The Ecology and Conservation of Freshwater Fish in the UAE

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Introduction and Background

The United Arab Emirates

- Hot, arid climate with variable, limited rainfall
- Few freshwater habitats
- No rivers or lakes- 'wadis' are the main freshwater habitats
- Low biodiversity of primary freshwater fish- only 15 species in Arabia

- Of the 15 species of Arabian primary freshwater fish, only two are found in the UAE
- The dominant species is *Garra barreimiae*, a small, bottom-dwelling cyprinid. The genus *Garra* is known from East Africa to South Asia. Of the 15 species of freshwater fish in Arabia, over half are *Garra* species.
- The secondary freshwater fish *Aphanius dispar* has a wide distribution in the UAE
- *Oreochromis* sp, a non-native [illegible] genus, are increasingly found in UAE wadis
- Geographical and climatic conditions of an arid zone make the existence of freshwater fish species extremely difficult- only those highly adapted to survive in such extreme environmental conditions will survive.

Garra barreimiae

Aphanius dispar

Oreochromis species

- Within the UAE, the Hajar mountains form a chain 35km wide from the Omani border in the south to the Musandam peninsula in the North.
- The mountain range is cut by wadis running East to West, those vary in terms of permanence of freshwater
- The Hajar Mountains are one of 200 areas identified by the World Wildlife Fund as the most critical regions for conservation. 'Global 200' areas are some of the richest, rarest and most endangered areas on the planet.

Aim, Hypotheses and Methods

Aim

The primary aim of this research is to examine the biology of freshwater fish in the UAE and the adaptations which enable them to survive in the harsh environments of an arid country. The practical applications of scientific research are also explored to demonstrate their relevance to conservation.

Hypotheses

Physical Environment
- Physical conditions within a wadi pool fluctuate both seasonally and diurnally
- Environmental fluctuations directly affect the ecology of *G. barreimiae*

Morphology
- Habitat type affects length frequency of *G. barreimiae*
- Standard length, total weight and mental disc diameter are affected by habitat type

Reproductive Activity
- Morphology and length frequency are affected by sex of *G. barreimiae*
- Reproductive activity is influenced by seasonal conditions

Upstream Migration
- *G. barreimiae* migrate upstream when prompted by environmental triggers
- Upstream migration behaviour is facilitated by the mental disc and pectoral fins
- Individuals of a specific morphology and sex display upstream migratory behaviour

Methods

- Wadi habitats in the UAE are rarely continuous, connecting only during flooding. Consequently, habitats are isolated and can vary considerably in depth, substrate and flow. Two primary habitats types were studied; deep, static, boulder pools [left] and shallow, flowing, rock riffles [right].
- Pools may be left after flooding events or be spring-fed. In contrast, riffle habitats have a varied length and depth. Substrate size, exposure and abundance of algae also varies.
- These physical characteristics influence the chemistry and biology of water bodies which directly affects the fish inhabiting them. In order to maintain a healthy population structure, *G. barreimiae* are thought to adapt to the habitat in which they exist.

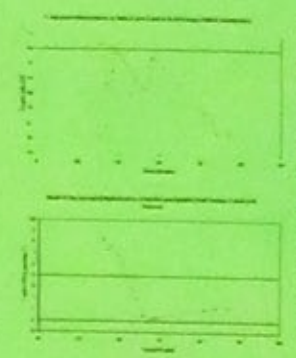
The study was carried out in Wadi Wurayah, Fujairah. Physical data was collected using a YSI multimeter.

- Maximum standard length (mm) using fine-scale digital callipers, 'standard length' is recorded from the most anterior part of the fish to the end of the caudal peduncle.
- Total wet weight (wg) a tared volume of water is kept on the scales, the live fish is added to the water and the weight recorded.
- Width of mental disc (mm) - using fine-scale digital callipers, mental disc width is measured at the widest point

510 fish were sampled using bottle traps; tests showed this to be the least obtrusive and most accurate representation of the population.

Physical Conditions

Temperature of water is a very important factor for aquatic life. It controls the rate of metabolic and reproduction activities and it affects the concentration of dissolved oxygen.
Factors influencing the temperature of freshwater bodies in wadis includes exposure to sunlight and shading from narrow wadi gorges or vegetation. Flow rate also influences the temperature, during dry seasons when there is less water and slower flows, the water will heat up more quickly and to much higher temperatures.
Respiration of organisms is temperature related; respiration rates can increase by 10% or more per 1°C temperature rise. Therefore, increased temperature not only reduces oxygen availability, but also increases oxygen demand, which can add to physiological stress of organisms.

