be due to the pile including shells that are more dense and add a lot of weight. The mollusk piles were made up of octopus, cuttlefish, and snails. The shells could have added extra weight from the snail as well. The cnidarians were primarily sponges that were scraped off the benthic zone, except for one jellyfish seen in trawl 1. This large jellyfish is the source for a much larger percentage of cnidarians in trawl 1 than trawl 2. Additionally, a small percentage of the discard pile consisted of target shrimp. The presence of shrimp in the discard pile is likely due to the net catch pile being so chaotic; the fisherman may have missed a few shrimp and possible a few other organisms not meant to be in the discard pile.

Looking at Figures 5, 6, and 7 compared to Figures 3 and 4, it can be concluded that gill nets have a lower discard pile of fish. This is due to trawl net fishermen are targeting shrimp and have little or

no use for the majority of their bycatch. Additionally, the mesh size of gill nets are larger in order to target larger fish as opposed to shrimp. For this reason, gill nets capture a lower quantity of fish. Fishermen with gill nets are more willing to sell anything they believe consumers are willing to buy because they have less fish they can sell.

Fish diversity

When looking at species diversity, no statistical analysis was done on the gill nets for the reason that R Commander could not operate with so many zero values. Trawl 2 was more diverse than trawl 1 (Figure 9). The species accumulation curve in figure 8 shows that like trawl 1, trawl 2 has a large standard deviation. This is due to the large number of repeated fish within the discard piles as seen in figure 10. For both the Shapiro-Wilk and nonparametric test, the p-values indicate that the fish diversity is not due to chance (Table 1). However, trawl 2 has a much lower p-value compared to trawl 1. Although both are considered to be statistically significant, trawl 2 has a much lower possibility that the data collected is due to chance.

Overall, there was a higher percentage of discards in trawl nets than gill nets. Both still are very wasteful fishing methods that remove organisms from their environment, only to be discarded as waste. Gill 2 is the only net that shows very little discard, which may be due to the sorting that was done beforehand. This prevents meaningful statistical analysis of Gill 2's discard pile.

The trawl nets may have been skewed from the fisherman being distracted by the presence of researchers while sorting through the discard pile. This may be one reason that the target catch, shrimp, were found in the discard pile. To test this, further research should be done on the size and weight of shrimp found in discard piles and those that are sold from the Market, indicating that whether those

shrimp discarded met the standards of shrimp sold. There is a large bias towards arthropods making up a large quantity of the composition. This may be due to the extra weight from the shells from the hermit crabs. Additionally, the large jellyfish found in trawl 1 added tremendous weight to the cniderian pile.

A Shapiro-Wilk, chi-squared and nonparametric test indicated that all the values analyzed were not due to chance. However, the accumulation curve seen in Figure 8 does not level off, showing that there needed to be one or two more sample sites calculated in order for the data to be an appropriate sample size. However, it does show that there is a large diversity within trawl 1 and 2, but they both contain large standard deviations. This is due to a large number of repeats of fish species. This can be seen in the abundance curve in Figure 10. In this figure, 24 species of fish are shown, but three have a much higher abundance.

Future research is needed to look at length size of discard fish at the species level. Such research would require a much larger sample size, and should focus on just one net type. Later, it could be expanded to different net types in order to compare fishermen opinions on marketable fish. Understanding this is important step towards developing fishing methods that preserve marine ecosystems. Many people rely on fish for food and jobs. Ensuring that sustainable fishing practices are devised and implemented is imperative for those whose livelihood depends marine-life.

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Characterizing the Mines of an Unknown Phyllocnistid on *Avicennia marina*

Grant Robinson

ABSTRACT

Mangroves play an important role in coastal ecosystems serving as a nursery for young coral fish and a host of other vertebrates and invertebrates. In this study the effects of a leaf mining moth from the genus *Phyllocnistidae* on the mangrove *Avicennia marina* are examined with special attention to the geometry of the mine itself. The mine was measured and plotted by distance mined vs width mined using calipers and digital image analysis. A 3rd order polynomial is regressed to both graphs (R^2 =.538, .691 respectively; P= $2.2x10^{-16}$ for both). The correlation between host leaf area and mine area are also examined (R^2= .44, P=$7.5x10^{-4}$).

INTRODUCTION

Mangroves have an impact on tropical coastal ecosystems that is disproportionate to their distribution. They occur only in the intertidal zone in the sub tropics and tropics. They are a hard surface in a usually soft bottomed and dynamic environment. Mangroves provide a habitat for many species and provide various habitat functions. They provide a medium for sessile filter feeders such as sponges and oysters, as well as marine plants such as algae (Nagelkerken et al, 2008). The leaf litter decays and creates a nutrient rich benthos which is aerated by pneumatophores (Burrows, 2003) that is home to many vertebrates and invertebrates. Some debates are still ongoing about the importance of mangroves as habitat for young offshore fisheries species (Nagelkerken et al, 2008), but their importance in estuarine systems is well known. Their rehabilitation and propagation is therefore becoming a topic of both study and practice. The role of insect herbivory has been studied at length by Burrows on *Avicennia marina* and his finds suggest that insects play an even more important role in mangrove systems than previously

concluded. Within the constituent insect herbivores, the leaf miners remain a relatively unstudied division.

The leaf miners are primarily from three main taxa: Lepidoptera, Agromyzidae (Diptera), and a few families within Coleoptera. While leaf miners occur across latitudes, the leaf mining larval strategy reaches its highest relative abundance in the tropics (Hespenheide, 1991). Leaf miners can cause copious damage as well as being a vector for fungal and viral attacks. Due to their endophytic larval strategy, leaf miners tend to be highly host specific, usually feeding on a single species or several species within a genus (Hespenheide, 1991).

This study focused on a leaf mining moth in the genus Phyllocnistis which attacks *A. marina* in southeast India. The larvae of this moth create serpentine mines which are silver in colour. The citrus leaf miner *Phyllocnistis citrella stainton,* which is originally from Southeast Asia (Wilson, 1991), has been extensively studied because of its impact on lime, lemon, and orange crops and these studies were heavily drawn on for an understanding of the Phyllocnistid moth attackin *A. marina*. The larvae of *P. citrella* are documented as having four larval instars. The first two of these instars feed within the leaf, the third migrates towards the edge while feeding and the fourth spins and pupates which causes a fold on the leaf margin. The study sought to describe the effects of these leaf miners in single leaves through the analysis of the geometry of the empty mines they leave behind.

RESULTS

The study area consisted of two stands of exclusively *A. marina* trees, one located in a shallow inlet approximately two kilometer south of the mouth of Pulicat Lake, and the other less than a kilometer from the mouth of Kalliveli estuary. The Pulicat lake site is planted and maintained by a women's group from a neighboring village and the ages of the trees vary from 0 – 3 years. The trees have reached a maximum height of two and a half meters. The site in Kalliveli estuary is very near to salt pans which most likely contribute to salinity stress on the stand of trees. The mangroves vary in age, but are short in

stature with a maximum of under two meters.

At Pulicat and Kalliveli leaves were gathered haphazardly by plucking and pressed between newspapers. After about two days of pressing the unmined leaf tissue turns a dark brown/black, while the leaf mine remains a silvery white. Two systems of recording the geometry of the mines were used, at Pulicat the leaf mine was marked at approximately 5mm intervals along the mines curve with a ballpoint pen. The distance of the mine was measured for each of these points with calipers and recorded along with the width of the mine. The distance between these points was adjusted to allow for greater resolution at points of rapid change in width. The leaves collected at Kalliveli were pressed and placed on a sheet of notebook paper and photographed. The photographs were imported and marks were again placed along the length of the mine. At these points the mines were measured digitally with ImageJ using the notebook lines to calibrate. The area of the leaf was measured and where parts of the margin were missing it was reconstructed as *A. marina* leaves are relatively symmetrical. Distances between marks were measured as well as the width. Distances were summed continuously to provide a running length. The total area mined was estimated using a trapezoidal Riemann sum. The length measurements from mines which the moth had pupated and exited were converted to percent to standardize. The measurements were graphed length vs. width to provide a growth profile for each individual mine. Data was analyzed with R for statistical analysis.

In comparison the two methods of measuring leaf mine structure both produced an 'S' shaped curve such that the best fit was a cubic of the form: ($W \sim Length^3 + Length^2 + Length$). R^2 of trial at Pulicat was .538 (Figure 1) where the method used with the samples from Kalliveli gave an R^2 value of .691 (Figure 2). Both had P values of $2.2*10^{-16}$. Mine area related to leaf area linearly ($R^2 = .44$, $P= 7.5*10^{-4}$) and is shown in Figure 3.

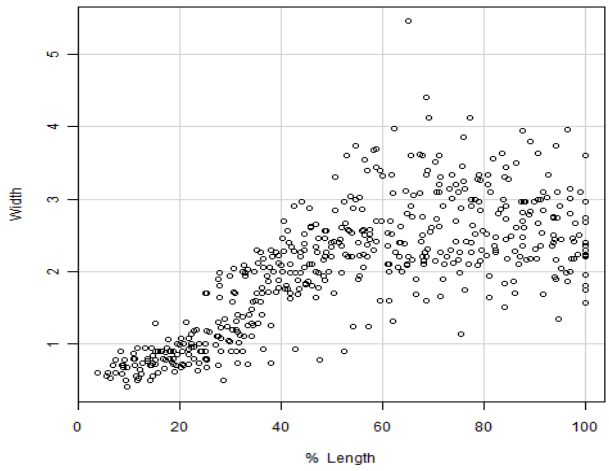

Figure 1. Width of mines at certain points along leaf mines sampled from Pulicat Lake. Length given in percent to standardize all samples

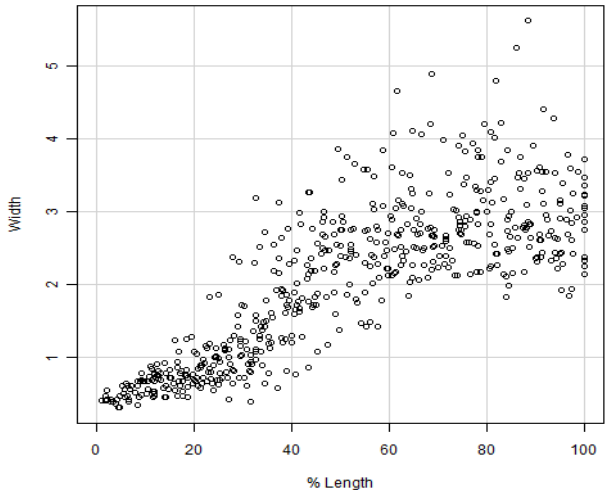

Figure 2. Width of mines at certain points along leaf mines sampled from Kalivelli Estuary. Length given in percent to standardize all samples

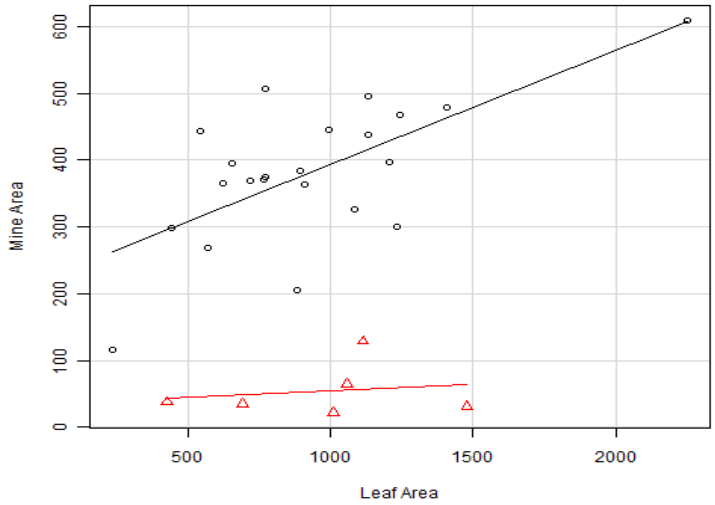

Figure 3. Host leaf area vs mine area. Circles represent omplete mines, triangles represent incomplete mines.

Figure 4. A. marina leaves from Kalliveli estuary showing an incomplete mine (left) and a complete mine.

DISCUSSION

The method of using ImageJ provided less error than the previous method, shown by the higher R^2 value of the regression, but there is much variance intrinsic to the mines themselves, as the mines do not represent the growth of the larvae so much as the consumption. Some of this variance in mine structure could also be the affect of other unknown factors e.g. genetics, plant stress (Farnsworth Ellison, 1991), leaf sclerophylly and chemistry (Kathireson, 2003) etc. The width of the mines is difficult to measure often because the direction of the mine is not constant. The width itself often varies by the micrometer and when estimating the area much of this was assumed to be mean-zero noise. The cubic model could possibly be explained by the three feeding larval instars of *Phyllocnistis spp* forming the segments between inflection points. The first instar therefore would show exponent-like increase in herbivory, the second showing a logarithm-like tapering off approaching a maximum, and the third either flat or slightly decreasing herbivory rate as it migrates to the leaf margin to pupate. The correlation between leaf area and mine area is evident among the samples of complete mines, but presumably it would be less marked on incomplete mines where early mortality occurred. One study reviewed sited crowding as a significant cause of premature larval mortality (Wilson, 1991) and it is feasible that lack of space could effect herbivory rates.

More sampling is needed to further reinforce the correlation between leaf size and area mined as well as more nuanced approach. Discrete sampling fails to account for the growth of leaves after the miner has exited. Also to be considered is that miners inhabit their leaf for weeks, and there is significant growth during that time. It is suggested that longer term study of individuals in their habitat be monitored as both the leaf and the miner grows in synchrony.

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Observations of the Diet and Morphometrics of *Sphyraena obtusata* Across its Distribution in Northern Tamil Nadu, India

Bradley Wells

ABSTRACT

As fishing communities along the Tamil Nadu coast continue to deplete finfish stocks, it is important to understand as much as possible about the fishes that are captured in their fishing efforts. One such species, is the Obtuse Barracuda (*Sphyraena obtusata*), a fish found with relative ease along the Tamil Nadu coast and excellent table fare. It was the intention of this project to look at the diet and morphometrics of the obtuse barracuda throughout its distribution in the northern section of Tamil Nadu. The project utilized gut content analyses and standard measurement procedures to gather data and in the end noted several trends between body size and sexual characteristics as well as gaining a better understanding of the diet of this fish.

INTRODUCTION

The obtuse barracuda (*Sphyraena obtusata)* is one of the smaller members of the family Sphyraenidae yet they are still armed quite effectively with large teeth and a deeply forked caudal fin for fast movements and prey capture. One can typically find the obtuse barracuda over sea grass beds and rocky substrates (FishBase, 2010). Here these speedsters can be found chasing down small fish and other small marine fauna either singularly or in a school. While hunting, obtuse barracuda along with their relatives in the family Sphyraenidae utilize a combination of speed and hydrodynamics as they refrain from opening their mouths to attack until the very last second (Porter and Motta, 2004). Because of their

size and relative abundance along the coast of India, they are commonly eaten and in some circumstances dried or frozen in preservation for seasons of low productivity.

It was the intention of this project to take observations on the relationships between several factors influencing the obtuse barracuda and its ecology. Alongside this, it was also the intention of this project to determine the diet of the obtuse barracuda throughout its distribution along the northern coast of Tamil Nadu.

This study occurred at two locations in Tamil Nadu on the eastern coast of India. Specifically these locations included the fishing villages near Pondicherry and Pulicat Lake. Samples were obtained either directly from fish landing centers or the local fish market depending on availability of fish and the ability to collect specimens by the researcher. All specimens were dissected within 48 hours of being brought from the fish landing center or fish market with the specific time for each varying with time availability.

METHODS

In performing this study, there were several very basic methodologies utilized in data collection. The primary method utilized in attempting to determine the diet was a basic gut content analysis via dissection. To begin each dissection, measurements were taken utilizing Vernier calipers or a measure tape, depending on the size of the fish, and the Total Length, Standard Length, Body Depth, and Girth were recorded. Following the recording of these measures the fish was slit using scissors from the anus, up the underside to the mouth and then carefully opened so as to easily access the stomach, intestine, and sex organs without mutilation. Once the fish was opened, the sex and reproductive state of each fish was recorded. To determine sexual state we looked at the coloration of the sex organs, with white testes representing undeveloped males and yellowish, more vascularized testes representing developed males. In females, a light pink, limp in appearance ovary was termed not swollen and a swollen ovary was termed

"swollen." Both of these conventions for determining the reproductive state of individual fishes were adopted from recommendations made during a conversation with Gokul, a researcher at the Madras Christian College Estuarine Biological Laboratory at Pulicat Lake, India. Once we had sexed each fish and determined its reproductive state, the stomach and intestine were carefully removed, measured using Vernier calipers and then weighed. Finally, after weighing the stomach and intestine, the stomach was opened and its contents were removed, identified as accurately as possible, and then recorded. For each of the 28 samples, this process was repeated precisely with the exception of specimens 1-9, when a functional scale was not available for use in obtaining the gut weight.

RESULTS

After meticulous measurements and dissections as well as hours sitting at the computer graphing the data recorded, the outcome of this project slowly came into focus. From the onset, the primary intention of this project was to identify components of the diet of the obtuse barracuda, however time factored against us in many instances and the data recorded from the gut content analyses became highly qualitative instead of the anticipated quantitative data. As a result, the focus of the project was then shifted towards looking for correlations between morphometrical observations and sex, size, and reproductive state. Figure 1 presents the average gut weight of sampled fish across the three different reproductive classes present. From the gut weight data we were also able to create Figure 4 which presents the gut weight of sampled fish shown in relation to their total length. Of the morphometry data collected, the most applicable and easily understood was the use of the total length measures. From these measures we were able to show the average total length across reproductive states (Figure 2) and sex (Figure 3). In addition, we were able to utilize total length to make comparisons with girth, Body Depth, and gut weight. For each of these comparisons we broke the data down into categories respective of the sex of the fish. Figures 4-6 express the comparison of the gut weights to the total length for the combined dataset, males, and females, respectively. Similarly, Figures 7-9 demonstrate the total length in relation to

girth and Figures 10-12 the relationship between total length and body depth. In accordance with the common sense idea that as a fish ingests more food, their stomach will expand, thus causing the soft underside of the fish to puff out, Figures 13-18 were included to show the trends between girth and body depth (Figures 13-15) as well as gut weight and body depth (Figures 16-18). Gut content analyses of specimens brought about a variety of organisms and some disappointing results due to digestion as can be seen in Table 1 below.

