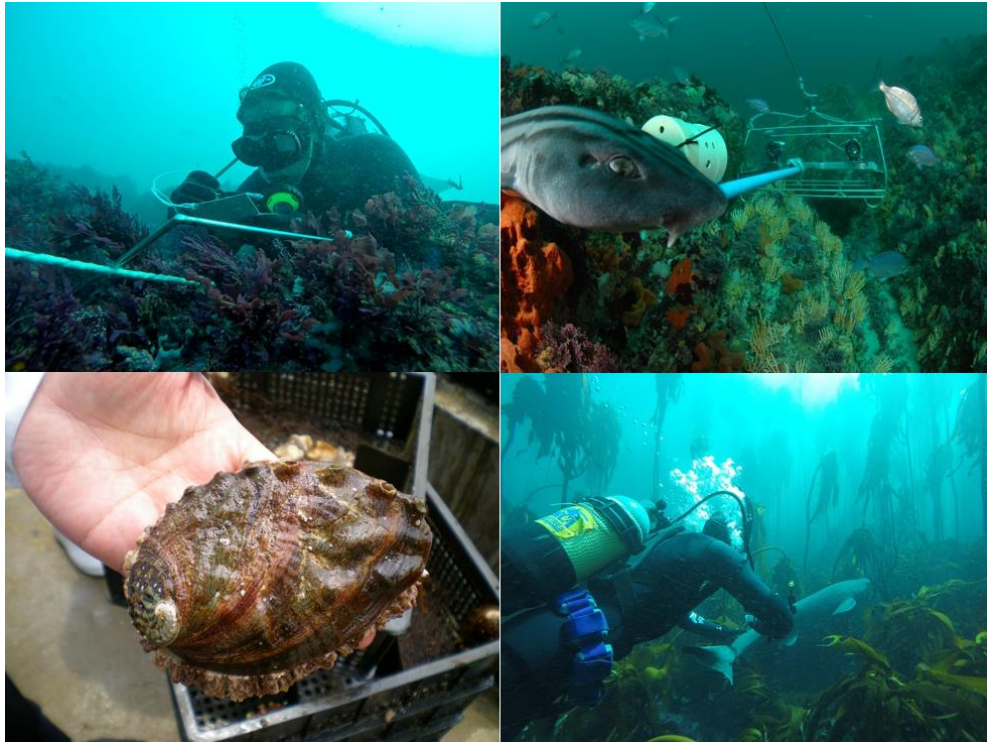# Department of Ichthyology and Fisheries Science

Photographs by Steven Benjamin, Warren Witte, Horst Kaiser ©

Research Report Series 2015

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The DIFS would like to sincerely thank the following for supporting its student research:

Department of Ichthyology
and Fisheries Science

Research Report Series 2015

October 2015
(Version 1)

Edited by: A-R Childs

Schedule of Events/Table of Content

Wednesday 7 October 2015

08h20-08h30: Welcome by Prof. Horst Kaiser (Acting Head of Department)

Honours seminars (Chair: Dr Warren Potts)

08h30-08h50: Jefferson Luke van Staden (BSc Honours student) - Conspecific mucous as an attachment attractant for abalone *Haliotis midae* larvae during the settlement phase

Supervisor/s: Prof. H Kaiser (h.kaiser@ru.ac.za)

Abalone are a commercially highly valuable species of molluscs belonging to the family Haliotidae. One of the limiting factors in the commercial production of abalone species is the consistent production of abalone in the post-larval to juvenile stage, so that they can be weaned onto artificial food and grown to market size. Settlement of abalone larvae in commercial production systems is highly variable, both seasonally and between the settlement methods used by hatcheries. Settling larvae onto fibreglass/plastic plates with a benthic diatom biofilm is highly variable with generally low success rates.

Three substrates were assessed to test the effect of the addition of conspecific abalone mucous to settlement substrates on the rate of attachment in *Haliotis midae* larvae. Abalone larvae were obtained from a commercial spawning at HIK abalone during August/July 2015, and were settled on plates with a substrate of a) benthic diatoms, b) abalone mucous or c) a combination of these two. Two plates were suspended in 2-L containers. The abalone were settled overnight. Sampling began the next day (day 1).

The number of abalone per plate was counted using the program OpenCFU. The mean number of abalone per plate was Log-transformed to meet the assumptions of normality required for analysis of variance. Analysis was carried out using a factorial ANOVA with density, treatment method of the plates and day as main effects. Treatment had a significant effect ($p \leq 0.0001$), and there was an interaction between treatment and day ($p = 0.013$). On day one attachment on the combined treatment was significantly higher than that of mucous alone ($p < 0.0001$) but not diatoms alone ($p = 0.188$) (Tukey's post-hoc test). On the day two settlement on the combined treatment was significantly higher than in the treatment containing only abalone mucous ($p < 0.0001$), but not diatoms alone ($p = 0.856$). On day three, the combined treatment had a higher number of attached larvae than both mucous alone ($p \leq 0.0001$) and diatoms alone ($p = 0.042$). In both high and low densities, the combined treatment plates generally had a higher number of settled larvae than either of the other two treatments. Conspecific mucous acts as an attractant to larvae competent to settle; its combined use with conventional practices may reduce variability and potentially increase overall successful settlement rates in commercial production systems.

Key words: marine; aquaculture; Haliotis; mucous; settlement; attachment; larvae.

08h50-09h10: Andreas Cross (BSc Honours student) - The effect of diatoms and adding two abalone mucous sources on metamorphosis in South African abalone (*Haliotis midae* L.)

Supervisor/s: Prof. H Kaiser (h.kaiser@ru.ac.za); Dr CLW Jones (c.jones@ru.ac.za)

Abalone or perlemoen (*Haliotis midae* Linnaeus, 1758) are native to the western coast of South Africa. This species of marine gastropod mollusk from the Haliotid family is native in waters ranging from 10-18 °C and can reach a size of up to 200 mm. The species typically feeds on diatoms as juveniles and begins feeding on a variety of seaweeds and algae as is enters adulthood (Wood & Buxton, 2010). This species is of commercial significance as a popular luxury food product in Asia. Abalone larvae use diatoms as cues for settling and for foraging after metamorphosis. However, over the winter periods, the diatom growth on abalone farms is slow, owing to lower temperatures and shorter days. The algal composition or quantity of the biofilms reduce the success rate of abalone settlement and metamorphosis during the winter periods. Literature suggests that mucous produced by abalone, attracts other abalone to their mucous trail.