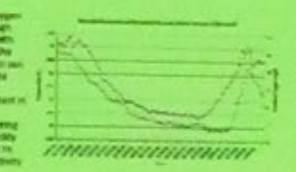


Annual fluctuations

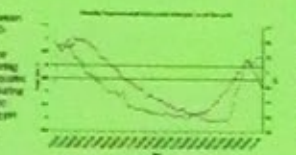
- Temperature of the sample pool fluctuates but overall temperatures are highest between weeks 13 and 30, declining between weeks 40 and 50 as winter begins.
- There is a sharp decrease in DO between weeks 13 and 36, which corresponds to the hottest summer months of late May through to July. This demonstrates how climate and seasons directly affect the level of DO present in freshwater bodies; the colder the water the more oxygen can be dissolved in the water.

During dry seasons, water levels decrease and the flow rate of a river slows down. As the water moves slower, it mixes less with the air, and the DO concentration decreases. During rainy seasons, oxygen concentrations tend to be higher as rain interacts with oxygen in the air as it falls. More sunlight and warmer temperatures also bring increased activity levels in plant and animal life which may increase or decrease the DO.

- Temperature and Dissolved Oxygen display decreasing levels through late afternoon and evening, with lowest levels recorded during the night. Concentrations of oxygen can decrease significantly during the night due to respiration. DO concentrations are usually highest in the late afternoon because photosynthesis has been occurring all day. DO levels rise more quickly around 7am, after sunrise, due to the onset of photosynthetic activity.



- pH values range from 9.23 between 4pm-5pm to 8.12 between 5.30-6.30am. Highest levels were recorded at 6-afternoon and the lowest levels were recorded during the night and early morning. Aquatic plants take in Carbon Dioxide during the day and release it during the night, consequently pH levels go up/down which can show diurnal/nocturnal fluctuations.

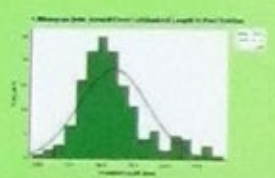


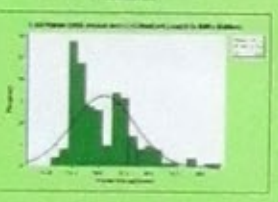
Diurnal fluctuations

Conditions are fluctuating in wadi habitats not just on a seasonal basis but on a diurnal basis, presenting a range of environmental conditions for fish to adapt to and tolerate.

Morphology

- both histograms suggest different population structures in the two different habitats.
- For pool populations the histogram is almost unimodal, representing the bulk of the population are similar in length to the mean. There are fewer large and smaller individuals which may be the result of a single cohort of recruitment into the population.
- In comparison, the riffle histogram displays a more complex frequency distribution, illustrating a bimodal distribution. The population could occur due to two separate cohort of recruitment, or possibly sex of the fish.

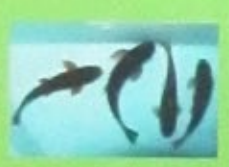




A Comparison of Length Frequencies of *Garra barreimiae* in two different habitats; Static Pools and Flowing Riffles.

Small habitat size can limit the number of large adults, which often exhibit strong territorial behaviours, increasing competition for food and space. Other factors influencing a deviation from a 'normal' distribution may include sex, seasonal fluctuations in food availability and frequency of habitat connection during flooding periods

A Comparison of Morphological Characteristics in *Garra barreimiae* between individuals found in Static Pools and Flowing Riffles.



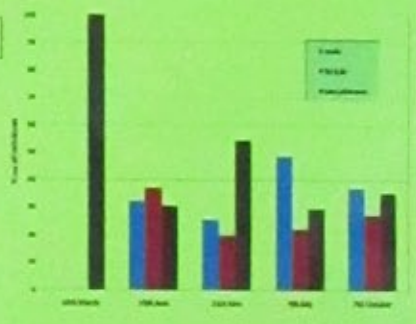
Variations in weight could be explained by behaviours related to habitat types with different energetic costs, e.g. swimming, flow and cryptic behaviour. Food availability may also be a controlling factor. A larger mental disc could be more beneficial to fish in riffles where there is a need to maintain position in the flow.

- No significant difference was found in standards lengths of fish inhabiting pool and riffle habitats.
- A significant statistical difference was found between total weight of individuals living in the two habitat types.
- A highly significant difference between the mental disc diameter of fish found in the two habitat types was produced by analysis of variance $F<0.001$. Fish inhabiting static boulder pools had a mean mental disc diameter of 2.05mm compared to a mean of 1.35mm in riffle dwelling fish.

Reproductive Activity

Garra barreimiae show no obvious sexual dimorphism and the sexes cannot be distinguished without internal examination. However, during months of reproductive activity, the presence of either eggs (female, left) or sperm (male, right) could clearly be seen by applying gentle pressure to the abdomen of the fish allowing sex of individuals to be determined

Sex of *Garra barreimiae* over an 8 month period in Wadi Wurayah



The most obvious conclusion to be drawn from this graph is the absence of any reproductive activity in March, with males and females only being externally distinguishable during the months of June and July. This data looks at total Garra recorded and eliminates the variable of habitat type. Sex ratio varies throughout time, with males being the dominant sex being males for the majority of the time.