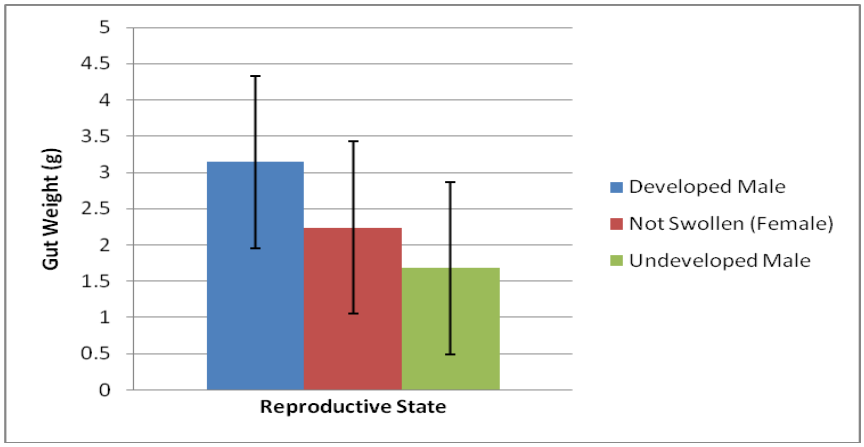

Figure 1. Representations of the average gut weight across reproductive states. The error bars represent one standard deviation

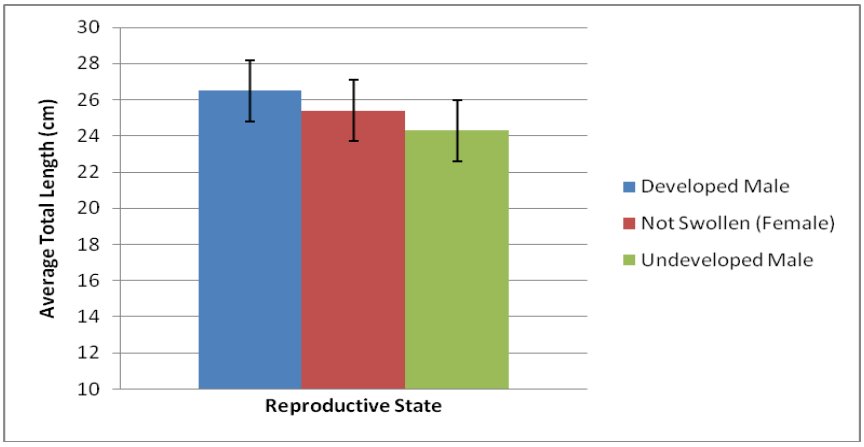

Figure 2. Depiction of the average total lengths across the sampled reproductive states in *Sphyraena obtusata* with error bars representing one standard deviation

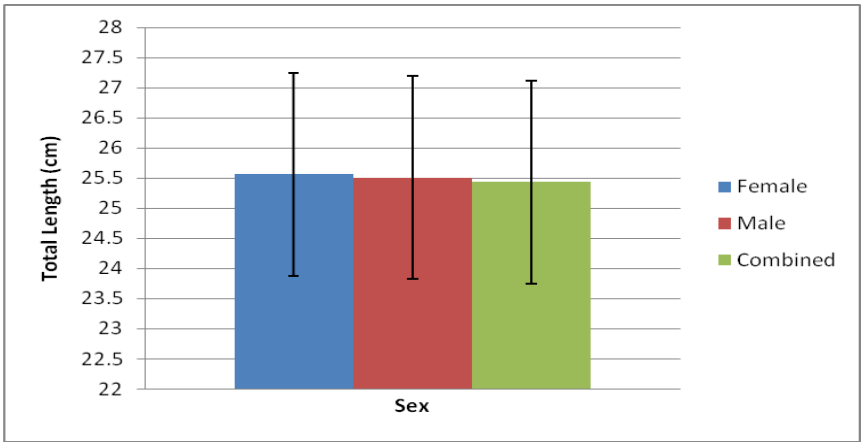

Figure 3. Graphical representation of the average total length across the sexes. Error bars are indicative of one standard deviation

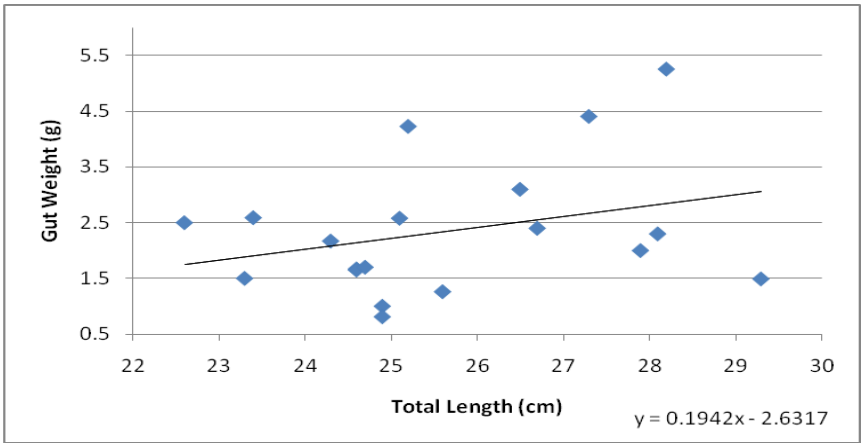

Figure 4. Scatter plot showing the relationship between gut weight and total length in both male and female obtuse barracuda

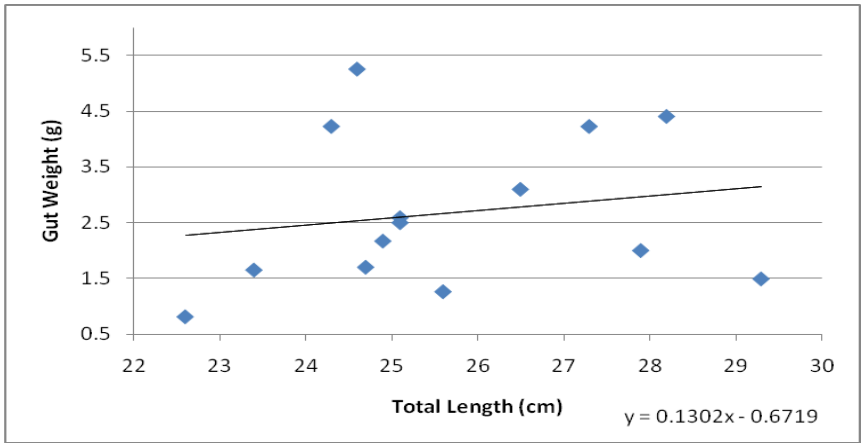

Figure 5. Shows the gut weight of male obtuse barracuda in relation to their total length

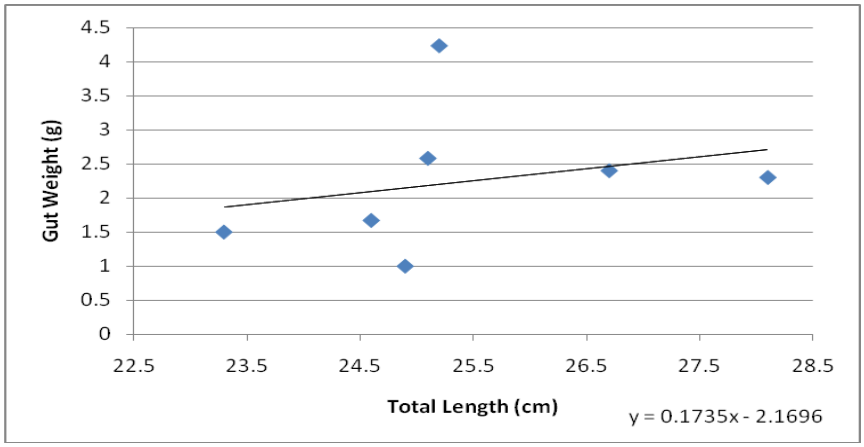

Figure 6. Depiction of the relationship between gut weight and total length in female obtuse barracuda

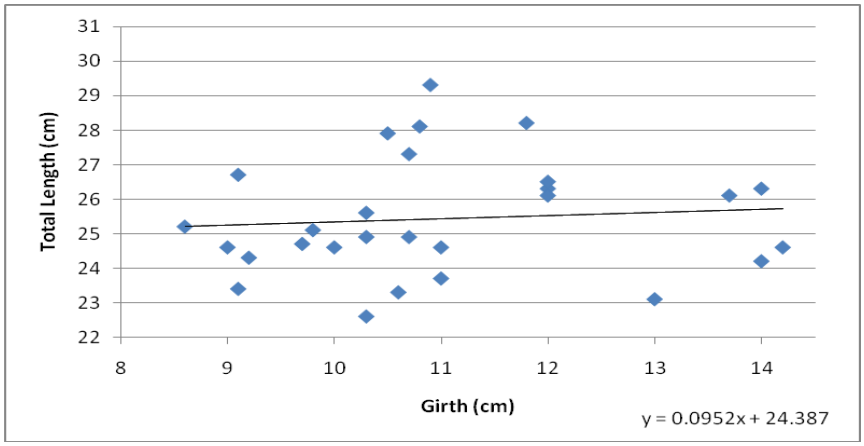

Figure 7. The total lengths of both male and female *Sphyraena obtusata* in relation to their girth measurements

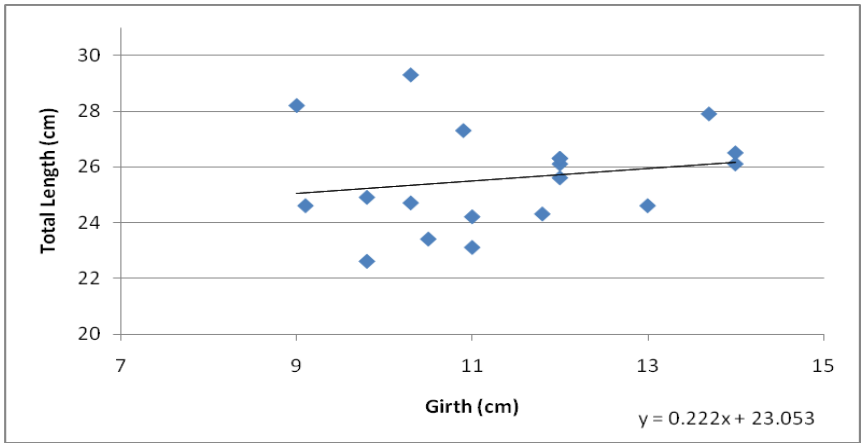

Figure 8. Relationship between the total lengths of sampled male obtuse barracuda and their girth measurements.

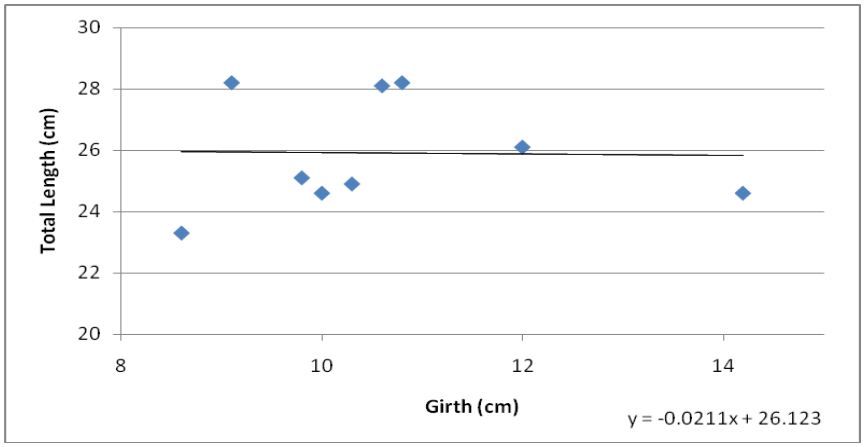

Figure 9. Total lengths of sampled female obtuse barracuda in relation to their girth.

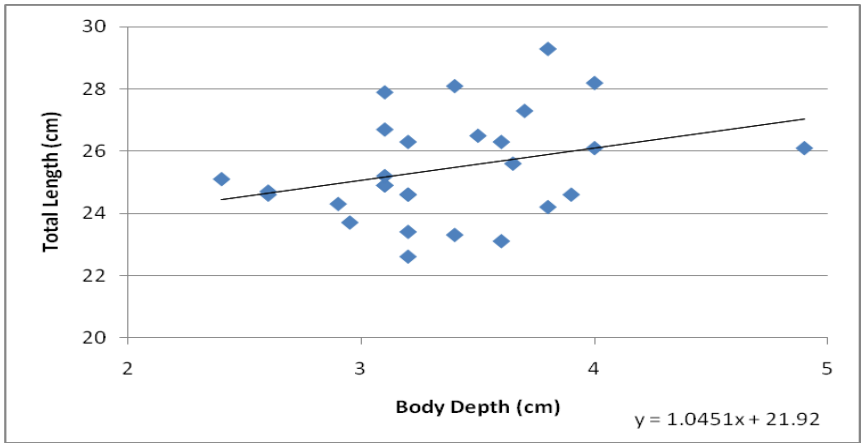

Figure 10. Relationship between the total lengths of male and female obtuse barracuda sampled and their body depth

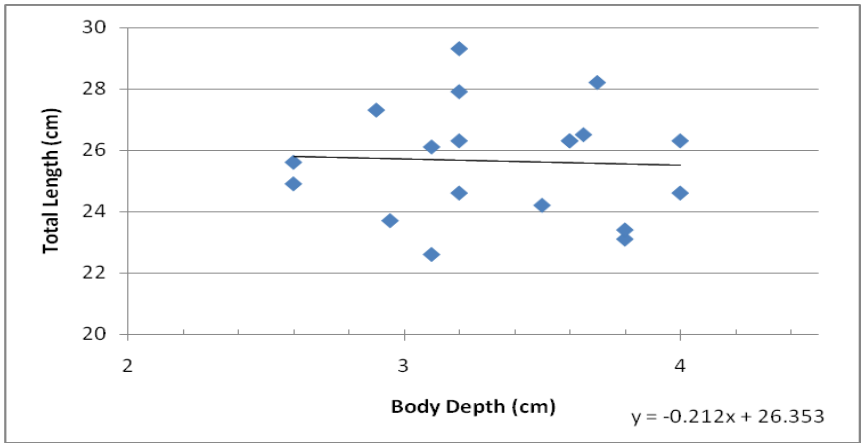

Figure 11. Total length's relationship to body depth in sampled male *Sphyraena obtusata*

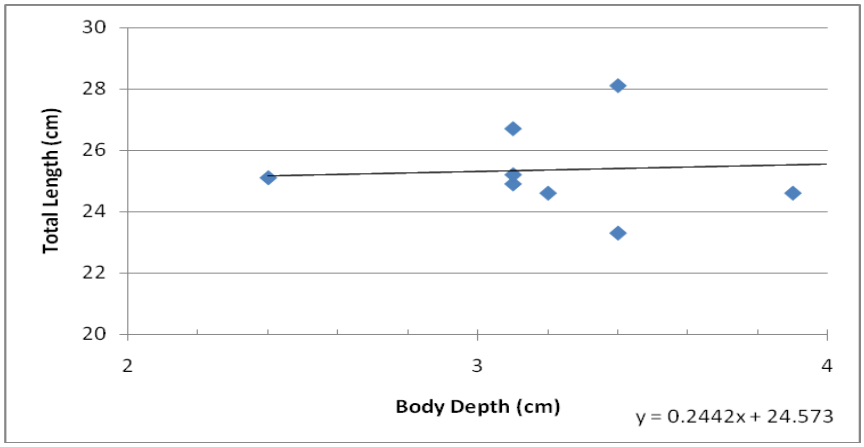

Figure 12. Depiction of the total length to body depth relationship in female obtuse barracuda sampled

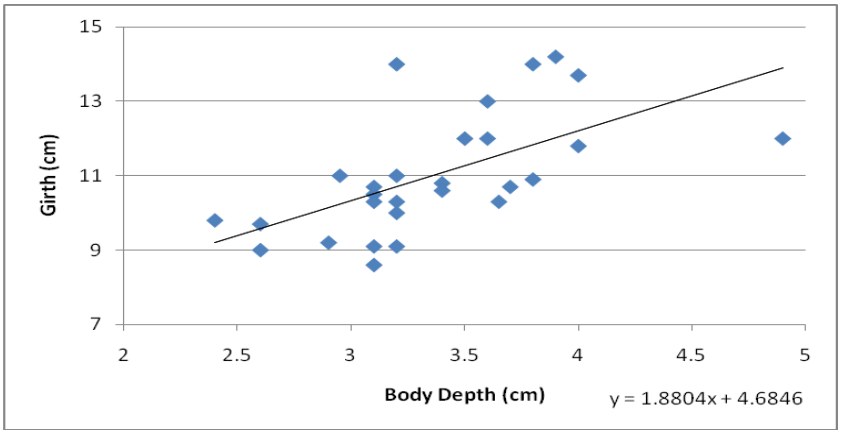

Figure 13. The relationship between girth and body depth for both males and females combined

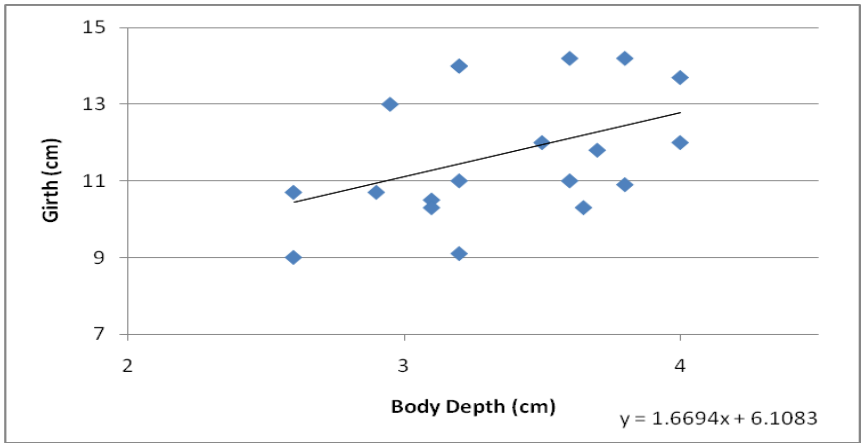

Figure 14. Depiction of the girth in relation to body depth in male obtuse barracuda