The aim of this experiment was to determine the effect of the addition of two mucous sources to settlement plates on the success of metamorphosis. Two mucous sources will be used in this experiment, i.e. mucous collected at the cannery and mucous from farmed abalone. To simulate the commercial tanks used by HIK, 2 litre ice-cream tubs were used and sosatie sticks were punched through the tubs. The settling plates could then be placed into the tanks, by securing them to the sosatie sticks with clothe pegs. Treatments included adding the two mucous sources to settling plates, i.e. plain diatom plates, diatom plates with mucous from farmed abalone and diatom plates with mucous from the cannery. Each treatment combination had 6 replicates with the experiment running over six days. Once the abalone larvae, obtained from HIK's commercial batch, were placed into the tanks the experiment lasted 6 days. All tanks were supplied by marine water inlets from HIK hatchery. Designates plates were removed each day for the six days and photos of the plates were taken. Afterwards the plates were placed under a microscope with a camera adapter and with the aid of a template made from clear plastic sheeting, with 8 small circular holes in it, photos were taken. All the photos were analysed and data of the counts and the stages of metamorphosis were recorded.

An analysis of covariance with temperature and flow as covariates was done to establish that temperature and flow we not significant covariates ($p = 0.568235$). A factorial ANOVA was used to test for the interaction between day and treatment ($p = 0.627608$). There was no significant interaction effect. There was a significant difference between treatments ($p \leq 0.000001$), whereby the plates with cannery mucous and diatoms had a significantly better settlement than the other two treatments. A multivariate test on the three stages, A (settlement of abalone larvae, but no sign of metamorphosis); B (metamorphosis has begun); C (metamorphosis reached), over the six days showed a significant difference ($p = 0.000898$) between the mucous cannery and diatom treatment and the other two treatments. The mucous cannery and diatom treatment had significantly more abalone larvae in stage C.

Key words: marine; aquaculture; perlemoen

09h10-09h30: Manda Kambikambi (BSc Honours student) - Growth of stock enhanced abalone at Cape Recife in the Eastern Cape

Supervisor/s: Prof. P Britz (p.britz@ru.ac.za)

Stock enhancement which is defined as the releasing of stock for the public good without the intention of directly benefiting an exclusive user group has been presented as a means to rehabilitate overfished abalone populations and enhance natural populations. This project aimed to measure the growth rate in abalone that were seeded from a hatchery into the wild at Cape Recife in order to assess the productivity of abalone in two habitats. The specific objectives where to:

- Measure the growth rate of abalone;

- Measure the effect of initial abalone seed size on growth rate;

- Measure the effect of habitat on growth rate.

An abalone farm, Wild Coast Abalone (Pty.) Ltd. supplied the seed used in the stock enhancement experiment. Two habitats were identified in Cape Recife and 18 circular experimental plots with an area of 10 m^2 & a radius of 1.8m were marked in each habitat. A total of 8400 abalone where seeded in 36 plots. The abalone consisted of two seed sizes and each plot was seeded with either had a small (15-35 mm) or large (35-55 mm) seed size. A year after seeding, the surviving specimens were collected by divers and frozen for analysis. The abalone were shucked and the shells cleaned to differentiate between seeded and wild abalone by means of the shell colour. The growth rate of the seeded abalone was determined by measuring the shell length at time of recovery minus the shell length at time of release/ the number of days at large. Analysis of Variance was used with R Statistical software to determine the significance of the relationship between growth rate, seed size and habitat. The average growth rate of habitat one was 0.793 and that of habitat two was 1.730. The growth rate of abalone differed significantly between habitats with deep habitat having a higher growth rate (state growth rate in mm/month) than the shallow habitat one (state growth rate mm/month) ($p = 5.3e^{-11}$). There was no significant relationship between initial abalone seed size and growth rate ($p = 0.557$). No significant relationship was found between growth rate and the interaction between habitat and seed size ($p = 0.663$). These results show that habitat is a more important factor determining the growth rate of seeded abalone than initial seed size.

Key words: marine; aquaculture; conservation; stock enhancement; growth rate

09h30-09h50: Pule Mpopetsi (BSc Honours student) - Patterns of genetic and morphological variation in the Eastern Cape Rocky, *Sandelia bainsii* (Pisces: Anabantidae)

Supervisor/s: Dr A Chakona (a.chakona@saiab.ac.za); Prof. P Skelton (p.skelton@saiab.ac.za)

The Eastern Cape Rocky (*Sandelia bainsii*) is a primary freshwater fish species that is endemic to South Africa where it has a limited geographic range. It exhibits a disjunct distribution, occurring in five currently isolated river systems in the Eastern Cape province of South Africa. The species is currently listed under the International Union for the Conservation of Nature (IUCN) as being endangered with decreasing populations. There is need for conservation measures to be put in place to prevent further loss of remnant populations of *S. bainsii*. However poor understanding of the taxonomic status of this species has been identified as a major impediment to implementation of effective conservation programmes to protect this species. Results from a preliminary molecular study conducted in 2005 revealed two genetically distinct lineages in *S. bainsii*, suggesting possible existence of hidden diversity within this species.

The aim of the present study was to integrate genetic and morphological data to determine the taxonomic integrity of *S. bainsii*. Surveys were conducted across *S. bainsii*'s geographic range to collect tissue samples for genetic analysis. Standard laboratory techniques were used for DNA extraction, amplification and sequencing. A total of 24 mitochondrial 16S sequences (458 bp) were generated. Neighbour joining analysis and genetic distances were calculated using the program PAUP. A haplotype network was constructed using the program TCS. Voucher specimens from five river systems (Keiskamma, Kowie, Great Fish, Buffalo and Nahoon) were obtained from the South African Institute for Aquatic Biodiversity (SAIAB) for morphological analysis. Eighteen morphometric characters and eight meristic counts were recorded for each specimen. These data were analysed using a principal component analysis (PCA). A PCA of the morphometric characters revealed that specimens from the five river systems overlap morphologically and that there was no clear separation between them. As such, these specimens cannot be separated based on their morphological characters. Neighbour-joining tree showed sequence divergences estimates among the river systems to range from no divergence (between Igoda and Buffalo) to 2.85% (between Kowie and Buffalo). The highest divergence was between Kowie and Buffalo systems, and ranged from 2.59 to 2.85%. The Igoda and Buffalo had a low divergence, from 0 to 0.26%. Results from the present study revealed that there are three genetically distinct lineages with strong geographical affinities (Kowie-Great Fish; Keiskamma; and Baffalo-Igoda) that are currently included under *S. bainsii*.
To conserve the genetic diversity within this species, the three identified lineages should be conserved separately and their translocations between their respective systems should be avoided.