- 69% of fish sampled were able to be sexed, none of these measured <32mm suggesting this may be the size at which *Garra* becomes sexually mature
- The majority of sexually active individuals were 56-66mm in length.
- 36% of sexually active individuals were male.
- Sexually active females displayed a wider size range and reached up to 84mm in length, compared to only 68mm in males.

An Investigation into the Reproductive Activity of *Garra barreimiae* in Wadi Wurayah

Upstream migration

Garra species have been observed in-situ 'climbing' upstream in what appears to be a method of migration to higher pools [see *G. dunsiri* [Oman] and *G. barreimiae* [UAE] left]. This ex-situ investigation plans to study the triggers for such movements as well as the physical adaptations which allow the fish to scale almost vertical rock faces.

Possible triggers for upstream migration;

- Change flow rate to see if this increases/decreases movements of fish
- Change temperature in top pool to simulate rainfall/floodwater (bags of ice in top pool?)- cooler water will then flow down to bottom pool.
- Physical disturbance in bottom pool (e.g.- someone wading in to water).
- Sprinkler hose falling onto surface of bottom pool- may stimulate rainfall.
- Food source placed in top pool and allowed to flow downstream to the bottom pool- does food availability encourage upstream movement?
- Adult *Garra* placed in top upstream pool- do chemical/hormonal cues from other adult fish stimulate upstream movements?

Method

- 100 adult *garra* individuals will be placed in the lower pool. Morphological measurements will be recorded for all individuals including sex, length, total weight and mental disc diameter.
- Each week, a different stimulus will be tested in the morning to see if the fish migrate upstream. The stimulus will be repeated several times.
- Any behavioural changes will be noted in the fish using a behavioural scoring system. If fish migrate upstream then they will be collected and the numbers of individuals, plus their morphological measurements will be recorded.
- If stimuli provoke migration behaviour, the stimulus will be repeated several times to collect as much data as possible on the behaviour of the fish.

Genetics

- *Extreme isolation and severe abiotic conditions can lead to a high degree of phenotypic divergence of freshwater fish, often with small populations living in small habitats.*
- *Many taxa are relicts from better-watered times that have been trapped in isolated springs and streams during the last 10,000 to 12,000 year post-pluvial period. This has resulted in a high degree of endemism.*
- *Several genetic and demographic consequences of such as isolated, fragmented distribution are likely*

- With increasing urban development across all seven emirates, it is important to highlight sensitive ecosystems and areas of unique biodiversity as a pre-requisite to conservation planning.
- Arabian and UAE freshwater fish are an "extinction-prone" group due to the limited geographic range and isolation of many species and populations.
- The Hajar Mountains, in which a large part of the data collection will take place, has been identified by WWF as one of 200 global 'eco-regions'
- Genetics is an essential part of ecological studies in conservation biology, a highly valuable tool in efforts to maintain healthy, diverse populations as part of conservation management strategies.

Areas of investigation

- Measure genetic distances between populations/ species of *Garra* to identify how far various populations of *Garra* are isolated from each other.
- Clustering- which populations are most closely related to each other?
- Separation between *G. barreimiae* and *G. longipinnis*- is *G. longipinnis* significantly different from *G. barreimiae* to be considered a separate species?
- Separation between *G. barreimiae barreimiae* and *G. barreimiae shawkishensis*- sub species or separate species?
- Genetic differentiation between the surface-dwelling [left, above] and the subterranean form [left, below] of *G. barreimiae*- is the case from the same species or a sub species?
- Are there any genetic population differences within *Cyprinion macrostomum muscatensis*? Identify conservation priorities for captive breeding?

Conservation

- Freshwaters are one of the most endangered habitats on the planet and being an arid country, the UAE is no exception to this.
- Coastal development, groundwater extraction, quarrying, pollution and introduction of non-native species all threaten UAE freshwater habitats.
- The UAE is developing in terms of business, tourism and urbanisation at an extremely fast rate, particularly in Dubai and Abu Dhabi.
- The worrying trend at present is the other emirates, many containing valuable natural resources, are trying to 'catch-up' and we see developments springing up in Fujairah, Umm al Quwain and RAK in the last few years.

Physical threats to wadis and freshwater fish

*Ecological threats to wadis - introduction of non-native species (*Gambusia affinis*) with it 'eaten' fish from a single pool)*

Environmental Awareness

- Trend in the UAE for 'going green' allows an opportunity to raise awareness of conservation issues within the media.
- The media is a tool which scientists should use to publicise their work and results; newspapers, magazines, TV, radio and websites are all positive ways of sharing information and promoting conservation.

Education

- Conservation and ecology is largely ignored in schools.
- Environmental sciences are not widely available for students in higher education.
- Students know more about conservation of animals in other countries.
- Cultural restrictions on students, particularly females, being actively involved in fieldwork.

Protected Areas

- Wadi Wurayah is the UAE's first mountain protected area.
- Successful collaborations between an NGO, government, corporate sector and local community.
- Highlights the ecological, economical and educational value of a protected area in the UAE
- Habitat protection provides conservation of all species within the area.