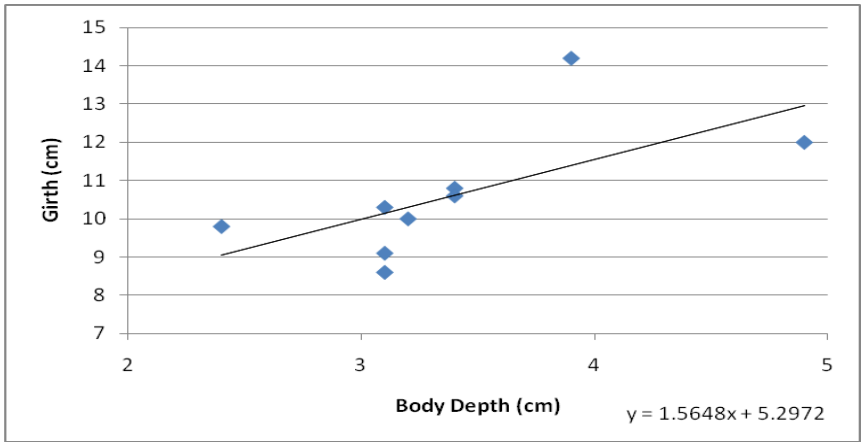

Figure 15. Representation of the comparison of girth and body depth in female obtuse barracuda

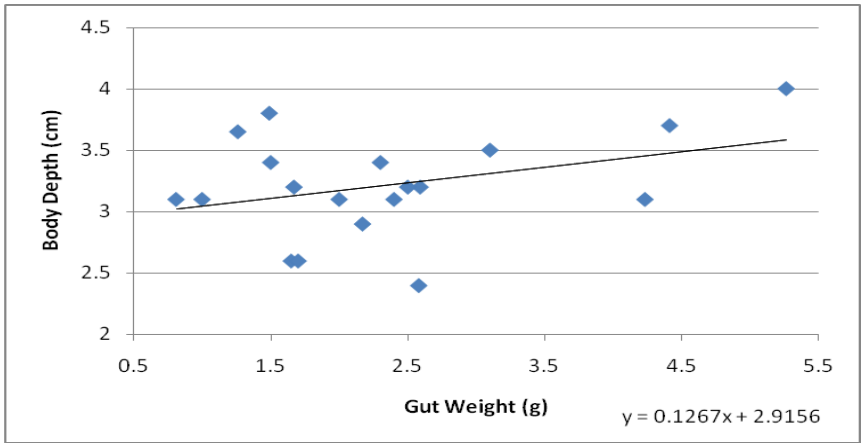

Figure 16. Graphical presentation of the relationship between gut weight and body depth in both sexes of obtuse barracuda

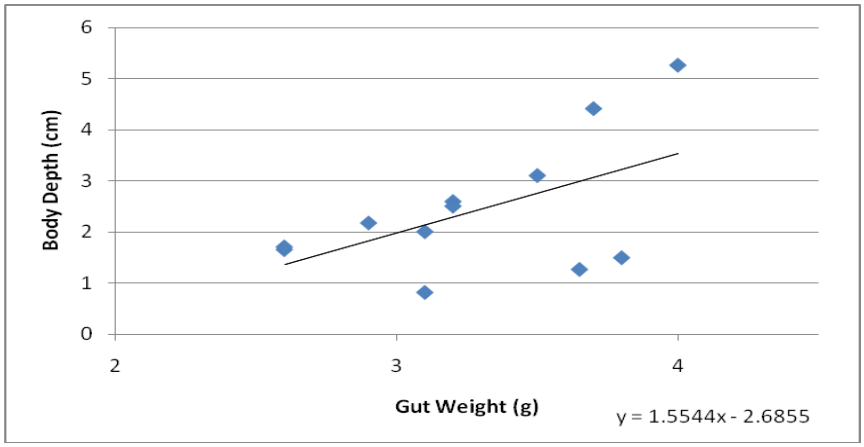

Figure 17. Gut weight compared to body depth in male obtuse barracuda

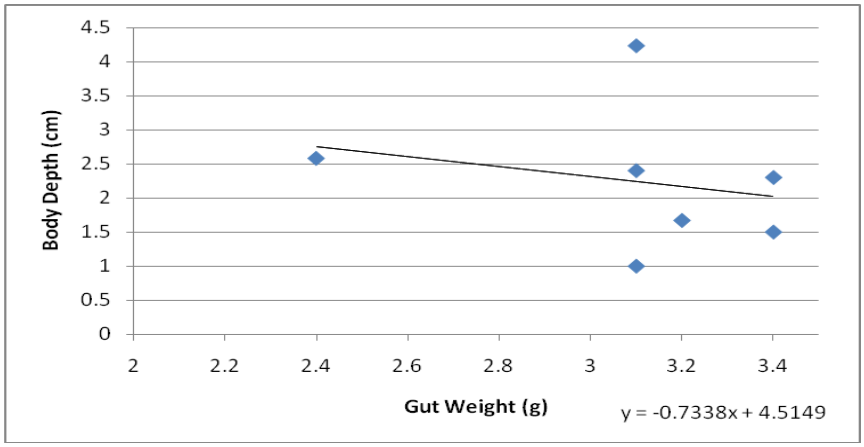

Figure 18. The relationship between gut weight and body depth in female obtuse barracuda

Figure 19. Picture of a Clupeoid found during gut content analysis

Figure 20. A small squid found during gut content analysis

Figure 21. Shrimp collected from the stomach of an obtuse barracuda during dissection

Specimen	**Sex**	**Gut Content**
1	M	whole anchovy+ vertebra from another fish
2	M	goo(degraded state)
3	F	1 clupeoid(possibly sardine (12.5cm))
4	M	goo(degraded state)
5	M	goo(degraded state)
6	M	Small Squid
7	M	small fish (6.8cm) possibly an anchovy
8	F	3/4 of a sardine(5.8cm) and 1 anchovy head(5.1cm)
9	M	Small fish degraded beyond ID. Only skull left
10	M	Sardine at 10cm
11	M	goo(degraded state)
12	F	goo(degraded state)
13	F	goo(degraded state)
14	M	goo(degraded state)
15	M	Small fish degraded beyond ID.
16	M	goo(degraded state)
17	M	goo(degraded state)
18	F	small fish degraded beyond ID
19	F	small fish degraded beyond ID
20	M	anchovy, digested fish remains
21	F	1 small unidentifiable fish(mostly degraded)
22	M	shrimp, mud, fish bones
23	F	Shrimp
24	M	digested squid
25	M	goo(degraded state)
26	M	small clupeoid and bones
27	F	Shrimp, small clupeoid
28	M	small sardine

Table 1. Table showing the sex and gut content of sampled obtuse barracuda

DISCUSSION

From this project, there were several conclusions that can be drawn about relationships between sex and reproductive states and morphometrical observations. In addition, a basic understanding of the diet of the obtuse barracuda was developed along with some important factors to feature in future gut content analyses.

As can be seen in Figure 1, the larger values for gut weight of the specimens for which gut weight was recorded fell into the developed male category. The most probable reasoning for this is because of all of the reproductive categories, the larger of the fish sampled tended to be developed males (Figure 2). As further evidence to defend the finding that a higher gut weight was associated with developed males, who subsequently represent the larger fish in the sample, is the trend appearing in Figure 4 where as total length increases, so does the gut weight recorded for each fish. The gut weight data collected from the fish further goes on to show that as the amount of food discovered during the gut content analysis increased, thusly did the gut's overall weight.

From the data collected on the total length of the fish sampled, slight correlations can be seen in comparisons of girth and body depth measures with those of total length. After comparing the girth to total length in the male obtuse barracuda, a general trend towards an increase in girth as total length increased can be seen in Figure 8. Figure 9 however, shows this same comparison from the females sampled and in this particular case no real correlation can be made. In a similar fashion to the comparisons made between total length and girth, we also compared the measurements for body depth and total length. These results are presented in Figures 10-12. When analyzed individually, there seems to be no real correlation in either the males or the females since trend lines have a near zero slope (Figures 11 and 12). On the contrary, when one looks at Figure 10, the comparison with both male and females

combined, a trend between total length and body depth appears to be a little more prevalent and leaning towards the conclusion that increased body depth is related to an increase in total length.

Following the comparisons of body depth to total length, we compared the body depth to the girth of the fish measured as well as the gut weight of the samples where weight was recorded. In looking at the relationship between girth and body depth, we refer to Figures 13-15. In these graphs we can see the beginnings of a relationship between the two in the male and female graphs separately. However, when we compare these measures for all of the samples combined, one is able to see a trend forming where an increase in body depth leads to an increase in girth. While working on these charts, the thought to compare body depth and gut weight came to mind and thusly Figures 16-18 came to life, depicting this relationship in the combined, male, and female forms. From these graphs, we were able to note an increase in body depth with a larger gut weight, in the combined and male graphs. This relationship seems to make sense because as the stomach expands from being filled, it should push against the soft underside of the fish causing it to expand. Strangely however, this relationship did not exist in the females sampled. In fact, the relationship depicted in Figure 18 represents the inverse; a decrease in gut weight with an increase in body depth.

The gut content analyses sadly provided us only with qualitative data as degradation caused many of the fish to have stomachs containing a liquid like substance, termed goo in Tables 1 and 2. While many of the samples contained “goo”, there was still a relatively wide variety of organisms found in the gut content analyses. Organisms found ranged from pieces of fish to whole shrimp (Figure 21), anchovies (Figure 19), sardines, and squid (Figure 20). Of these, the most prevalent were degraded members of the Clupeoid family who were only discernible through several characteristics key to this family such as large eyes and a superior mouth alignment. These Clupeoids were found in the gut contents of fish across the range sampled, from Pulicat Lake north of Chennai, to Pondicherry. Generally speaking the diet of the

obtuse barracuda can be said to be primarily piscivorous due to their large intake of fish, however, they are also capable and willing to eat other marine organisms if the opportunity presents itself.

When considering the information presented, it is important to note that the error bars in Figures 1-3 represent one standard deviation. Such large error was most likely the result of having to use a mixture of techniques for measurement as the calipers utilized were not large enough to take total length measurements, so a measure tape was used. Another factor to consider in the error show in these figures is that the scale being utilized for weighing the gut of the fish was being shared with another project and on several occasions grains of sand and other dirt particles fell out of the scale during use. These particles could potentially have affected the reading given and if they had penetrated deeper into the machine could have caused problems with zeroing the scale before use. Other graphs presented do not contain error bars for the ease of viewing so many points on a single chart; however this does not mean that they are free of error. Error for these charts is likely caused by similar problems as mentioned previously and could also have been skewed due to the relatively small sample size in comparison with wild populations as well as the lack of a scale for use in gut weights for the first nine samples.

Overall, the results from this project, demonstrate that there are several relationships between growth and sexual characteristics in the obtuse barracuda. Future exploration on the obtuse barracuda would be of particular interest on the relationships between growth and sexual characteristics as this project simply recorded these datum in addition to the gut content analyses. Had the main focus of the project been on collecting this type of information it is highly possible that these trends could be further explained and better represented over a larger sample size.

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Complexity of Mangrove Root Systems as a Determinant of Mangrove Macrofauna Diversity and Abundance

Cara Mayo

ABSTRACT

Mangroves play a vital role in intertidal ecosystems. Due to the various unique characteristics that mangrove and mangrove habitats possess, they become a haven for many species including crabs, snails and oysters. A field experiment was developed to examine the root structure of three mangrove species: Rhizophora, Bruguiera, and Avicennia- to see if the complexity of these roots drives the diversity and abundance of four commonly found macro invertebrates: the truncated mangrove snail (C*erithidea decollata*), the common periwinkle (*Littorina littorea*), mangrove crabs and oysters. Though all of the data was shown to be not normal through the Shapiro-Wilk test of normality, there was a clear preference of diversity and abundance of mangrove animals to more complex root systems.

INTRODUCTION

Mangroves play a vital role in the lives of humans and animals. It is an important contributor to socio-economic and medicinal development as well as ecological stability and health. Mangroves function as a nursery, protect coast lines from erosion, storms and floods, trap sediment, and provide nutrients, forest products, and indigenous medicine to name a few (Kathiresan). One of the defining characteristics of mangroves is their unique root system which helps in pulling oxygen from the air while remaining an intertidal species. The difference in shape and complexity of mangrove root system varies from species to species.

Mangroves make an ideal habitat for many species because of their unique characteristics. Attributes such as high abundance of food and shelter and low predation pressure make these areas idyllic for many animals (I. Nagelkerken, 2008).

The common groups seen in mangroves are snails, crabs and oysters. These mangrove invertebrates play an important role in nutrient cycling, filtration and biochemical processes (I. Nagelkerken, 2008), (Stefano Cannicci, 2008), (Smith, 1991) and are most often easily seen in mangrove forests, especially at low tide.

This study attempts to examine the root structure of three mangrove species: Rhizophora, Bruguiera, and Avicennia- to see if the complexity of these roots drives the diversity and abundance of four commonly found macro invertebrates: the truncated mangrove snail (C*erithidea decollata*), the common periwinkle (*Littorina littorea*), mangrove crabs and oysters.

AIM AND OBJECTIVE

The aim of this study is to determine whether or not one type of mangrove root system is preferred as a habitat to Mangrove snails, periwinkles, oysters, and crabs. The objectives are two-fold: 1) to observe 3 different kinds of mangrove root systems (Avicennia, Rhizophora, and Bruguiera) for Mangrove snails, periwinkles, oysters, and crabs and 2) to identify any relationships

between the density and abundance of the four target species relative to the type of mangrove root system.

MATERIALS AND METHODS

3.1 Design of experiment

This study took place in an old growth mangrove forest. Old growth forests will have more complex and stable populations of common species than new growth or disturbed mangrove forests. An old growth forest is therefore a more reliable environment to sample from. The materials that were used were a one meter quadrate, a red tree marker, notebook and pen. A one meter quadrate was chosen to determine a fair and reasonable sized site to observe the four target species of this study.

3.2 Methods

To begin the study, the red tree marker was thrown into the old growth mangrove forest at no particular spot. The location where the tree marker landed was the first site and was determined as the center of the one meter quadrate study site. After careful inspection of all roots in the one meter area, the tree marker and one meter quadrate were taken about 10 meters away to ensure study sites were not repeated or too close together.

Once 10 meters apart, the tree marker was again thrown into the air at random to choose the next study site. The above steps were repeated 15 times for Avicennia, Bruguiera, and Rhizophora. Bruguiera study sites were at times closer than 10 meters apart as they were not always encountered sufficiently at each study site. This was done so that data of all three root systems were somewhat at equilibrium.

A number from 1-3 was given to each of the root systems to determine the level of complexity from greatest complexity to least respectfully. Rhizophora was given a root complexity number of 1, Bruguiera: 2 and Avicennia: 3.

It must be noted however, that due to severe time constraints, samples were not taken in an approved random fashion and this may have skewed the data due to preferential selection of study sites.

RESULTS

The Shapiro-wilk test of normality shows that the results of this study are not normal. Mangrove crab has a p-value of 6.47e-07, oyster has a p-value of 0.0001647, periwinkle has a p-value of 1.038e-07, and snail has a p-value of 1.181e-06. (Figures 1, 2, 3 and 4).

While at least one of the four species was found on Rhizophora and Bruguiera, none were found on the roots of Avicennia. Therefore, the Avicennia results were taken out of the analysis for accuracy purposes.

4.1 Truncated mangrove snail

2 truncated snails were found on the roots of Bruguiera and a total of 17 on Rhizophora.

The boxplot (Figure 5) shows a significant difference was found between the numbers of snails on each of the two root systems (Figure 5). To further test this relationship, of snail abundance to mangrove root systems, the Kruskal-Wallis test was performed and a p-value of 0.004777 was obtained (Table 1).

4.2 Periwinkle

Figure 6 clearly shows no overlap between the two boxplots indicating a significant difference. A p-value of 0.005216 was given. The Kruskal-Wallis test was performed further proving the significant difference between the number of Periwinkles on Rhizophora and Bruguiera (Table 1). There were 3 Periwinkles found on Bruguiera root systems compared to 34 on Rhizophora root systems.

4.3 Mangrove crab

The mangrove crab numbers were much closer in numbers compared to periwinkles and truncated snails. 9 crabs were found on Rhizophora root systems and 8 on Bruguiera root systems. Figure 7 clearly demonstrates this similarity between the two root systems and shows a non significant relationship. The Kruskal-Wallis gave a non-significant p-value of 0.7529 (Table 1).

4.4 Oysters

53 oysters were found on Bruguiera root systems and 50 on Rhizophora. There is significant overlap in the boxplot comparing the significance of numbers of oysters to mangrove root systems (Figure 8). This relationship is further proven by the Kruskal-Wallis test which gives a p-value of 0.949 and shows that the relationship is not significant (Table 1).

4.5 Diversity comparison of mangrove macrofauna and the complexity of mangrove root systems

To determine the difference in diversity of mangrove macrofauna based on the complexity of the root system, the Simpson's diversity index was used. In this equation the closer the value is to 0, the higher the diversity index. Rhizophora, with the highest root structure complexity, came out with the lowest diversity index of .33 while Avicennia, with the lowest root structure complexity remained the highest at a value of 1 (Figure 9).

4.6 Abundance comparison of mangrove macrofauna and the complexity of mangrove root systems

As with the diversity index, Avicennia (3) has the lowest abundance of the three root systems, with a total of 0 organisms observed on the roots. When comparing Rhizophora and Bruguiera root systems (complexity numbers 1 and 2 respectively) (Figures 5-8), Rhizophora has the most significant abundance of species (snail and periwinkles), while it has been determined that the difference between crab and oyster levels on the two root systems is not significant and cannot be judged as having a higher or lower abundance.