Key words: freshwater; systematics; conservation; molecular genetics; morphometrics

09h50-10h10: Martinus Scheepers (BSc Honours student) - Paternity in clinids (klipfishes) and its implications

Supervisor/s: Dr G Gouws (g.gouw@saiab.ac.za); Mr O Gon (o.gon@saiab.ac.za)

The family Clinidae are marine perciform fish of the sub-order Blenniodei. In South Africa, they are commonly referred to as klipfishes. They are benthic fishes, occurring in the inter- and sub-tidal nearshore areas, usually in algal covered rocky habitats. Different reproductive strategies are employed by this group of fishes. Some species form territorial pairs, and eggs are deposited into a nest which is guarded. Other species are viviparous. Viviparous clinids are found predominantly in South Africa and Australia, exhibiting two differing reproductive strategies. Fishes of the Australian genera *Cristiceps* and *Heteroclinus* produce large numbers of small eggs that develop synchronously and are released all at once. South African species of the genus *Clinus* produce fewer and larger eggs that develop asynchronously, large mature embryos are released throughout the year, a process called superfetation. An unknown facet of the reproductive history in clinids is the role which paternity plays in their reproductive strategy, and the effect thereof on overall genetic diversity in this group. The reproductive features of species within the genus *Clinus* indicate that multiple paternity of broods may occur, and our objective was to use genetic methods to ascertain whether individual broods are fathered by more than one sire.

Clinids were collected from a single rock pool near the Fish River Mouth. The most common species was *Clinus cottoides* which was used for our genetic study. DNA sequence data were generated for the first intron of the S7 ribosomal protein gene. These were taken from three females, and fifteen embryos from their respective broods. All mature males, eighteen in total, were also sequenced. Initial comparisons of embryo sequences with that of their mother indicated that multiple paternity may occur. However, insufficient polymorphisms ruled out a statistically meaningful result. The use of the Amplified Fragment Length Polymorphism Technique (AFLP) was used to confirm the results from the S7 intron.

A mating system where females mate multiply with different males can lead to increased genetic diversity within the group. Increased diversity buffers a population against abrupt environmental changes, a mother hedges her bets as to her offspring's genetic makeup. Multiple mating ensures fertilization and avoids inbreeding depression. Small groups moving into new areas could potentially carry more genetic diversity when a few females carrying multiply sired broods are present. Future research into the mating system of clinids will look into the role of paternity, singular or multiple, in overall genetic diversity, whether multiple mating is sequential or concurrent, and the role of female choice in this group of fishes.

Key words: marine; genetics; parentage; AFLP; reproductive strategy; mating system

10h10-10h30: Sibusiso Yokwana (BSc Honours student) - Risk assessment of impacts of climate change for key marine species in the southern Benguela system

Supervisor/s: Prof. KL Cochrane (k.cochrane@ru.ac.za); Dr K Ortega Cisneros; (k.ortegacisneros@ru.ac.za); Prof. WHH Sauer (w.sauer@ru.ac.za)

The southern Benguela system covers the shelf region to approximately 500 m depth and constitutes 26.94 % of South Africa's EEZ (exclusive economic zone). Several important commercial fisheries take place in this zone, as well as an important small scale sub sector. The southern Benguela has been recently identified as a hotspot of climate and social change. Climate change is one of the factors that affects the marine ecosystem. The aim of this study was to conduct a risk assessment for the key marine species in the southern Benguela system by identifying their sensitivity to climate change impacts. This study also aimed to highlight priorities for future research.

For our analysis, species were nominated on the basis of economic, ecological and recreational importance. A total of 28 species were analyzed in this study using the Ecological Risk Assessment methodology developed under the National Ecologically Sustainable Development reporting framework for Australian Fisheries. A comprehensive literature review was conducted to gather information for assessing the risk under different sensitivity attributes for 28 species. The sensitivity of a species was estimated using indices based on abundance, distribution and phenology. A total of 14 sensitivity indices were evaluated to determine the sensitivity and capacity to respond to climate change of the selected species. A category from low (1) to high (3) sensitivity was given to each indexs based on the available information. From these species assessment profiles were created.
The analysis identified the St. Joseph shark, white stumpnose, white steenbrass, white musselcracker and carpenter, in order of vulnerability, as the most sensitive species to climate change impacts in the southern Benguela system. From the results, it can be concluded there are information gaps on fecundity, larval dispersal and on settlement and metamorphosis cues on most of the evaluated species. The information from this study can be used by resource managers to better prioritize what type of monitoring, intervention or planning may be required given limited resources.

Key words: marine; fisheries management; southern Benguela; climate change; sensitivity

10h30-11h00: Tea break

Honours seminars continued (Chair: Dr Warren Potts)

11h00-11h20: Sheena Talma (BSc honours student) - The movement behavior of blacktip reef sharks *Charcharinus melanopterus* in the shallow waters of the remote Aldabra atoll, Seychelles

Supervisor/s: Prof. PD Cowley (tagfish@gmail.com)

Funder/s: South African Institute for Aquatic Biodiversity (SAIAB); Seychelles Island Foundation; Seychelles Fishing Authority