CONCLUSION AND DISCUSSION

In the future, this study should be further refined by not only looking at groups of species. All the organisms should be identified on the species level. The focus of the study should perhaps be re-evaluated to include mangrove roots and area covered by roots.

Does a more complex root system lead to a higher diversity and abundance of mangrove macrofauna?

It can be concluded, that the more complex the root system, the higher the diversity of macrofauna. A positive correlation can be found in the relationship between abundance of macrofauna and root complexity, although more data and further research is required to examine this hypothesis further.

From the analysis it can be concluded that the most complex root systems have the highest diversity index, while abundance is not as clear. Rhizophora root systems did have significantly higher numbers of periwinkles and snails; however the difference between the abundance of crabs and oysters and root complexity remains negligible. There is a significant increase in abundance of organisms from Avicennia (lowest root complexity) to Rhizophora (highest root complexity), and a less significant change between Bruguiera and Rhizophora. Rhizophora remains the most abundant, however.

The reason that both Bruguiera and Rhizophora have similar numbers of crabs

and oysters could be the fact that both of these trees provided the required habitat for the organisms. The oysters were always found in notches on the roots which indicates a habitat preference that both Bruguiera and Rhizophora could provide, but not Avicennia. The gastropods seemed to have more of a preference to roots that were long and had more vertical space which is provided by Rhizophora but not Bruguiera.

The low surface area and height of Avicennia's root system could indicate the reason for which it has the lowest abundance and diversity of the three root systems. Lower surface and height means less area for macrofauna to cling to and live on.

It must be noted however, that even though Avicennia lacked the physical presence of the groups mentioned on its roots, multitudes of mangrove crabs and truncated snails surrounded the base of the roots.

The high density of these species should go to show that the hypothesis of this study-i.e., a more complex mangrove root system will support a higher abundance and diversity of mangrove species may not be true at all. The surface area and height that Bruguiera and Rhizophora provide do give certain species advantages in low/high tide situations and predator/prey relationships, but the roots of Avicennia could be providing a service that is equally as valuable, which would explain the high abundance of crabs and snails.

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APPENDIX

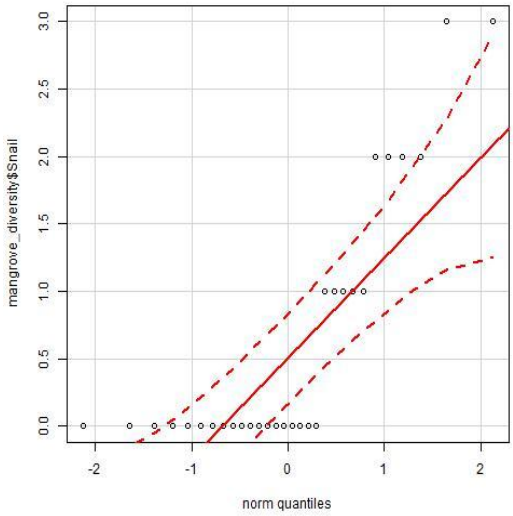

Figure 1. Quantile-comparison plot of snail

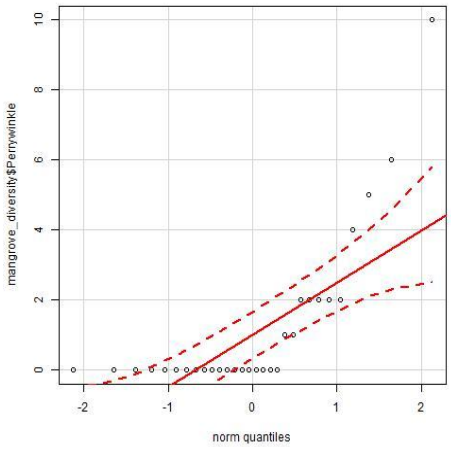

Figure 2. Quantile-comparison plot of Periwinkle

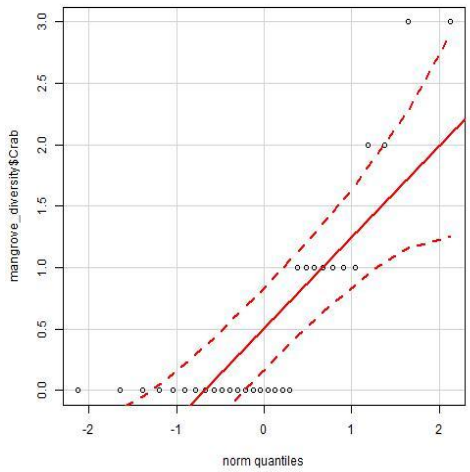

Figure 3. Quantile-comparison plot of crab

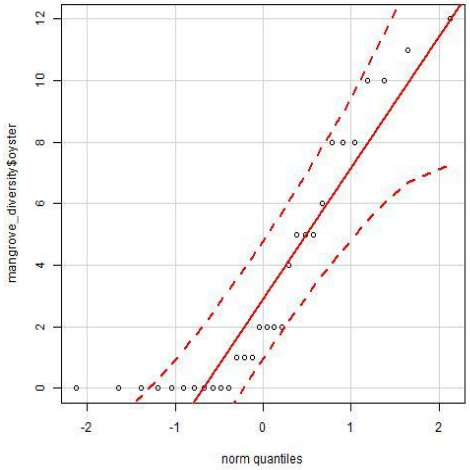

Figure 4. Quantile-comparison plot of oyster

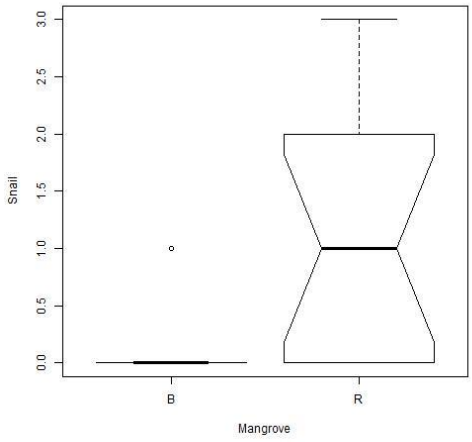

Figure 5. Boxplot of snail

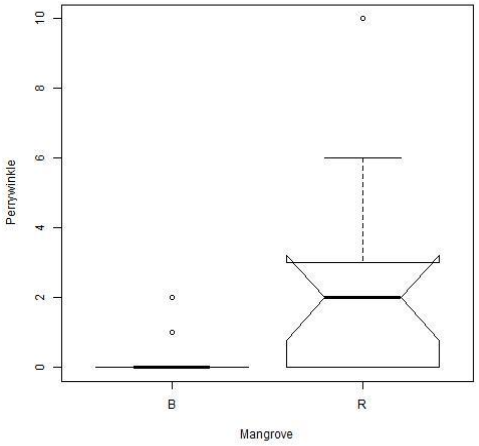

Figure 6. Boxplot of periwinkle

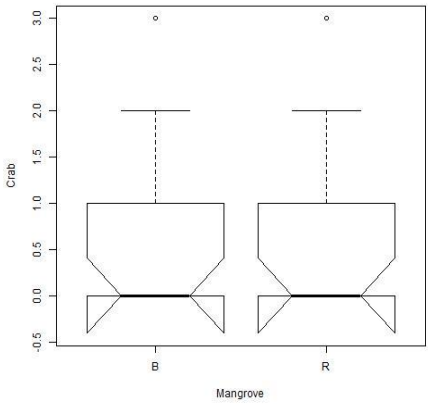

Figure 7. Boxplot of crab

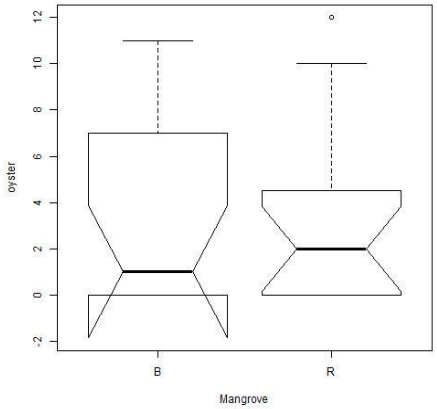

Figure 8. Boxplot of oyster

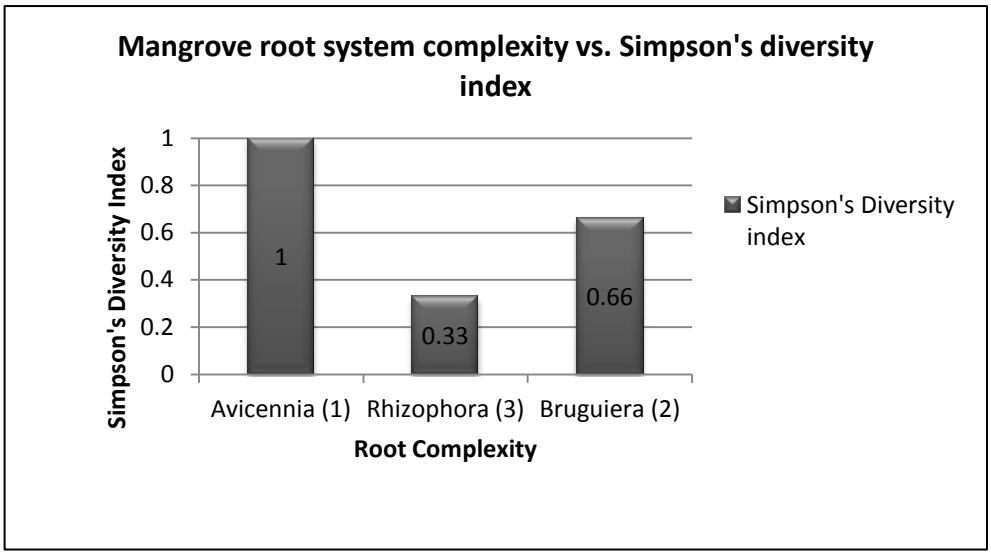

Figure 2. Mangrove root system complexity vs. Simpson's diversity index

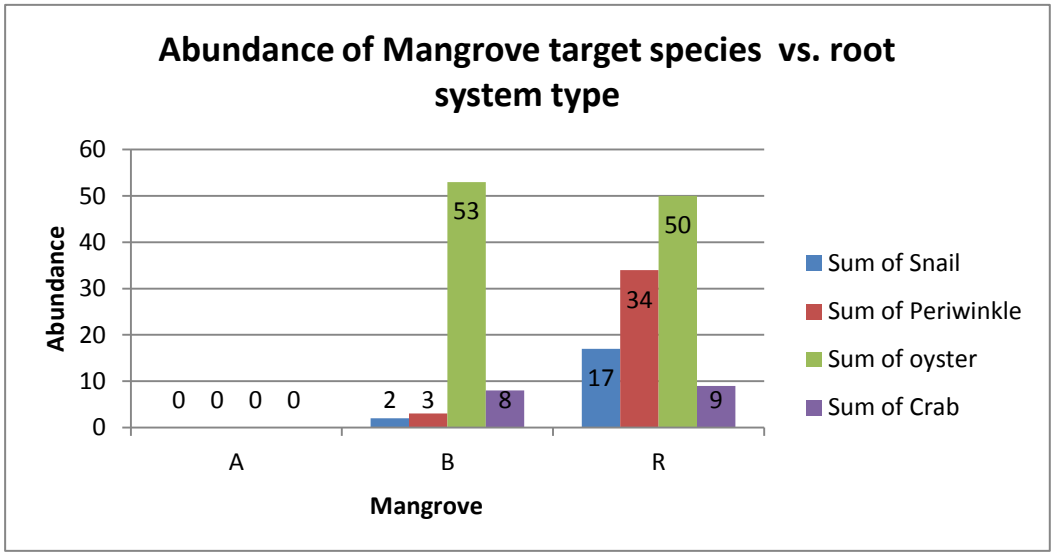

Figure 1. Abundance of mangrove target species vs. root system type

Table 1. Shapiro-Wilk test of normality

Crabs/mangrove	Oyster/mangrove	Periwinkle/mangrove	Snail/mangrove
p-value = 0.7529	p-value = 0.949	p-value = 0.005216	p-value = 0.004777
Non-significant	Non-significant	Significant	Significant

Declining Crab Fisheries in the South of India Cause Need for Closer Analysis of Berried Crab Fishery Catch

Cara Mayo and Corinne Dorais

ABSTRACT

Crab fisheries in South India are declining at a noticeable rate due to increased international demand for crab meat. A partnership with FERAL's ongoing fisheries research study created the perfect opportunity to analyze the berried crab catch on the South coast of India between surveys taken in 2008 and 2009. We examined the depth at which most crabs and berried crabs were caught and the nets used in the catch of crabs. Our results proved significant in both areas. A Kruskal-Wallis p-value of 0.0017 gave the most abundant berried crab catch at 8-12 meters of depth. Crab gillnets (locally called Nandu) caught significantly more crabs and berried crabs (Kruskal-Wallis p-values of less than 2.2e-16) than all other nets used by artisanal fishermen. These results are significant in the conservation of crab fisheries on the South coast of India. Further research in seasonality of berried crab catch is planned to further the research in this critical area of marine animal conservation.

INTRODUCTION

With the crab fisheries of South India declining at a noticeable rate for the past few decades, along with changes in species composition and seasonal availability (Lawrence, T., 2008), the artisanal fisherman of Tamil Nadu must ask themselves if their fishing methods will secure a livelihood for them years down the road, or if it will lead to the demise of their proud social class. The demand for live and whole cooked crabs has recently gained significant preference from the local and international markets around the globe (Varadharajan, D., 2009) (Rajamani, M., & Palanichamy, 2008) (Dumas, P., 2012). Along the coasts of India, crabs are ranked 3rd after shrimp and lobsters for their importance as an esteemed seafood delicacy (Rajamani, M., & Palanichamy, 2008).The increased demand for crabs has caused indiscriminate fishing activity and is leading to the overexploitation of crab fisheries (Rajamani, M., & Palanichamy, 2008) (Varadharajan, D., 2009) (Lawrence, T., 2008). Along with the demand for more crabs has also come a change of nets used by artisanal fisherman of coastal villages. While the hook and line method is still used among artisanal fishermen, there has been a strong shift towards ring seine operations and gillnets to increase the biomass of the catch (Lawrence, T., 2008). Crabs are not only declining in numbers because of an increase in demand, but also because they are a nuisance to fishermen's' nets. A caught, non-target, crab means one less hazard for his net while out at sea.

The declining crab fisheries noticed by locals is cause for concern, both on the part of the fishermen's livelihoods and ecological health. Conservation for crabs (notably the most commercially important fishery species including *P. pelagicus, S. serrata, P. sanguinolentus, C. lucifera and*

M. mercenaria) needs to be taken into consideration and monitored. Ensuring that berried crabs are able to reproduce is one important technique to conserve the declining crab populations (Rajamani, M., & Palanichamy, 2008) (Varadharajan, D., 2009). Berried females can sometimes make up a third of the total female catch (Rajamani, M., & Palanichamy, 2008).

Female crab eggs are bright orange when extruded and turn grey-black when ready to hatch. Each batch may contain over 2 million eggs and many crab species may spawn more than once per season. (Phelan, M., & Grubert, M., 2007) (Government of Western Australia, 2011) (Varadharajan, D., 2009*).* It may take a few weeks to a month for a female's eggs to be ready to hatch (Government of Western Australia, 2011). Spawning seasons are species specific as are the amount of times a crab will spawn per season *(*Varadharajan, D., 2009). *P. sanguinolentus*, for example, seems to have three distinct peaks of berried females during August, January, and March while *P. pelagicus* breeds continuously throughout the year (Varadharajan, D., 2009) (Government of Western Australia, 2011).

Many conservationists strongly encourage a carapace width limit on crab catches to ensure crab reproduction due to the fact that a crab's sexual maturity can be determined by its width (Varadharajan, D., 2009) (Rasheed, S., & Mustaquim, J. 2010). It must be underlined, however, the importance of assuring that the berried females are not overexploited when they are so close to giving the crab population yet another chance to rebound.

This study is part of a longer and ongoing project with FERAL which is collecting fishery data from the landings of Tamil Nadu and Pondicherry. This particular study aims to examine berried crab species from 17 different villages along the Southeast coast of Tamil Nadu to determine if there is a depth range at which most berried crabs are caught and which gear type results in the highest berried crab catch.

Ecological Importance

Crabs and crustaceans play a vital role in marine ecosystems. While crabs are important indicator species (McLaughlin, P., S. Ahyong & J.K. Lowry, 2002),one of their most important assets to the marine environment is their major role in energy transfer (Hill, Fowler & Van Den Avyle, 1989). At various stages in the development, a crab will perform consumer, predator and decomposer roles which indicate that they are tightly woven into the marine food web (Hill, Fowler & Van Den A vyle, 1989) ("Crustacea," 2012).

An important aspect of crab life history to keep in mind is that crabs are broad spawners. In other words, they lay millions of eggs at a time which supports populations of fish (Hill, Fowler & Van Den Avyle, 1989). Thus, a decline in berried crabs not only directly affects crab fishermen; it also indirectly affects the fishermen who are targeting fish that rely on crab eggs as a main source of food.

MATERIALS AND METHODS

The larger project

Field Surveys Funded by the FAO in 2008, six months of field data collection were completed and due to project closure, further data collection could not be pursued. An additional six months of field data collection was done later in 2009 funded by an internal effort of FERAL and this was then expanded to a larger area along the Coromandel coast which was funded by the Ruffords Small Grants Foundation for a year and a half (Sept 2010 - March 2012).

The project started with 17 villages spread across Cuddalore, Pondicherry and Villupuram. It was then expanded to 30 villages (10 from each district) on the Ruffords project. Collection of samples began in the second round of data collection which was funded by FERAL and later continued by the Ruffords.

Field data collection involves visits to each of the major landing centers in the respective districts and an assessment of types of craft and volume and frequency of landing. Particular note will be made of landing centers which cater to specific varieties and markets.

Fishlanding surveys Surveys in the selected villages will comprise of a short structured questionnaire recording all fishery related details i.e., gear and craft, manpower, effort etc. Photographic samples of the catch will be collected; collection of specimens will be done in select areas to verify the identification as well as for age determination studies. Quantification of the craft and gear (including net mesh size) and assessment of all being used and those not in use will be done to assess proportion of capacity utilization.