Blacktip reef sharks *Charcharinus melanopterus* are common, reef-associated, apex predators in Indo-Pacific tropical waters. The behavioural ecology of blacktip reef sharks has received considerable recent research attention using acoustic telemetry methods. In particular, some research has looked at how human interactions may alter sharks' normal behaviour. The bulk of this research has been performed in the Pacific Ocean with little research conducted at Indian Ocean islands. This study was conducted at Aldabra, one of the Seychelles' remote coralline atoll islands and a UNESCO world heritage site. The Atoll has a human population of only 20 researches all of whom reside at the research station site on the North West coast of the atoll. This study aimed to investigate aspects of the spatio-temporal behaviour of acoustically tagged blacktip reef sharks at two sites; one in front of the research station and another (bone channel) approximately 7 km away. It was hypothesized that blacktip reef sharks at the research station have become habituated to human presence due to the disposal of food scraps into the water. Fifteen blacktip reef sharks were tagged with Vemco V13 (one-year lifespan) transmitters at two sites; research station site ($n = 8$) and the bone channel site ($n = 7$). The residency patterns and movement behaviour were monitored by an array of 14 acoustic receivers deployed in pairs at five offshore sites on the western side of the atoll and two inshore sites where the sharks were tagged. All receivers were collected after a year. The time spent at the receivers and the movements of sharks tagged at the research station site and the bone channel site were compared. A residency index (RI) calculated for each shark for the duration of the study showed that the sharks tagged at the research station had a significantly higher ($p < 0.0001$) RI ranging between 0.03 to 1.0, with a mean $\pm$ SD of 0.79 ± 0.34 compared to sharks tagged at bone station (range $= 0.02 - 0.70$, with a mean $\pm$ of 0.45 ± 0.30). A comparison of total time spent by resident sharks at the two sites showed that significantly more time was spent at the research station compared to bone station (Kruskal-Wallace, $p < 0.05$). Preliminary analyses of the data suggest that sharks tagged at the research station (site of food disposal into the water) were resident and spent a high percentage of their time at this site. In contrast sharks tagged at the bone channel site had a lower residency index and spent less time at their tagging site. Although blacktip reef sharks are known to exhibit resident behaviour, the presence of large aggregations and high site fidelity observed by tagged sharks at the research station site suggests that they have become habituated to human presence, albeit limited, at this remote Indian Ocean atoll.

Key words: marine; ecology; acoustic telemetry; Aldabra; blacktip reef sharks; behaviour

11h20-11h40: Lesley Bloy (BSc Honours student) - The effect of short-term temperature variability on the reef fish communities detectable with baited remote underwater stereo-video systems

Supervisor/s: Dr A Götz (albrecht@saeon.ac.za); Dr A Bernard (ant@saeon.ac.za)

Funder/s: National Research Foundation (NRF) (UID 98163), South African Environmental Observation Network (SAEON) Elwandle Node, South African National Parks (SANParks), British Ecological Society

It is accepted that fish distribution and activity patterns are influenced by a number of factors, including water temperature. Off the southern coast of South Africa, in the Tsitsikamma National Park (TNP) Marine Protected Area (MPA), upwelling events, resulting in rapid drops of sea surface temperature, are regularly experienced. It is expected that such upwelling events may significantly influence the detectability of different fish species during monitoring within this MPA. This project aimed to measure the influence of short-term temperature variability on the fish community structure observable with baited remote underwater stereo-video systems (stereo-BRUVs) and to develop draft recommendations for standardized monitoring protocols.

The data collection was conducted over three consecutive summers (2013-2015) on a shallow reef complex (10–50 m) in the center of the TNP MPA. In 2013, 20 samples were collected during water temperatures of below 14°C and 20 samples during water temperature above 16°C. In 2014 the temperature ranged between 9 and 21°C while in 2015 the temperature ranged between 9 and 18°C. The stereo-BRUVs samples were analysed with the custom-made software package EventMeasure to determine species richness, abundance and size. The fish reviewed in the videos were identified with the standard literature as well as an electronic reference library. To extract abundance and length data from a video sample the maximum number of individuals of each species within a frame (MaxN) was recorded along with their lengths. To determine the impact of temperature variability on the detectability and abundance of fish the analysis focussed on *Chrysoblephus laticeps, C. cristiceps, Boopsoidea inornata* and *Spondyliosoma emarginatum*. Furthermore, the data was examined to test for differences in reef fish community structure and species abundance/biomass observed during cold water events (<13ºC) and warm water events (>16ºC) within (short term effects) and between field trips (long-term effects). The univariate, species specific analysis was conducted with generalized linear regression techniques while the community analysis, which is based on multi-variate data, will be conducted with a permutational analysis of variance (PERMANOVA).

Key words: marine; ecology; monitoring; Tsitsikamma; stereo-BRUVs; upwelling

11h40-12h00: Bianca Hannweg (BSc Honours student) - How do South Africa's marine protected areas rank according to five key design criteria: no-take, enforced, old, large and isolated (NEOLI)?

Supervisor/s: Dr A Bernard (ant@saeon.ac.za); Dr A Götz (albrecht@saeon.ac.za)

Marine protected areas (MPAs) are global tools for the conservation of marine biodiversity and the maintenance of exploited populations. Although there is information available for many MPAs globally, there is a general lack of information for South African MPAs thus hindering our ability to assess the functioning of these areas. The performance of an MPA will be compromised if it is poorly designed, there is poor management or regulations are not enforced. In order to determine the effectiveness of these MPAs field surveys can be carried out and this will lead to certain classifications which will aid in determining whether the MPA I effective or not. However, these field surveys can prove expensive and time consuming whereas using surrogates are quick and inexpensive. Edgar *et al.* 2014 make use of a classification system whereby each MPA globally is classified using five factors and this classification as a whole is known as NEOLI. The NEOLI classifications are as follows: No-take in which an MPA allows no-take of any marine resources; enforced in which regulations area adhered to monitored and managed effectively; old which has been described above; and whether or not there is an isolation factor or barrier associated with the MPA.

The aim of this study was to classify South African MPAs according to these criteria by carrying out questionnaire and desktop studies. The desktop study revealed that the age of MPAs in South Africa ranges from 8 years (Amathole in the Eastern Cape) to 55 years (Tsitsikamma in the Western Cape). The size of the MPAs ranged from 1,237 km² (Pondoland in the Eastern Cape) to 13 km² (Sardinia Bay in the Eastern Cape). Out of the 12 South African MPAs studied here, only 50% of them were considered large according to the NEOLI classification introduced by Edgar *et al.* 2004 (MPAs >100 km² are classified as large). Questionnaire based studies conducted at various MPAs around South Africa revealed the extent to which poaching is occurring at each MPA. A mixture of marine conservation staff including field rangers and MPA managers were questioned. Preliminary analysis revealed that mainly reef fish and rarely game fish are being targeted during poaching events. Most transgression were related to a phenomenon called 'fishing the line', where fishing boats and shore anglers are found right on the MPA boarder. Poaching events were more common during holiday seasons compared to outside holiday seasons. In the majority of MPAs, it could be shown that patrols took place on a daily basis and on average for more than 240 minutes a day, however, most of these patrols were shore based. This was due to the fact that many MPAs were not equipped with enforcement vessels, their vessel was out of commission or they had other infrastructure related problems. The results indicate a gap in the enforcement of these South African MPAs. Such gaps, if adequately addressed, could significantly improve the protective effect of these MPAs.

Key words: marine; Marine Protected Areas; NEOLI; compliance and enforcement data

12h00-12h20: Edward Butler (BSc Honours student) - A rapid assessment of the effect of rules and regulations on the catch-and-release practices within a competitive rock and surf fishery

Supervisor/s: Dr WM Potts (w.potts@ru.ac.za)

The practice of catch and release (C&R) has become prevalent as a conservation measure in fisheries around the world. In South Africa, C&R is utilised as a management tool within all fisheries sectors through the implementation of bag and size limits. More recently, its voluntary practice has become popularised within the recreational sector due to the growing and highly valued nature of the sport. Despite the widespread use of C&R, there is very little information pertaining to its effects on fish health and survival, particularly in a South African rock and surf context. The potential effects of an array of factors associated with C&R were assessed during the national Rock and Surf Super Pro League (RASSPL) national rock and surf tournament in East London. Researchers collected information associated with the C&R including air exposure, cumulative total time of the capture event, hook damage and extent of bleeding. Blood samples were collected from the caudal vein of the fish and blood glucose and lactate levels was measured as an indicator of stress in conjunction with four "reflex responses" which acted as predictors of potential post-release mortality. A sub-sample of fish were also retained over a 12 hour period to monitor their recovery and survival. Multiple regression analyses of blood data found that air exposure was the best predictor of blood lactate levels in teleosts ($p = 0.02$) and blood glucose levels in elasmobranchs ($p = 0.02$). A log-linear analysis found that the difficulty of hook removal was the most significant predictor of negative reflex responses post-capture ($p = 0.06$). Hook placements in the throat of fish led to a significantly higher percentage of difficult hook removals ($df = 4$, $p < 0.01$). The baseline reflex response scores of fishes after the recovery period was found to be significantly better than the post-angling scores ($p < 0.01$). Based on the results, it is recommended that circle hooks should be used to reduce throat hooking and in so doing, reduce handling times. Furthermore, air exposure should be reduced by implementing rules that require anglers to place fish in buckets of seawater during the unhooking event. The results also show that C&R angling has the potential to negatively impact fishes and future research into the direct and indirect effects of C&R angling is warranted.

Key words: marine; recreational fisheries; RASSPL Africa; catch-and-release; rock and surf

12h20-12h40: Nicholas van Wyk (BSc Honours student) - Understanding the long term growth patterns of silver kob *Argyrosomus inodorus* using otolith schlerochronology

Supervisors/s: Dr WM Potts (w.potts@ru.ac.za); Dr A-R Childs (a.childs@ru.ac.za)

Information regarding the age and growth of fish is of paramount importance when it comes to stock assessment models and estimating the productivity rates of species. This information is required when setting quotas and catch restrictions. If growth rates of species are changing due to climate change or anthropogenic influences, this needs to be taken into account when setting new regulations. The silver kob *Argyrosomus inodorus* is a commercially exploited fish species in South Africa's linefishery and as by-catch in the hake and sole trawl fishery. The stock status is currently listed as 25% (collapsed) with trends in CPUE declining throughout the 20th century. There is evidence of stock recovery after 2002 when new legislation was put into place to reduce fishing effort. The objective of the study was to determine if the growth rates of silver kob have changed over the past 50 years due to climate change.

Otoliths were obtained from a historical collection by Mark Griffiths (1980s) and the Department of Agriculture Forestry and Fisheries line fish observer program (2010-2011) as well as contemporary collection for the 2015 calendar year. All otoliths were collected from fish in the Port Alfred area on South Africa's east coast. Otoliths were embedded in resin and sectioned at a width of approximately 0.4 mm using a double-blade diamond edge saw. Sections were viewed and photographed with a Lieca dissection microscope under transmitted light. Increment widths between annual rings were measured using the program Image J. Using programs and techniques developed in dendrochronology (tree ring analyses) a master chronology depicting the growth rate of the species was created. The program COFECHA was used to cross-date and statistically verify measurements. The program ARSTAN was then used to develop the master chronology by detrending the data to remove the age effect on the growth rate of the fish. The chronological data was then correlated to sea surface temperature (SST) obtained from the AVHHR Pathfinder 5.2.

A total of 16 otoliths from the 1980's and 56 otoliths from 2000-2015 were analysed. Preliminary results suggest a decline in growth since the 1980's and this may be related to the decrease in average SST during the corresponding time periods, something which may be driven by the increase in upwelling events along the Eastern and South Cape. Future analyses will examine the relative influence of additional factors such as population density (measured as CPUE) and food availability (measured as chlorophyll 'a') on the growth rate of silver kob using a general additive model. Ultimately, these findings will allow us to make predictions on the relative growth of the species which will be informative for fisheries managers.

Key words: marine; fisheries management; dendrochronology; climate change

12h40-14h00: Lunch break

Aquaculture and water treatment (Chair: Adejoke Adesola)

14h00-14h20: Kyle Lloyd (MSc student) - Determining the quantitative lysine requirement in *Haliotis midae*

Supervisor/s: Dr CLW Jones (c.jones@ru.ac.za); Dr T Shipton (ihts@imaginet.co.za)

Funder/s: National Research Foundation (NRF); Technology and Human Resources for Industry Programme (THRIP); Marifeed (Pty) Ltd