Data entry

Once collected, photos from each catch were scrutinized for crabs and identified on the species level. In excel spreadsheets each species has a column to identify the total number of individuals in the catch, whether or not any had orange or grey eggs, were non-gravid or had an unknown gravid status. Species were labeled as “unknown” if they could not be identified

Cycles 1, 2, 3, and 4 have been entered and processed with contributions from FERAL staff.

Data analysis

Results were analyzed using Rcmdr and Orange software. KMggPlots2 and Coin plugins were used in the analysis to produce boxplots, scatterplots, tests for normality and the Kruskal-Wallis test.

RESULTS

A regression tree analyzing the effect of depth on gravid crab catches revealed that crabs were most likely to be caught between a depth of 8 and 12 meters. Similar analysis of the effect of net type used demonstrated that nandu nets had the highest average crab catch of all nets in this study.

These initial findings were supported by boxplots which showed a significantly higher catch of all crabs (Figure 1) as well as only gravid crabs (Figure 2) between 8 and 12 meters with p-values of 0.0012 and 0.0017 respectively. Boxplots also showed a significant relationship between use of nandu nets and higher total crab catch (Figure 3) and total gravid crab catch (Figure 4) both with Kruskal-Wallis p-values of less than 2.2e-16.

A boxplot and Kruskal-Wallis test were also used to determine the impact of depth and net type as dependent factors (Figure 5.) It was found that more crabs are caught when using a nandu net and fishing in the 8-12 meter depth range than are caught when using a nandu net outside of that depth range or when fishing within the 8-12 meter band but using a different net type. This relationship was shown to be significant with a p-value of less than 2.2e-16. The same tests were run to compare total number of gravid crabs caught (Figure 6.) This

relationship was also found to be statistically significant with a p-value of less than 2.2e-16.

Effect plots of a generalized linear model were used to further demonstrate the significant relationships between total number of gravid crabs caught and depth of fishing, net used, and total number of crabs caught (Figure 7.)

Catch per unit effort tests such as crew vs. total gravid crab catch were also run; results were qualitatively the same as those listed above.

Discussion and Conclusion

Results are highly significant and point towards specific management practices. First, as the majority of crabs (both gravid and non-gravid) are caught between depths of 8 and 12 meters, restricting fishing activity in these areas would greatly decrease the number of crabs caught. Secondly, nandu nets (which appear to be used specifically to target crabs) catch far more crabs than other nets. Restricting their use, especially within the 8-12 meter depth range, in combination with nets of similar mesh size, would likely have a great impact on reducing gravid crab catch.

Further research will focus on seasonality of gravid crabs at the species level as well as fishing practices (such as equipment used, distance traveled, and crew size) that may have an impact on gravid crab catch.

Acknowledgements and Contributions

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Another warm acknowledgement to Dr. Neil Pelkey and Ravi Bhalla for mentoring and statistics advice and critique throughout this process.

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APPENDIX

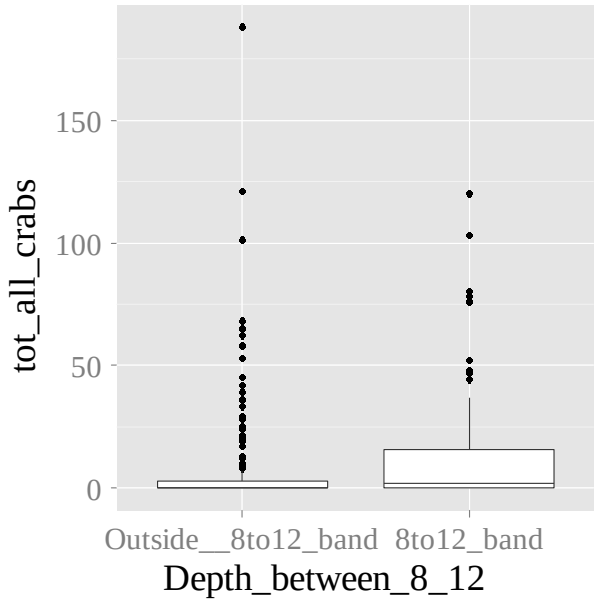

Figure 4. Boxplot showing relationship between total number of crabs caught between 8 and 12 meters of depth (right) and total number of crabs caught outside the 8-12 range. Analysis using Kruskal-Wallis provided a p-value of 0.001155.

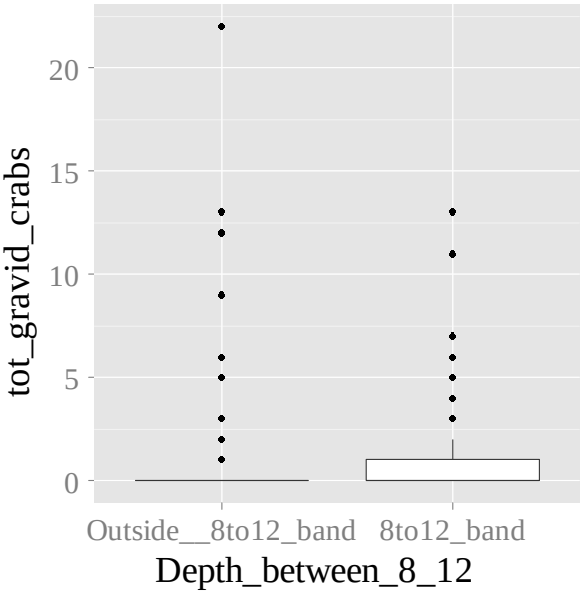

Figure 3. Boxplot showing relationship between total number of gravid crabs caught between 8-12 meters (right) and outside the 8-12 range (left.) Kruskall-Wallis p-value of 0.001743

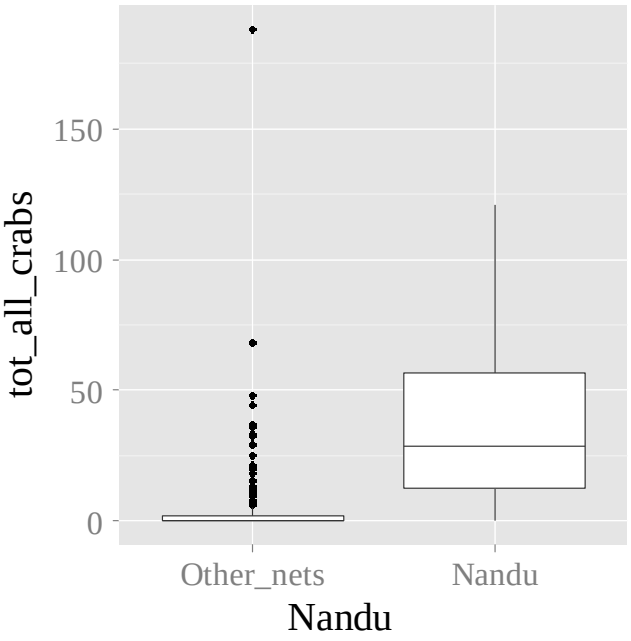

Figure 5. Boxplot demonstrating higher catch of all crabs when using nandu net over other net type (Kruskal-Wallis p-value of less than 2.2e-16.)

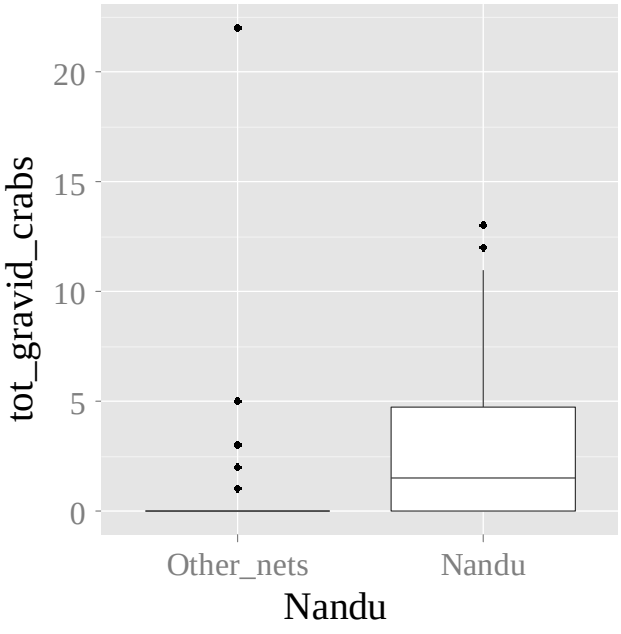

Figure 6. Boxplot showing relationship between higher total gravid crab catch when using nandu nets (Kruskal-Wallis p-value of less than 2.2e-16.)

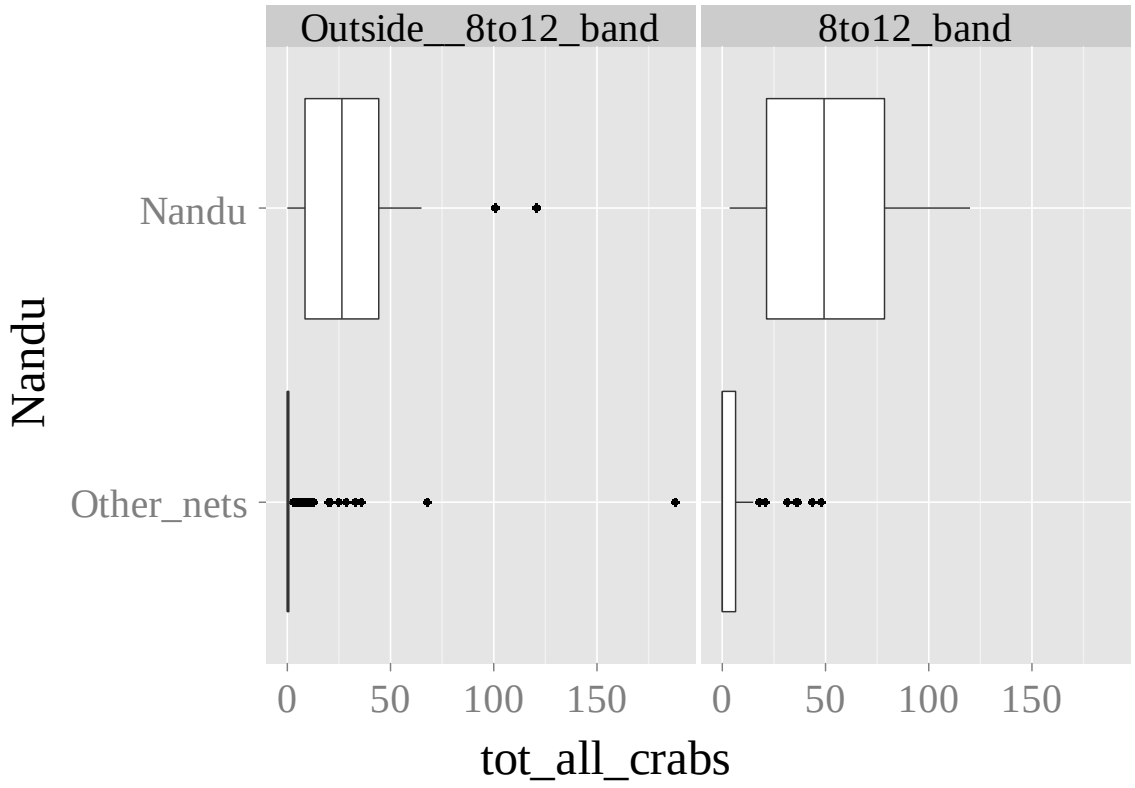

Figure 8. Boxplots showing a higher number of crabs are caught when fishing in the 8-12 meter depth band while using a nandu net than are caught otherwise. A Kruskal-Wallis test provided a p-value of less than 2.2e-16.

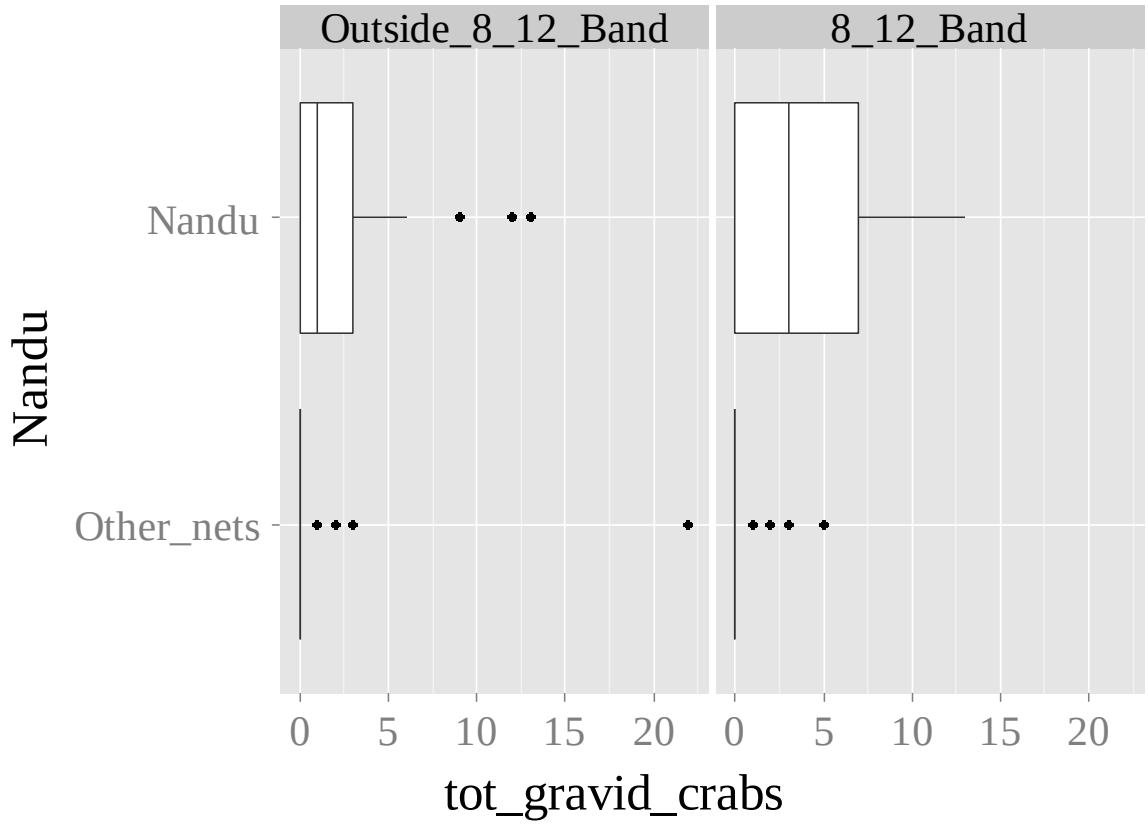

Figure 7. Boxplot demonstrating that more gravid crabs are caught in the 8-12 meter range when using a nandu net than are caught when fishing in the 8-12 band or using a nandu net alone (Kruskal-Wallis p-value of less than 2.2e-16.

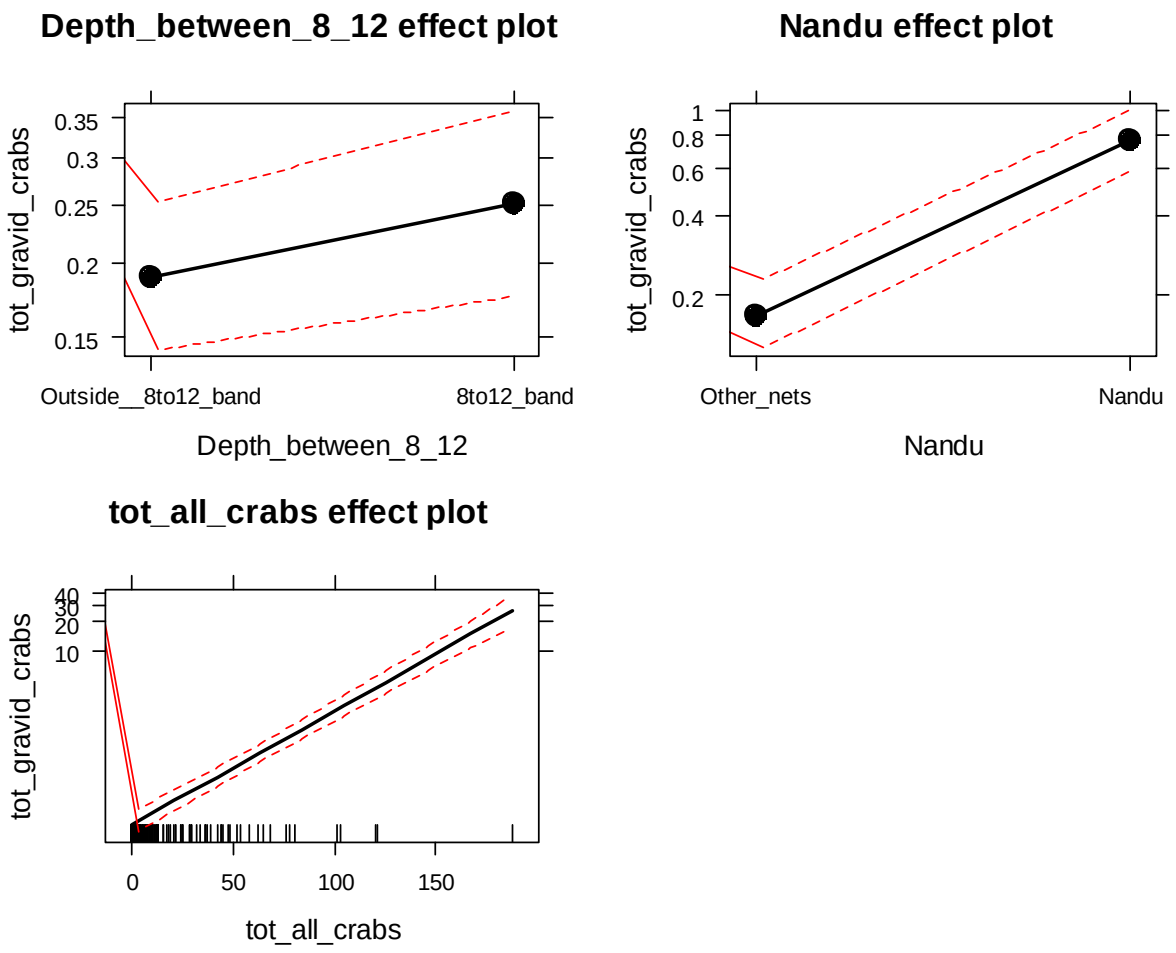

Figure 9. Effects plots of generalized linear models showing the significant relationships between total number of gravid crabs caught and fishing in the 8-12 meter range (upper left), fishing with a nandu net (upper right), and the total number of crabs caught (bottom left.)

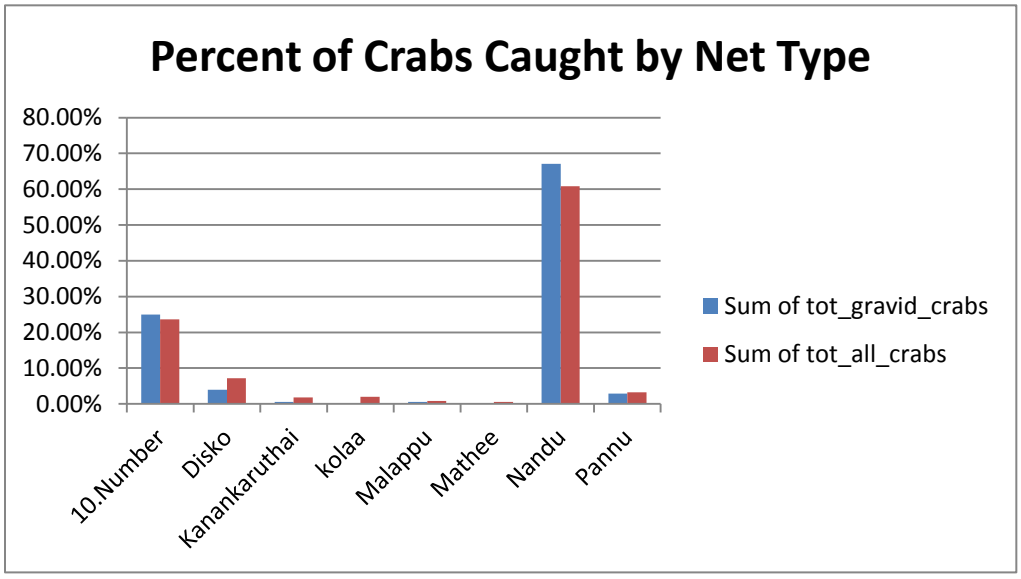

Figure 10. Graph showing percent of all crabs (red) and gravid crabs (blue) caught by net type.

THE EFFECTS OF GROYNES ON BEACH EROSION AT QUIET BEACH IN PONDICHERRY, TAMIL NADU, INDIA

Lauren Bauernschmidt, Lydia Bridi, Taylor Cox, Ashley Fersch, Kelsey Kohrs, Emily Layman, and Samantha Rock

January 2013

ABSTRACT

Coastal erosion is prevalent along the coast of Pondicherry. This study investigates one of the many causes of erosion along the Tami Nadu coastline, with particular interest in man-made structures including harbors, sea walls and groynes. The focus of this study is the effect of groynes on the coastline. Results did not show correlations between distance from the shoreline and grain size, distance from groyne and grain size or elevation and grain size. While these results did not prove to be significant, erosion along the coast is visually evident. Further research is required as results obtained were inconclusive, mostly due to a large margin of error.

INTRODUCTION

Erosion of beaches is a global problem that causes socioeconomic and environmental issues (Schiavina 2010). This problem is becoming more prevalent, specifically in India due to the construction of man-made structures that change the natural movement of sand through the process of long-shore drift. During the Southwest monsoon season about 0.5 to 1.0 million cubic meters of sand are pushed northwards by the waves, winds and littoral currents (Schiavina 2010). This same situation occurs again during the Northeast monsoon and the sand is then driven southwards.

In Pondicherry, along the Tamil Nadu coastline, a small commercial harbor was built in 1989 in order to gather revenue for the fishing industry (Schiavina 2010). Due to the construction of this harbor and a lack of a sand by-passing system, severe erosion has occurred over the past 24 years. The government has since been forced to construct sea walls and several groynes in order to protect the lives of those that live downwind of the harbor. Despite the construction of these structures, homes and livelihoods are still being destroyed because the high tide line continues to move farther and farther inland (Schiavina 2010).

Man-made structures have detrimental effects on the coast because they interfere with the movement of waves and subsequently with the deposition of sand, accelerating the erosion of the

beaches (Schiavina 2010). Shoreline change is not the only indicator of erosion however; sand grain size can also work as an indicator of beach erosion. The presence of certain grain sizes can operate as an indicator of the amount of stress placed on the environment. The presence of a higher percentage of larger grain sizes is an indicator that erosion is occurring because smaller grain sizes are swept away by the waves (Farahi and Mohammadi 2012). Steep inclines along the shore may also signify higher erosion rates because of the angle at which the waves crash into the shore.

The purpose of this study was to analyze the extent of the erosion in proximity to groyne structures along Quiet Beach in Pondicherry. This study was done by analyzing grain sizes, distances and elevation differences along the coast.

MATERIALS AND METHODS

Site Selection

In order to evaluate the impacts of the two groynes on Quiet Beach, the area was divided into three sections the beach south of the first groyne, the beach in between the two groynes, and the beach north of the second groyne.

Field Work

Transects were placed every 10 meters for the first section studies and 20 meters apart for the final two sections. Distances were measured with 30 or 50 meter tapes[3]. Transects were then broken up into three-meter segments moving from the coastline inland. These three-meter segments were established using a three-meter rope joining two stadia rods. At the vertex of each segment, height measurements were taken using the four or five meter stadia rods following the Emery method. The height difference is estimated using the horizon line as a level reference point. The Emery method established height by taking the height difference between the two stadia rods. This method was used for the entirety of the study.

A dumpy site level[4] was used as a benchmark reference to orient the heights of transects to the site level. At the beginning of each transect a compass and GPS[5] reading were taken in

[3] Freeman measuring tape
[4] Brand Lynx Lawrence & Mayo model number 13068
[5] Etrex and Garmin GPSmap 76

order to orient the transect to the dumpy sight level, another GPS reading was taken at the end of each transect.

Sand was collected every six meters for the first section i.e., the beach south of the first groyne. Collection consisted of placing approximately 0.5 kg of sand into a plastic zip lock bag, which was later sorted by size via four different sieves[6] of 5.0 mm, 1.75 mm, 1.0 mm, and 0.5 mm mesh sizes respectively.

Equipment Used

Beach Profiles:

-Stadia rods

-Compass

-Dumpy site level

-GPS

-Meter tape

Sand Processing:

-Plastic zip lock bags

-Scale

-Sieves 5.0 mm, 1.75 mm, 1.0 mm, and 0.5 mm mesh sizes

Analysis

All data was analyzed using R Studio and Microsoft Excel. ANOVA statistical tests were run on each of the different variables to determine variables significance, if determined significant the results were plotted in Microsoft Excel, following which the R^2 value was determined. GPS data points were downloaded into QGIS to geo-locate the data set onto satellite imagery using Googlemaps/earth package.

RESULTS

The data did not reveal anyconclusive patterns for the effects of elevation, distance from shoreline, or distance from groyne on grain size ratios.

Significant ($p<0.05$) F-statistics were found for:

1. 5.0mm and 1.0mm grain sizes for elevation data (Table 1a),
2. 5.0mm, 1.0mm, and 0.5mm grain sizes for distance from shoreline (Table 1b),

[6] Jayant Sieves

3. The 5.0mm grain sizes for distance from groyne (Table 1c).

Plotting the data revealed that mean ratios for each grain size category all had R^2 values of less than 0.5, with the exception of 0.5mm and <0.5mm grain sizes for elevation data. The latter had R^2 values of 0.95419 and 0.71707, respectively. Trend lines for these two grain sizes showed an inverse relationship between distance from shoreline and ratio for < 0.5mm grain size, and a direct relationship for 0.5mm grain size (Figure 1).

Table 1. F-statistics and p-values for five categories of grain size in relation to elevation, distance from shoreline, and distance from groyne. Values were calculated using an ANOVA test run on RStudio. Table a shows results from elevation vs. each grain size category, b shows results from distance from shoreline, and c shows results from distance from groyne.

a)

Grain Size	F statistic	p-value
5.0mm	10.190	0.00209
1.7mm	1.538	0.21899
1.0mm	9.149	0.00345
0.5mm	1.596	0.21054
<0.5mm	.031	0.86008

b)

Grain Size	F statistic	p-value
5.0mm	10.719	0.00163
1.7mm	3.696	0.05851
1.0mm	6.285	0.01444
0.5mm	10.757	0.00160
<0.5mm	0.122	0.72791

c)

Grain Size	F statistic	p-value
5.0mm	5.995	0.0168
1.7mm	0.745	0.3908
1.0mm	1.209	0.2752
0.5mm	1.129	0.2915
<0.5mm	0.008	0.9269

An ANOVA was completed on the sand grain sizes versus the distance from groyne at each section of the beach analysis. There was not significant correlation between grain size and

the distance from each groyne. The 5.0mm grain size showed significance compared to the distance from the groyne, but no trend was seen (Table 1c). An ANOVA was completed on the sand grain size versus the distance to the shoreline. There was a lack of significance for this data as well (Table 1b). The ratio of 0.5mm sand increases as the distance from shoreline increases and vice versa for the ratio <0.5mm sand (Figure 1), although the high variance in the data indicates that this relationship might not be accurate. An ANOVA was also completed on the sand grain sizes versus the elevation of the beach as it moved in from the shoreline. Elevation compared to grain size was significant for the 5.0mm grain size and the 1.0mm grain size (Table 1a). The 5.0mm significance was omitted due to errors in sand collection.

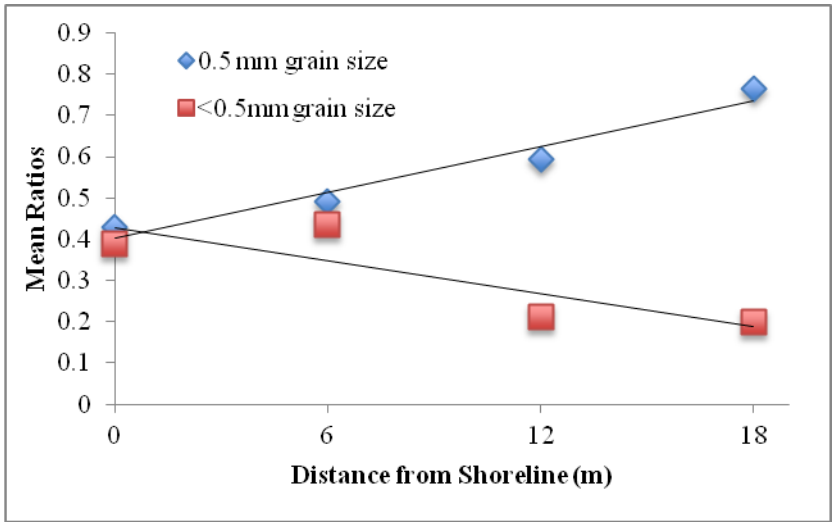

Figure. 1. Mean ratios of grain sizes 0.5mm and <0.5mm in relation to distance from the shoreline on Quiet Beach in Pondicherry. R^2 values are 0.95419 for the 0.5mm grain size and 0.71707 for the <0.5mm grain size.

DISCUSSION

A greater amount of smaller grain sizes was expected in the middle of the two groynes. The two groynes were thought to protect against erosion. It was also expected that there would be a decrease in smaller grain sizes on the outer edges of the groynes due to erosion (Mohanty et al. 2012). The data did not prove any of these expectations. The data did reveal that grain size changed solely due to the distance from the shoreline (Hall et al. 1991).

Groynes cause a rise in elevation of adjacent beaches (Bull et al. 1998). As accepted by scientific literature, all coastlines follow the trend where sediment grain-size increases as elevation of the beach increases (Shih and Komar 1994). This was the expected relationship between grain size and elevation. The 1.0 mm significance determined, however, did not follow

this trend after further analysis. Overall, the elevation versus grain size data did not yield significant results. Further research could explore whether the presence of groynes magnifies the grain size gradient in relation to elevation.

The analysis could be skewed by multiple errors in data collection which was further compounded by the physical characteristics of the beach. Some of the sand collection sites were located on berms of the high and low tides, which could explain the significance between the distance from the groyne and the largest grain size. The 5.0mm category consisted of shells, sticks, rocks, etc, but appeared to lack sand grains larger than 5.0mm. The larger materials, such as shells and rocks, were sometimes removed from the sample during sand collection, which may have affected the analysis. During the sieving process, the 0.5mm sieve and <0.5mm sieve were switched out half way through data processing. Further research examining the impacts of groynes on beach erosion is required to achieve accurate and conclusive results.

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Our group after data collection.

Our group during data collection.

INVERTEBRATE DIVERSITY AND HABITAT PREFERENCE FOR THREE SPECIES OF MANGROVE TREES IN NORTH WANDOOR, ANDAMAN ISLANDS

Ashley Fersch

February 2013

ABSTRACT

Invertebrate populations occupy many essential niches in mangrove ecosystems (Balasubramanian et al. 2005). Evaluation of their habitat preference and diversity enables an understanding of how prevalent they are in the ecosystem as well as what each individual's essential role may be. The diversity of invertebrate species in the canopies of nine mangrove trees, three each of *Rhizophora*, *Avicennia*, and *Lumnitzera*, was assessed. One 20-minute observation and one tree shake were completed for each tree. A Rényi biodiversity profile was plotted along with a species accumulation curve. One-way ANOVAs were run to assess the preference of certain orders and a few dominant invertebrate species to a particular tree genus or to certain tree traits. *Avicennia* trees were found to have to most invertebrate diversity, followed by *Lumnitzera* and *Rhizophora.* A significant relationship was found between presence of Hemiptera and *Littorina scabra* individuals and type of tree. No conclusive results were obtained with reference to the preferences of other invertebrate species or groups to tree type or tree traits. The species accumulation curve shows that only a small portion of the total arachnid, insect, and mollusk species were observed during the 18 completed trials, and more data collection is necessary to draw any definite conclusions.

INTRODUCTION

Invertebrates in the mangrove ecosystem cover an extensive number of niches. Some can be herbaceous, feeding on the leaves, stems, and roots of the mangrove, while others use the trees as a place to stalk or trap their prey. Some take shelter in the canopy or under the tall above-ground roots of the trees. Pollinators use nectar and pollen from their bright inflorescences as a food source. In the case of the Andaman Islands, invertebrate species almost certainly provide sustenance to the many rare and endemic birds that inhabit the mangroves. Many invertebrates function as detritivores, recycling the leaf litter from the trees, acting as the mangroves' waste disposal (Balasubramanian et al. 2005).

With all of these associations and roles within the mangrove ecosystem, it is important to understand each invertebrate's function within the ecosystem and as well as gauge the diversity of this group of animals (Balasubramanian et al. 2005). In biology, diversity is used to describe the variation within a particular group. Usually this term takes into account the number, variety, and variability of the individuals being described (Balasubramanian et al. 2005; Ramakrishna et al. 2010). Diverse regions are often those that are the most necessary to conserve, as their high concentration of species can provide economic, social, scientific, ecological, and recreational services (Balasubramanian et al. 2005). One aspect of diversity, endemism, takes the importance of conservation one step further by recognizing the number of species that are found only in a certain region (Ramakrishna et al. 2010). The Andaman and Nicobar Islands in particular are home to a large number of endemic arachnids, insects, and mollusks. Ramakrishna et al. reported 28 species of scorpions and spiders, 485 species of insects, and 75 species of land mollusks to be endemic to the Andaman and Nicobar Islands (2010). Figures from Rao et al. are less conservative, estimating 604 endemic insects and 100 endemic land and freshwater mollusks (2009).

Despite the numerous functional roles and high levels of endemism of invertebrates, invertebrate diversity in the mangrove systems of the Andaman Islands seems to be a bit overlooked. In one recent study of the Andaman and Nicobar Islands, the number of recorded species of ants on the islands doubled. Researchers acknowledged that methodology was not thorough and even more species may remain to be discovered (Mohanraj et al. 2010). Those studies that have focused on insect and arachnid life in the mangroves have reported that many of the species are found to inhabit only one type of vegetation (Veenakumari and Prashanth 2009). Often times though, associations are not even a part of the study since researchers are still getting a handle on the sheer number of insects they encounter (Bandyopadhyay 1997; Mohanraj et al. 2010).

The aim of this study is to assess the diversity and habitat preference of insect, arachnid, and mollusk populations in three genii of mangrove trees, *Rhizophora*, *Lumnitzera*, and *Avicennia* in North Wandoor, South Andaman Island. While a very wide range of invertebrates are present in the canopies of the mangroves, Das and Dev Roy (1989) mention a few commonly encountered insect and mollusk species. Of the few snail species that are found in mangrove trees, only *Littorina scabra,* common name the mangrove periwinkle, is found above 1.5 m. in

the canopy of the trees. Weaver ants (*Oecophylla smaragdina*) are expected to be found on mangrove trees with large leaves that can be used to build their nests, such as the *Rhizophora* tree. Coccids (*Cataenococcus* sps.) are also commonly found feeding on mangrove leaves, accompanied by certain ant species that 'tend' to these scale insects.

High rates of diversity are expected for all mangrove trees. It is also expected that each mangrove tree genus will have a distinct set of invertebrates associated with it, due to the high rate of specialization within the ecosystem. Some more mobile invertebrates should be found across all genii. The study is intended as a preliminary study and data is exploratory in nature.

MATERIALS AND METHODS

Location

All studies were completed in the mangrove forests directly outside of the A.N.E.T. (Andaman and Nicobar Environmental Team) property in North Wandoor, South Andaman Island.

Tree Selection

Three trees from each of three genii of mangrove tree, *Rhizophora*, *Lumnitzera*, and *Avicennia*, were selected for the study, based mostly on ease of data collection. Although *Bruguiera* trees were present in the area, this genus was omitted because canopies were impossible to reach using the equipment available. For each of the nine total trees that were selected, approximate height, girth, and percent cover were recorded. Height was calculated by taking photographs of each tree with a scale reference, in this case a 1.52m tall person, and using ImageJ to estimate the height of the tree. Girth was measured using a five-meter measuring tape to find the circumference of the tree at breast height, approximately four meters from the ground. Percent cover was calculated using a five-point scale, one corresponding to very sparse and five corresponding to very dense. Each tree was rated based off of a visual scan of the canopy.