Animals generally do not have a requirement for protein, but instead have a requirement for specific essential amino acids (EAAs) and non-essential amino acids (NEAAs). NEAAs are those that can be synthesised by the animal, however, EAAs cannot be synthesised and must therefore be supplied as part of the diet. When these AAs are supplied in the correct ratios and with the correct level of digestible energy, nutritionists can maximise somatic growth from proteins. This has resulted in increased research into the use of crystalline AAs in feed formulation research in order to quantify the AA requirements in aquaculture species, and allow for alternative protein sources (other than fishmeal) to be utilised. In common with other water soluble nutrients, leaching of crystalline AAs from diets prior to ingestion is of concern in an aquatic environment. Microencapsulation techniques have been successfully employed to restrict micronutrient leaching, and improve ingestion rates. In this research, lysiPEARL^{TM} (Kemin®) was used as a means to determine the lysine requirement in *Haliotis midae*. This encapsulated lysine product is used in the dairy cattle industry as an effective source of rumen bypass for intestinal release of lysine. Six isonitrogenous diets enriched with 5.5, 6.5, 7.5, 8.5, 10.5% lysine (as a % of protein) in triplicate were fed to 20 *H. midae* (20.41 ± 1.95 mm SL 1.51 ± 0.44 g w.wt) for 90 days. Wet weight and shell length measurements were taken every 30 days and specific growth rate (SGR) (% body weight.day^{-1}), feed conversion ratio (FCR), protein efficiency ratio (PER), feed consumption (% body weight.day^{-1}) and condition factor were calculated for each dietary treament. There was a significant difference found in the SGR of abalone fed the different dietary treatments (ANOVA, p = 0.009) where 5.6% (0.43±0.05) and 6.6% (0.47±0.03) were found to be significantly different to 7.6% (0.57±0.01) (Tukey post hoc p < 0.05). There was a significant difference in FCR of abalone fed the different dietary treatments (ANOVA, p =0 .028) where 7.6% (1.51±0.05) and 8.6% (1.99±0.21) were found to be significantly different from one another (Tukey post hoc p = 0.035). There was a significant difference in PER of abalone fed the different dietary treatments (ANOVA, p = 0.016) where 7.6% (2.45±0.07) and 8.6% (1.88±0.18) were found to be significantly different from one another (Tukey post hoc p=0.02). There was a significant difference in feed consumption (% body weight.day^{-1}) (ANOVA, p<0.05) where 5.6% (0.59±0.02), 6.6% (0.63±0.001) and 7.6% (0.68±0.01) were found to be significantly different to 8.6% (0.80±0.04), 9.6% (0.75±0.03) and 10.6% (0.77±0.04) (Tukey post hoc, p<0.05). There was a significant difference in condition factor of abalone fed the different dietary treatments (ANOVA, p=0.012) where 7.6% (1.00±0.01) and 10.6% (0.98±0.04) were found to be significantly different from one another (Tukey post hoc, p = 0.006) and 9.6% (0.97±0.03) and 10.6% (0.98±0.04) were found to be significantly different from one another (Tukey post hoc, p = 0.049). It has previously been proposed that crystalline AAs are not suitable for AA studies in *H.midae* due to the slow feeding rates of the species as well as the solubility of these AA's. However, results from this study show that if microencapsulation techniques are used, it is possible to effectively determine optimum inclusion levels.

Key words: marine; aquaculture; abalone; nutrition; amino acid; lysine; microencapsulation

14h20-14h40: Lwazi Nombembe (MSc student) - The use of catfish to harvest algae from effluent treatment tanks

Supervisor/s: Dr CLW Jones (c.jones@ru.ac.za); Mr R Laubscher (r.laubscher@ru.ac.za)

The removal of microalgae from high rate algal ponds in waste-water treatment systems remains a constraint to the use of high-rate-algal-ponding in effluent treatment systems. The aim of the study was to determine if African catfish *Clarias gariepinus* could be used to remove microalgae from waste-water treatment ponds and thus convert algal biomass into fish biomass. The objectives were to (1) see if gill raker distance (i.e. ability to filter microalgae) was related to catfish age, (2) assess the rate at which catfish of different ages remove algae from algal ponds , and (3) determine if catfish can survive in the fluctuating environments that characterise these ponds and monitor fish health in the ponds. Two size classes of catfish and a control treatment without fish, all with and without the use of algal flocculation technology will be replicated three times. Changes in algal biomass, chlorophyll concentration and algal community structure will be recorded in the different treatments and fish health will be monitored.

Data has been gathered to address the first objective (ability of catfish to filter feed on microalgae) and regression results showed that the width between gillrakers was related to fish age. The study is now in the second stage of experimentation whereby data investigating algal removal rates, chlorophyll concentration and algal community structure is being collected.

Key words: freshwater; aquaculture; catfish; waste-water treatment

14h40-15h00: Mmathabo Mogane (MSc student) - Treatment of brewery effluent using high rate algal ponds: establishing the identity of microorganisms in algal ponds and creating an understanding of nutrients removal

Tertiary treatment of wastewater using high rate algal ponds (HRAPs) involves the aerobic biodegradation of organic matter in the effluent by bacteria and fungi. This aerobic degradation results in the release of inorganic substances such as carbon dioxide and ammonia. These inorganics are reduced from the effluent through algal assimilation. When HRAPs are operating optimally, they can effectively remove nitrogen and phosphorus from wastewater. At the Ibhayi Brewery, situated in Port Elizabeth, HRAPs were used to treat a portion of anaerobically digested (AD) brewery effluent at an experimental scale. The HRAPs were efficient in the removal of nitrogen and phosphorus from the effluent. However, the microbial community structure playing a significant role in nitrogen and phosphorus removal and the mechanisms behind nutrients removal were not fully understood. It is believed that an understanding of the microbial complexes in the pond, nutrients removal mechanisms and the effects of environmental parameters on the HRAPs can provide an understanding of how HRAPs operate under various environmental conditions. Once understood, this knowledge will provide wastewater treatment plants the tools to better manage nitrogen and phosphorus at their facilities when using HRAPs.

In this study, the microbial community structure and the physicochemical parameters in HRAPs used to treat AD brewery effluent at Ibhayi Brewery were investigated. The effects of seasonal variation on the microbial community and physicochemical parameters was tested over a period of 12 months while a campaign experiment tested the effects of inflowing effluent flow rates on the microbial community structure and reduction of the effluent's nutrient load over a period of a month. An experiment to test the effects of temperature and pH on microbial community structure and nutrients removal was also set in a control environment room. Biological parameters in the HRAPs displayed strong seasonal signals, particularly species succession in microalgae and bacteria community, chlorophyll a concentrations and the standing biomass. Chlorophyll a and biomass ranged from 583.24 to 1551.36 μg/L and 0.10 to 0.87 g/L in winter and summer respectively, and had a marked effect on nutrient reduction in ponds. A relationship between the nutrient loading and the standing biomass in the ponds was observed when the flow rates of AD effluent into the HRAPs were manipulated, and thus hydraulic retention time (HRT) altered. The number of microalgae taxa decreased; chlorophyll a concentration and algal biomass decreased from 1088.91 to 0.00 μg/L and 0.4 to 0 g/L respectively. In conclusion, this study suggests that the operation of HRAPs is strongly influenced by the seasonal variation of environmental parameters and that a HRAP with a surface area of about 15.0 m^2 could treat a maximum of 1800 L/d of effluent effectively.