Observation

Observations occurred at each tree for 20 minutes. For each insect that was observed, time of observation, a pseudo-identification, and number of individuals observed were recorded. Photographs were taken whenever possible to help with identification. Most observations were made on lower branches that could be seen either from the ground or by climbing. Binoculars

were used for at least three minutes at each location, although no invertebrates were observed using this method.

Tree Shakes

A 1.1 x 4.3 m net with 2mm mesh size was set up underneath each tree approximately 0.5m from the ground. Upper and lower branches were then shaken one time through. All four layers of the net were then thoroughly searched for any invertebrates that had fallen from the canopy. Time of the tree shake, pseudo-identification, number of individuals, and notes regarding the individual were recorded. Individuals were also collected and photographed to assist with identification. This process took about 40-50 minutes for each tree.

Identification

Insect and spider species were identified using *Spiders of India* (Sebastian and Peter 2009), *An Introduction to the Study of Insects* (Borror et al. 1989), *A General Account of the Mangrove Fauna of Andaman and Nicobar Islands* (Das and Dey Roy 1989) as well at fact sheets from the Zoological Survey of India. A hand-held microscope (power 60-100X) was used to examine specimens that were collected during the tree shakes. Identification was carried to the most specific level of classification possible. Those specimens that could not be classified to a species level were given pseudo-identification for analysis.

Analysis

A Rényi Diversity profile was plotted using BiodiversityR for the three mangrove genii (Kindt and Coe 2005). Observation and tree shake data were combined for analysis, giving a total of six trials for each tree type. A regression analysis was completed to determine if canopy cover, time of day, height of tree, or girth of tree had any effect on the total number of invertebrates observed. One-way ANOVAs were run on the number of individuals observed in each order as well as for a few dominant species for the three tree types. A species accumulation curve for 18 sites was calculated using BiodiversityR to assess the scope of potential future studies.

RESULTS

Of the three mangrove tree genii, *Avicennia* exhibited the highest level of invertebrate diversity, followed by *Lumnitzera* then *Rhizophora* (Figure1). The Rényi diversity profile also showed that species evenness was the same for all three mangrove genii. Overall, more

individuals were observed per trial on *Avicennia* trees. Number of individuals observed per trial was approximately the same for *Lumnitzera* and *Rhizophora*, *Lumnitzera* having a wider range in the data (Figure 2). The steep slope of the species accumulation curve indicates that invertebrate species richness in the mangrove canopy is very high in the North Wandoor mangrove forest (Figure 3).

Few of the groups of invertebrates showed a relationship between the tree type and number of individuals. Of all of the orders that were observed during the trials, only two, the true bugs (Hemiptera) and sea snails (Neotaenioglossa) had any significant difference ($p<0.05$) in means (Figure 4). Although clear patterns arose in the field as to the number of *Oecophylla smaragdina*, *Cataenoccus* sps, and *Crematogaster* sps. (Valentine Ant) individuals on each type of tree, the effect of tree genus on number of individuals was only found to be significant for *Cataenoccus* sps. ($F=5.0$, $p=0.02$).

No relationship was found between the traits of individual trees (Table 1) and the number of insects, arachnids, or mollusks. Regression analyses for all of these relationships produced R^2 values of less than 0.50, except for the relationship between canopy cover and number of individuals. Further analysis using an ANOVA showed that there was no difference in number of individuals for the levels of canopy cover ($F=0.57$, $p=0.58$).

Of the 423 individuals observed during the study, 35 percent were identified to the species level, 13 percent to genus, 28 percent to family, and 24 percent to order. One individual could only be identified to class.

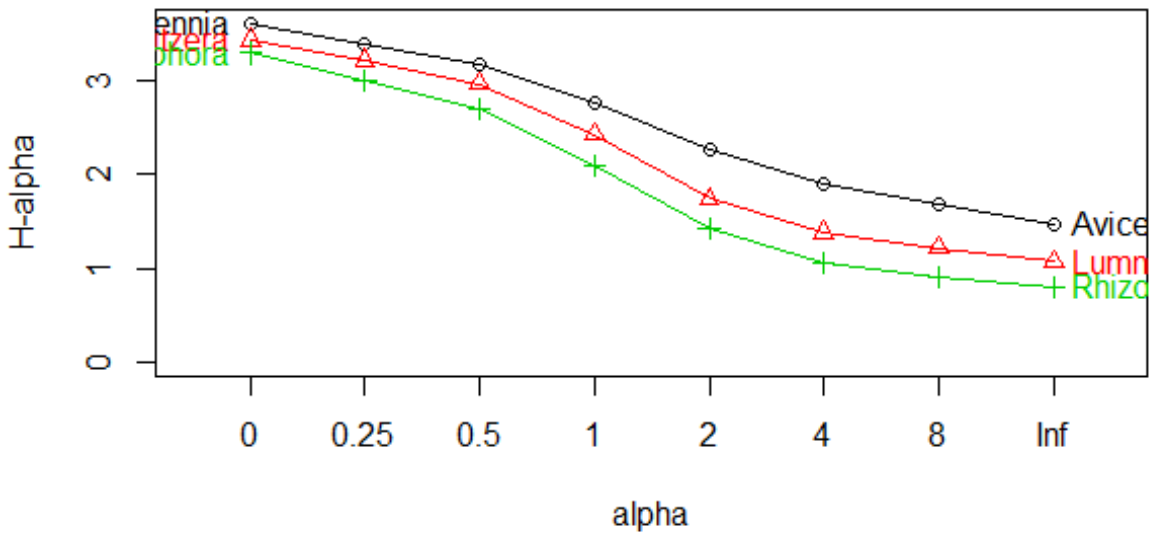

Figure. 1. Renyi diversity profile for three genii of mangrove tree in North Wandoor, South Andaman Island. Invertebrate diversity in terms of tree type from greatest to least diverse is Avicennia, Lumnitzera, *then*Rhizophora. *Data was plotted using BiodiversityR.*

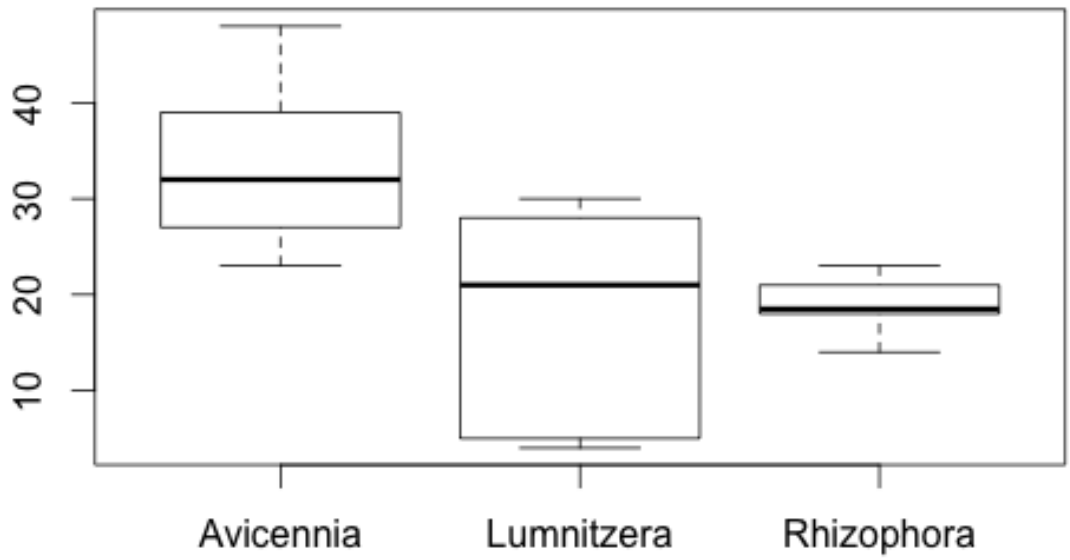

Figure. 2. Boxplot of number of individuals per trial for three mangrove genii. The most individuals were observed per trial for Avicennia *trees.* Lumnitzera and Rhizophora *trees both showed similar number of individuals per tree, with* Lumnitzera *trees having a wider range in the data. Data was plotted using R.*

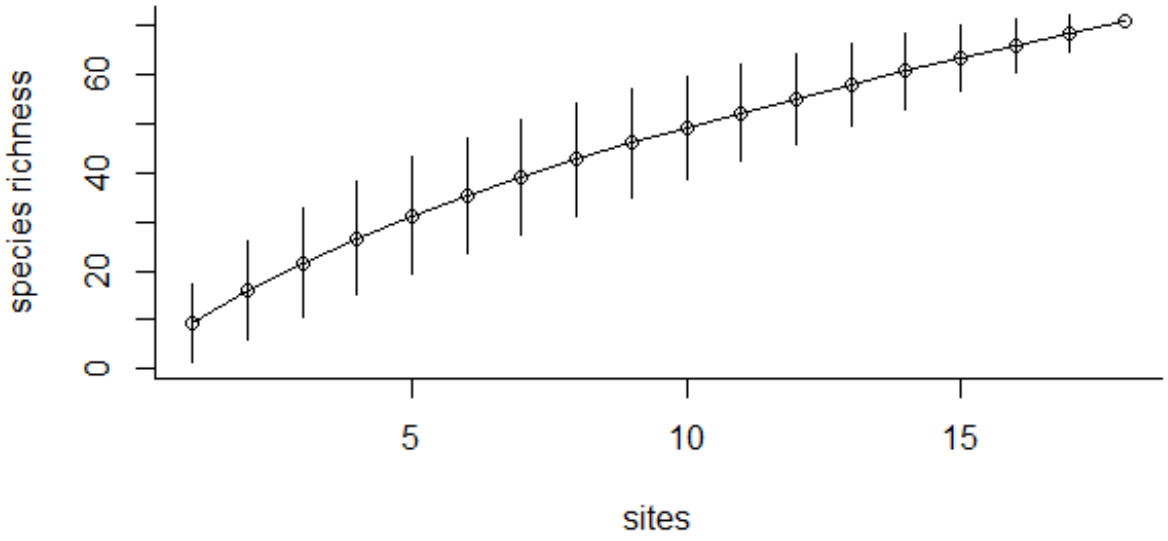

Figure. 3. Species accumulation curve for invertebrate species in mangrove canopies in North Wandoor, South Andaman Island. 18 sites were surveyed. Data was plotted using BiodiversityR.

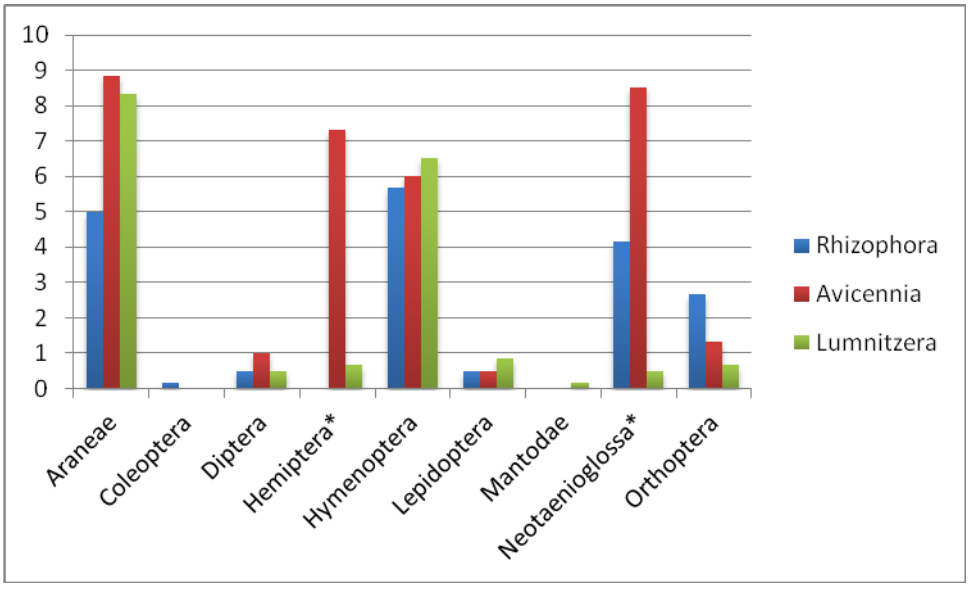

Figure. 4. Number of individuals of each order per tree per trial observed on three genii of mangrove tree.Six total trials where completed, including observations and tree shakes, for each category of tree.'' indicates those orders with a significant difference in the values.*

Table 1. Traits of mangrove trees selected for study. Girth, height, and canopy cover were calculated for each tree. Canopy cover is rated on a scale ranging from one to five.

Species	Number	Girth (cm)	Height (m)	Canopy Cover
Avicennia	A1	45	7.6	3
Avicennia	A2	31.5	7.8	3
Avicennia	A	28.8	4.9	2
Lumnitzera	L1	25.2	3.5	2
Lumnitzera	L2	18.6	4.6	4
Lumnitzera	L3	25	4.8	2
Rhizophora	R1	47	6.9	4
Rhizophora	R2	28.8	5.6	4
Rhizophora	R3	33.2	6.5	4

DISCUSSION

Invertebrate diversity for the three mangrove tree genii was greatest for *Avicennia*, then *Lumnitzera* and *Rhizophora*. There is no clear answer as to why this division occurs. Factors such as leaf composition, canopy cover, tree structure, tide levels, physiology, etc. should all be considered. It is likely that one factor is not responsible for the varying levels of invertebrate diversity, but rather multiple environmental and ecological factors all contribute. In addition, the species accumulation curve for the data indicates that many more trials are necessary to have a complete picture of the species richness in the North Wandoor mangrove forests. Until more trials are completed, an accurate depiction of diversity across mangrove tree types is not possible.

Although a lack of significance in the data suggests that there is no difference in invertebrate species that inhabit the canopies of mangrove trees, clear patterns were observed while in the field, implying insufficient data. Patterns were statistically supported for the presence of *Littorina scabra* the only species observed in the Neotaenioglossa order. Clear preference was given to the *Avicennia* tree, followed by *Rhizophora* with hardly any individuals recorded on the *Lumnitzera* trees. *Littorina scabra*are are generalist herbivores so tree preference may be due to environmental factors rather than the chemical structure of the mangrove tissue (Alfaro 2008).

Like *L. scabra*, members of the order Hemiptera also showed a strong preference for *Avicennia* trees. Members of this order were primarily coccids from the *Cataenoccus* genus and leaf hoppers from the Cicadellidae family. These species are herbaceous, so leaf composition may influence these species' preference (Varsheney et al.). Although it was not found to be significant, species of ant from the genus *Crematogaster* sps were also observed to be present only on *Avicennia*. During observation, these individuals were seen tending to coccids on the underside of a leaf. This behavior is typical of the genus and suggests that their presence on *Avicennia* trees is related to the tree preference of coccids. Presence of *Crematogaster* sps helps keep the population of scale insects at a suitable level which reduces damage to the trees (Ozaki et al. 2000).

Weaver ants, *O. smaragdina*, also showed a clear preference in the field, despite converse results. During the trials, weaver ants were never observed on the leaves of *Avicennia*, while individuals were noted all over *Rhizophora* and *Lumnitzera* trees. Experimental error may have resulted in this lack of a clear pattern with *O. smaragdina*as well as *Crematogaster* sps. Although many individuals were present in the canopy during tree shakes, ants appeared to be more skilled than other insect species at staying on the branches. As a result, hardly any were collected during the tree shake trials, while many were counted during the observational portion of the experiment. Similarly, those insects capable of flying were poorly represented in tree shake trials. Those few that were caught were mostly juveniles or nymphs who lacked wings.

While some orders may not have shown much difference in the number of individuals per tree, other patterns may emerge with further analysis from a more specific taxonomic level. For example, while the numbers of ants observed during each trial was relatively even, each tree seemed to have only a few types of ants that inhabited the respective tree genus. Better collection techniques, access to literature on identification, and more experience with the process of identification would allow for a better understanding of invertebrates' relationships with mangrove trees. While some may be generalists, due to the increased pressures on mangrove ecosystems, specialization in the invertebrate community is expected.

For future studies, a larger sample size would be required to ensure that all types of invertebrates are represented. Better sampling techniques need to be employed to increase the success of collection and to ensure accurate identification. A combination of several collection techniques should be used so that all types of invertebrates are captured. These techniques can

include controlled fogging, collection using aluminum or cloth funnels, (Blanton 1989; Erwin 1989), light traps (Thomas 1996), and Malaise traps (Faulds 1995). Rope and pulley systems can also be used so that tall trees, including the *Bruguiera* genus, can be included in the study (Erwin 1989).

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Stanley looking for insects, spiders, and snails in the nets under a Rhizophora *tree*

Juvenile Tenodera superstitiosa on collection net

FAUNA DIVERSITY ACROSS ROCK AND WOOD SUBSTRATES, SOUTH ANDAMAN ISLAND, INDIA

Samantha Rock

February 2013

ABSTRACT

This study looked at fauna diversity across wood and rock substrates with respect to distance from the shoreline along the north east coast of the South Andaman Island, a Union Territory of India. Organisms encountered on the substrates were identified up to common groups. If colonial organisms were encountered a 10 cm square was used take the average number of animals in an area. This was done by counting the number of organisms and then multiplying that number by the number of 10 cm squares could fit in the occupied region.Wood substrates were found to have a higher diversity than rock, and a linear relationship with respect to diversity and distance from the shoreline was also found. The slope of this relationship is -0.435, and is due to colonization properties of organisms on both substrates. T-tests showed that there is significance with a variance between T-critical and T-stat of 0.02 and a P-value of 0.048 when diversity was compared between the two substrates with respect to the distance from the shoreline.