Key words: freshwater; aquaculture; microalgae; bacteria; metagenomics

15h00-15h20: Richard Taylor (MSc student) - The use of brewery effluent that has been treated using high rate algal ponds and/or constructed wetlands as a water and nutrient source in crop irrigation

Supervisor/s: Dr CLW Jones (c.jones@ru.ac.za); Prof. MD Laing (Laing@ukzn.ac.za)

Brewery effluent can be treated using technologies such as anaerobic (AD), facultative ponds (PFP), high rate algal ponds (HRAP) and constructed wetlands (CW) at the experimental wastewater treatment plant at Ibahyi Brewery (SAB Ltd). There is potential to use this treated brewery effluent as a water and nutrient source in agriculture (i.e. production of crops in soil). However, each of these effluent treatment processes results in brewery effluent having a different set of water quality parameters such as pH, form and concentration of nitrogen, concentration of phosphorous and electrical conductivity (EC). These parameters have been found to affect plant growth and soil fertility. It is therefore essential that the most suitable pre-treatment method of brewery effluent is found so that the nutrients in the effluent are made accessible to the plants without compromising the environment in any way.

The aim of this study was to determine the best pre-treatment method or combination of pre-treatment methods required to make brewery effluent suitable for crop irrigation. This was done by comparing the change in soil characteristics and growth of crops irrigated with effluent to crops irrigated with a conventional irrigation solution. Cabbages were irrigated with brewery effluent subject to either AD, PFP, HRAP, CW or a commercial nutrient solution, with and without pH adjustment. The mass, height, weight, diameter and health of the plants under each irrigation treatment was determined and compared between treatments. Physical, chemical and biological properties of the soil were also recorded to determine the effect each irrigation treatment has on the soil fertility.

Brewery effluent is suitable for use as an irrigation water source and contains sufficient nutrients to support crop growth. The pH adjustment of brewery effluent had no effect on plant growth or the chemical, physical and biological fertility of the soil (Multifactor ANOVA, $p > 0.05$). Post AD or PFP brewery effluent is most suitable for crop irrigation as it contains the highest concentration of plant nutrients and the lowest conductivity. However brewery effluent is an inferior irrigation water source compared to a commercial irrigation water source with added inorganic fertiliser. Post HRAP and CW brewery effluent is least suitable for crop irrigation due to it having the lowest concentration of nutrients and highest concentration of salts. The sodium, chloride and conductivity concentration is the biggest concern when using brewery effluent as an irrigation source as it causes an increase in the SAR, ESP and conductivity of the soil which puts osmotic stress on the plants resulting in reduced growth (Multifactor ANOVA, $p < 0.01$) . The application of post AD and PFP brewery effluent did not significantly decrease the biological and physical fertility of the soil, however after prolonged use it may negatively affect the soils physical structure and reduce the soils biological fertility due to the sodium and chloride present in the effluent. Future studies should investigate the long term effects of irrigating soils with brewery effluent.

Key words: freshwater; aquaculture; effluent treatment; waste water; soil; irrigation

Thursday 8 October 2015

Climate Change (Chair: Alex Winkler)

08h30-08h50: Dr Kelly Ortega-Cisneros (Post-doctoral fellow) - Modelling the impacts of climate change and variability on the southern Benguela system using two complementary modelling approaches

Academic host: Prof. K Cochrane

The southern Benguela system supports a productive fisheries sector including several coastal communities that depend on fishing for their livelihoods. The southern Benguela has been identified as a hotspot of climate and social change because it is warming faster than 90 % of the ocean and is undergoing rapid social change and development at the same time. It is one of five hotspots included in the international GULLS (Global Learning for Local Solutions) project, of which this study forms a part. Our study aims to explore the impacts of climate change and variability on the key species and fisheries in the southern Benguela using the ATLANTIS modelling framework and a minimally realistic model (MRM) (also referred to as a MICE model).

The ABACuS (Atlantis on the Benguela and Agulhas Current Systems) model has been updated and adapted to evaluate the effects of climate change on the Southern Benguela system. The effects of climate change will be simulated using a 100 year time series (2000-2099) of physico-chemical parameters derived from the NEMO − MEDUSA 2.0 models. The possible ecosystem effects of climate change on the southern Benguela and the most vulnerable fishery resources will be assessed. Different catch and management scenarios for the small pelagics fisheries will be tested to identify robust management strategies to climate change.

The MRM models for sardine and anchovy are age-structured biomass models with 3 spatial zones, which cover the major life history migrations, modelled simultaneously. The model equations account for juvenile and adult movement between zones, growth, recruitment, natural and fishing mortality. The growth and natural mortality parameters used in our model are derived from the standard anchovy and sardine stock assessment models used by DAFF for management advice. The model is being fitted to the acoustic survey recruit and adult biomass data (available from 1987 to 2014) by minimizing the negative of a lognormal likelihood objective function. The models will be used to forecast the likely future status of sardine and anchovy stocks under different climate and catch scenarios.

The results of this work are expected to contribute to identifying adaptive strategies that consider ecological and economic trade-offs for the small pelagics fishery while strengthening their resilience to climate change.

Key words: marine; fisheries management; southern Benguela; climate change; ecosystem

08h50-09h10: Willem Malherbe (MSc student) - A vulnerability assessment of five Solomon Islands communities to climate change

Supervisor/s: Prof. S Aswani (s.aswani@ru.ac.za); Prof. WHH Sauer (w.sauer@ru.ac.za)

The Global Understanding for Local Solutions (GULLS) project is a scientific collaboration between seven countries aimed at reducing the vulnerability of marine-dependent coastal communities. Having identified a number of regions which are at risk of increased oceanic warming, global hotspots have been recognized where resource dependent communities are most likely to be affected.

Hotspots are characterized by communities with different stages of social and economic development which relates to differences in the communities' reliance on resources. By assessing the differences in community adaptation techniques at each hotspot, GULLS hopes to develop a climate change adaptation framework for other communities characterised by similar stages of development. Participating experts across various scientific fields will combine to achieve an interdisciplinary approach which includes biological, physical, social and economic considerations before seeking solutions with practical application to vulnerable communities. Solutions will ultimately include providing and implementing adaptation tools to affected communities in order to lower their vulnerability to climate change.

The focus point of the study is the Solomon Islands hotspot, with this region being identified as an area of considerable future oceanic warming. Solomon Islands constitutes communities characterized by low levels of economic development. Five villages were surveyed for a total count of 110 surveys carried out. Surveys comprised a comprehensive questionnaire to determine each of the categories of vulnerability: sensitivity, exposure and adaptive capacity, along with their various components. Data analysis is currently taking place with each vulnerability indicator being scored and constructed into a vulnerability matrix. Preliminary results indicate that all communities are characterised by a subsistence lifestyle with fishing and farming making up the majority of livelihood activities. The high reliance of these rural communities on coastal resources, accompanied with the predicted impacts of climate change, would suggest high vulnerability.