INTRODUCTION

Rocky intertidal substrates are usually characterized by species that have adaptations that allow them to remain attached to their substrate, such as suckers, vacuums, and ability to bore into rock. Woody intertidal substrates are usually characterized by species that can burrow, attach themselves, or be small enough to hide in crevasses in the wood as it splinters due to weathering. There is also a pattern of higher diversity in intertidal regions where there is more shelter for organisms and more forgiving terrain such as mudflats which also experiences the greatest diversity (ADFG. 2013). Wood also provides organic material that can be digested, and a more secure hiding place from terrestrial predation (ADFG. 2013). However it is important to mention that intertidal zones are affected by many factors and a few relate to wind, tidal fluctuations, terrestrial predation and aquatic predation. These factors make the region a hard

place to live in and from a scientific perspective an interesting and complex system to study (Scrosati R. A. 2010).

The study was performed in the Andaman Islands. This chain of islands is located in the Bay of Bengal west and south of Burma and is a Union Territory of India. The islands geology consists of sedimentary rocks (Pal 2003). The islands are part of a series of submarine mountains that eventually surpassed sea level by the rising of ridges caused by tectonic movement, which forced them to the surface (Pal 2003). The sites used were located along the north east corner of the South Andaman Island. They are located in the tropics and home to many reefs, jungles, and people. Due to its location it is a great nursing ground for many marine organisms such as sea turtles, tropical fish, and octopi.

MATERIALS AND METHODS

Data collection

Data was collected over a three day period along the northeast corner of the South Andaman Island, spanning from the North Wandoor beach to Kanai dera (Figure 1). The beach was observed at low tide around noon every day. Each site was divided into three even sections and observed only once. An observation time of 10 minutes was used to count organisms observed on each section. Colonial organisms such as barnacles, limpets, and snails were counted using a 10 cm by 10 cm quadrat. The conditions at each site were noted, ie whether the site was submerged at low tide or exposed. All sites were perpendicular to the coastline. The height and length of each substrate was also measured and all substrates were around 15 meters in length. Measurements were taken using a FREEMANS 30m fiberglass measuring tape.

Sites

Five wood sites and five rock sites were chosen based on the following criteria:

1.The site had to be perpendicular to the shoreline to provide a look at different littoral conditions along the substrate.

2. At some point the site had to be partially submerged.

3. The sites needed to consist of either wood or rock.

Figure 1. Is the stretch of beach used for this study. This is a Google satellite image of north Wandoor on South Andaman Island,11° 36 -34" N and 92° 30.00" W.

Analysis

Diversity was measured using the Shannon-Wiener Diversity Index, Microsoft Excel and RStudio were used to organize data, create graphs, and T-tests. Google maps provided an image of the study sites.

RESULTS

Clear patterns can be seen between colonization behaviors in relation to substrate. The T-test shows that the data is significant indicating that there is more diversity with wood substrates than with rock substrates (Table 1, Figure 4). There also is a clear pattern of colonization in respect to shore line, showing more diversity when substrates are closer to the water than to the shore (Figure 3). Figure 2 demonstrates the preferences of groups to certain substrates. Figure 5 is a species accumulation curve demonstrating that this study has observed most of the diversity for the sites combined.

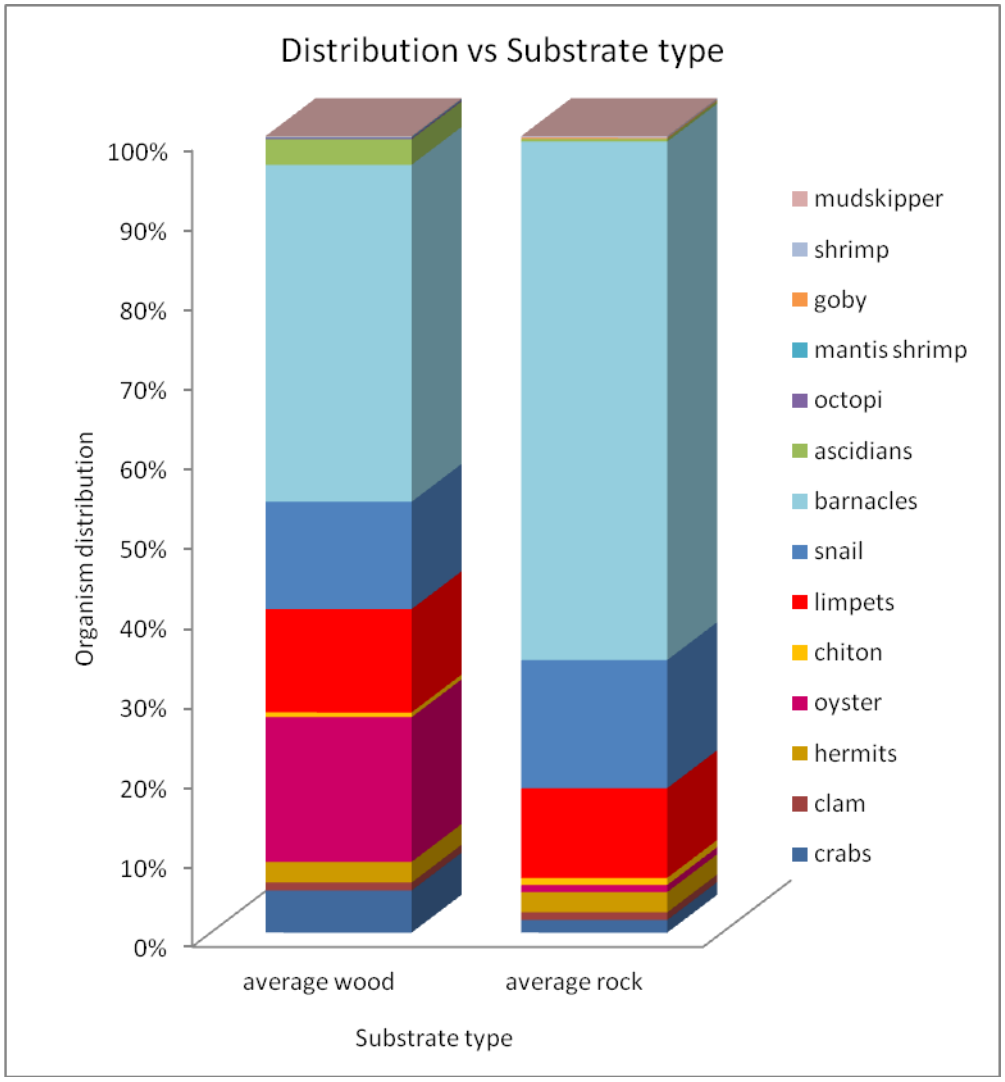

Figure 2. Is a graphical depiction of the organism distributions on wood and rock substrates. The graph shows organism preferences for specific substrates, such as ascidians and oysters are found more commonly on wood substrates where there is a higher percentage of barnacles.

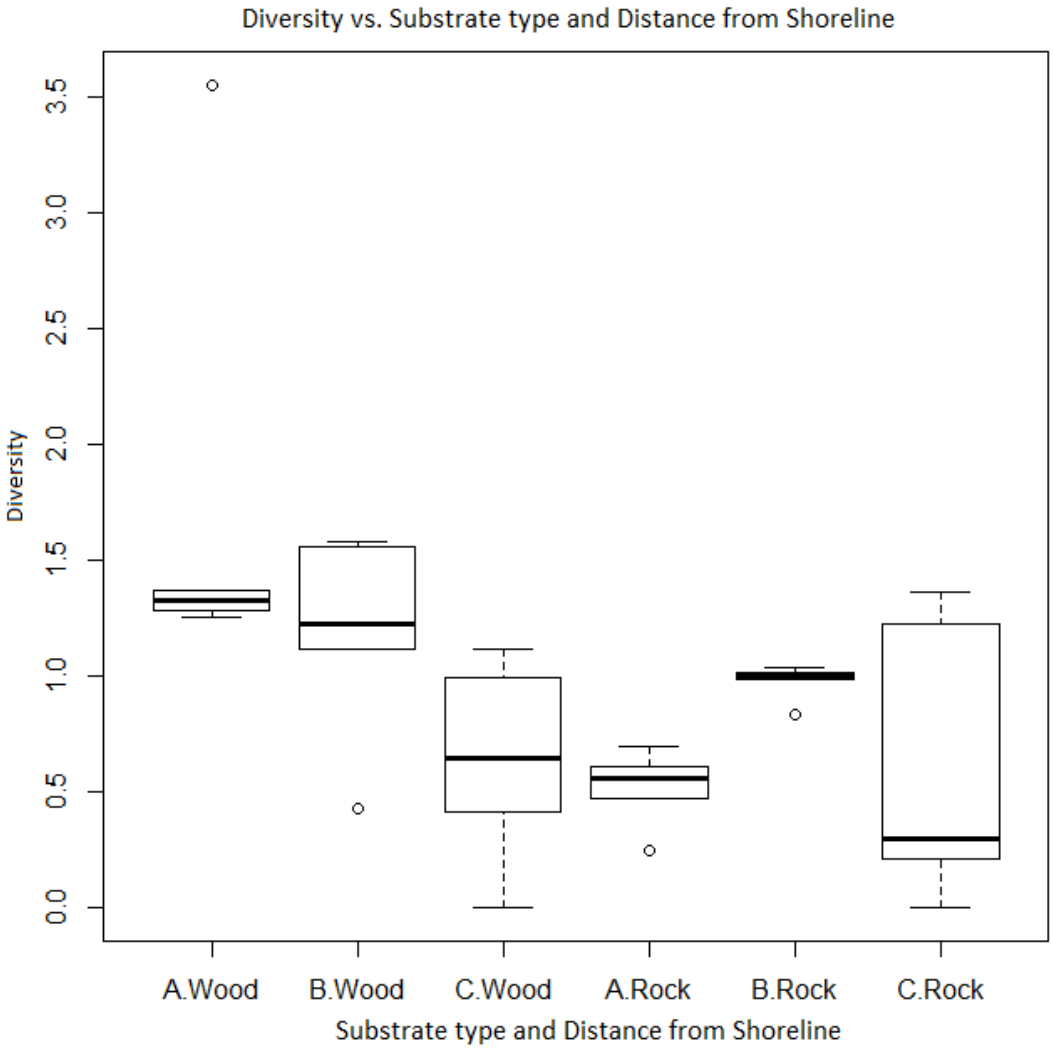

Figure 3. Is a box and whisker depiction of the relationships between diversity to shoreline and substrate material. The diversities from the 5 different sites (5 wood, 5 rock) were used to create this graph. Site A were closest to the water and site C were furthest inland. Diversities were calculated with the Shannon-Wiener Diversity Index. Rock substrates appear to have a consistent diversity where as wood appears to have a decreasing diversity as sample sites move further inland.

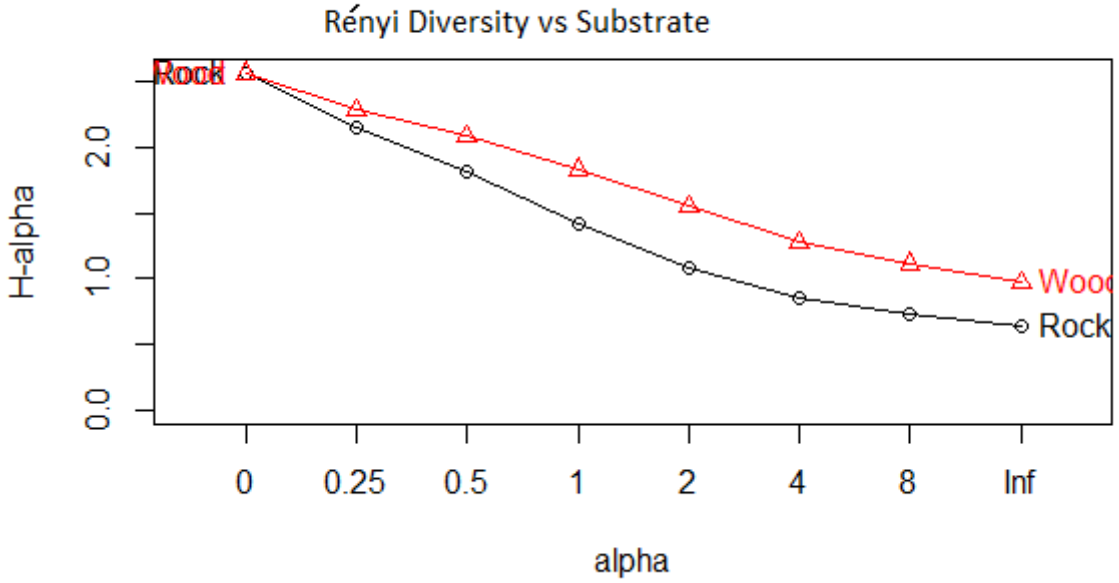

Figure 4. Is a Rényi diversity profile comparing rock and wood substrates. The graph shows clearly, wood substrates have a higher diversity than rock substrates.

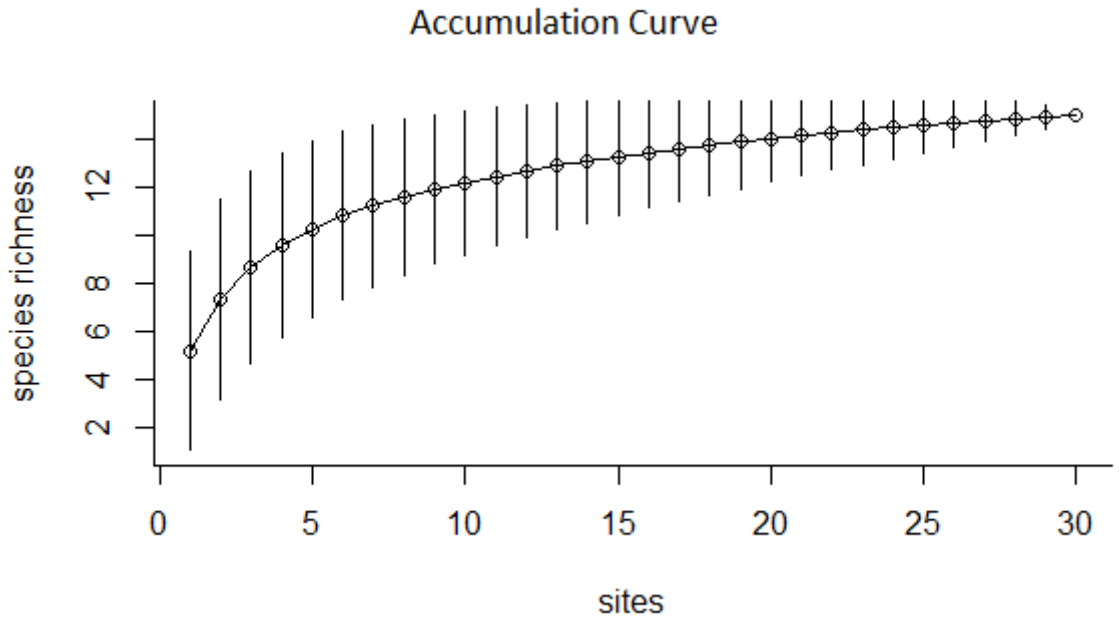

Figure 5. Is a species accumulation curve demonstrating the preferable sample size for collecting data. The vertical lines are standard deviation lines and demonstrate the pattern that, with more samples there are less errors that can skew data sets.

Table 1. Is a table of the T-tests run looking at the comparison of diversity with respect to distance from shoreline and substrate type. The test indicated that the null hypothesis is false and that the results seen are not due to random chance.

t Stat	2.379461002
P(T<=t) one-tail	0.024460431
t Critical one-tail	1.894578604
P(T<=t) two-tail	0.048920862
t Critical two-tail	2.364624251

DISCUSSION

There are distinctive patterns seen between diversity and distance from shoreline as well as substrate preferences. The T-test gave a T-critical for a Two-tailed T-test of 2.365 and the T-stat for the data stat comparing diversity to distance from the shoreline and different substrates is 2.379, proving the data is statistically important (Table 1). This finding is not surprising as wood provides a more forgiving substrate and is therefore more suitable for many organisms (ADFG. 2013). Wood not only supports a higher diversity than rock (Figure 4) but also demonstrates a linear relationship when diversity means and distance from the shoreline are compared (Figure 3).

This linear relationship is explained by the fact that the further inland the substrate is, the harsher the environment, due exposure to terrestrial and aquatic pressures. This requires the organisms to have some form of protection from predation in both instances, and may therefore possess adaptations such as hard shells, seen in snails, hermit crabs, and barnacles to afford protection and prevent desiccation. This varies greatly from the organisms found in the lower part of the surf, or the low tide zone. Organisms here do face similar problems, but terrestrial pressures are not as common, and habitats in this zone experience less fluctuation in comparison to organisms located in the high tide zone (Young 2013). These pressures make these sections closer to the low tide a more suitable environment for more organisms (Figure 3).

Organisms that live on rocky substrates often times have hard shells that protect them and aid them in their ability to stay connected to their respective substrates. Whereas organisms on woody substrates can hide within the wood and need to be able to leave the wood after it has been fully desecrated (Newell. 1970). These organisms tend to lack hard structures and are more mobile; examples of these are ascidians, crabs, and octopi (Figure 2). Organisms that live on

woody substrates prefer to be close to the water to aid in movement and protection from terrestrial predators (Scrosati. 2010). The exposed portions of substrates were observed to be dominated by organisms that had the ability of attaching themselves to the substrates and having hard shells, similar to those organisms seen on rock substrates. Hard shells protect organisms on the surface from the unforgiving nature of rocky substrates and the breakers that crash against them (Newell 1970). Our data suggests rocky substrates appear to be uniform regardless of the distance from the shoreline.

These patterns have to do with the nature of the substrates and environmental pressures. Wood is easier to burrow into and unlike rock will disintegrate, whereas rock as it gets older it smoothes out and does create small dents on its surface but does not provide much protection from the surf (Scrosati. 2010). In order to live on rock, organisms are required to have characteristics that allow them to solidify themselves in place. In contrast, wood substrates can accommodate a variety of species.

The possible sites of error could have occurred during estimating of mass colonies of species. Another source of error could have occurred during counting; organisms could have been missed due to insufficient observation time at sites. Another source of error could have occurred with the differences in size of sampling. This would skew results due to surface area being not taken into account for each segment. This is a preliminary study which requires further research with longer observation periods, measuring surface area, and more replicates is strongly encouraged (Figure 5).

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Fauna sampled during study.

Substrate sampled during study.