Key words: marine; fisheries management, climate change; vulnerability

09h10-09h30: Jessica Joyner (MSc Student) - An investigation into the relationship between climate change and the abundance of chokka squid, *Loligo reynaudii*, off the Eastern Cape of South Africa

The chokka squid (*Loligo reynaudii*) is a commercially important species in the Eastern Cape of South Africa, providing many families with the means to survive. In the past two years the industry has seen a marked decrease in the abundance of squid resulting in record low catches. This led to the industry undergoing a voluntary closed season of three months over autumn and early winter in 2014. Due to the low catches, speculations have been made about the cause of the low abundance, one of which is the effect of climate change on the productivity of the squid. This study is being conducted in order to establish whether there is a relationship between temperature, upwelling events, wind patterns, chlorophyll-a concentrations and squid abundance.

In order to conduct this study underwater temperature recorder data was obtained from the Department of Environmental Affairs, catch data was obtained from the Department of Agriculture, Forestry and Fisheries, wind velocity and direction data was obtained from the South African Weather Service and chlorophyll-a concentration was obtained from NASA. Due to the lack of updated UTR data an additional diving trip will be conducted in October to dive out the UTR and obtain the latest data. Due to the data being sourced from multiple sources; extensive manipulation and collaboration of the data has been done in order for further investigation into the relationship to be done. The monthly variation in temperature and wind direction and velocity is being used, while monthly average catches are being utilised. The monthly average chlorophyll-a concentration is also being used. This manipulated data will then be used in a statistical program such as R to run a general additive model to attempt to find a quantifiable relationship between environmental parameters and *L. reynaudii* abundance.

This project hopes to find a relationship between climate change and squid abundance in order to provide for a greater insight into the fishery. This could lead to adjustments which could be made to the management measures currently implemented in the fishery and potentially provide the industry with a more sustainable management plan.

Key words: marine; fisheries management; squid; *Loligo reynaudii*; chokka; climate change

09h30-09h50: Kerry-Ann Van der Walt (PhD student) - Thermal tolerance and the potential effects of climate change on coastal and estuarine organisms in the Kariega Estuary and adjacent intertidal coastline

Supervisor/s: Dr NC James (n.james@saiab.ac.za); Dr WM Potts (w.potts@ru.ac.za); Dr F Porri (f.porri@saiab.ac.za)

Temperature is among the primary factors controlling physiological and life history functions in aquatic organisms. It affects growth, recruitment, feeding, mortality and distribution. Aquatic ectotherms are obligate poikilotherms that do not physiologically regulate their temperature but depend on the environmental temperature. Considering global warming scenarios, an increase in temperature may make aquatic ectotherms vulnerable to thermal stress, which could affect their distribution and abundance. Average sea surface temperatures are predicted to increase by up to 3℃ in tropical and temperate seas within the next 100 years. It has been suggested that research into climate change in the marine environment should focus on coastal and estuarine environments, along with their associated fauna, as these environments are shallow and highly dynamic with little thermal inertia, a good indicator of climate change. An understanding of physiological changes is needed to reliably project the effects of climate change on animals, such as fishes. Thermal tolerance is described as a favourable range of temperature or performance breadth. It is measured by an end point, which is usually a loss of equilibrium. By incorporating several taxonomic groups to tolerance studies, one may be able to understand which community components are more vulnerable to warming. There have been very few studies on the thermal tolerance of South African coastal species, particularly fish.

The main aim for this study is to determine the thermal tolerance of various warm-temperate, cool-temperate and tropical fish and invertebrate species from different habitats occurring in the warm-temperate Kariega Estuary and adjacent intertidal environment. To achieve this, the following objectives will be carried out: 1) Evaluate long-term water temperature records from temperature loggers in different habitats (intertidal and estuarine) in the Kariega Estuary and intertidal gullies; 2) Determine the Critical Thermal Maximum (CTMax) and Critical thermal minimum (CTMin) of cool-temperate, warm-temperate and tropical fish species from different habitats (intertidal, benthic and estuarine); 3) Determine the CTMax and CTMin of invertebrate species from different habitats (intertidal and estuarine); 4) Compare long-term water temperature records from the different habitats to upper and lower temperature tolerances of fish and invertebrate species to determine which species live closer to their upper and lower thermal optimal temperatures. Fish species will be collected using beach seine nets, cast nets and hand nets. Invertebrates will be collected with hand nets and dip nets. Organisms will be transported live in aerated containers to the Port Alfred Marine laboratory. CTMax and CTMin, cortisol and heat shock proteins will be used to test thermal tolerance. Research into experimental procedures will be carried out for the duration of 2015. In 2016, field sampling, lab experiments and analysis will take place for both summer and winter. The final year will be dedicated to the writing up of the thesis as well as publishing in peer-reviewed journals. The outcome of this PhD is to contribute to the limited estuarine and marine-ecophysiology linked climate change research in South Africa. As well as to provide new information on the temperature preference of a range of estuarine and marine organisms.

Key words: estuarine; ecology; climate change; temperature; ecophysiology

09h50-10h10: Murray Duncan (PhD Student) - Thermal physiology of the South African linefish; *Chrysoblephus laticeps* **in context of localised exploitation and global change**

Supervisor/s: Dr WM Potts (w.potts@ru.ac.za); Dr NC James (n.james@saiab.ac.za); Dr SE Kerwath (SvenK@DAFF.gov.za)

Funder/s: National Research Foundation (NRF); Rhodes University Sandisa Imbewu Fund

Two of the biggest threats to fisheries are over-exploitation and climate change. Synergistic interactions between these threats can amplify species responses making them more vulnerable to disturbances. An understanding of the pattern and process of vulnerability to fishing effort and climate change is required to disentangle their effects on fish stocks and improve the predictive accuracy of species vulnerability assessments.

Population wide responses to changing sea surface temperature (SST) affects the balance between rates of mortality, growth and reproduction, ultimately resulting in distribution and abundance changes. Changes in physiological rates occur as a first response and underlie observed changes in the distribution and behaviour of fish. Oxygen and capacity limitation of thermal tolerance (OCLTT) theory suggests that marine ectotherms, on an individual level, have a thermal window where physiological performance is maximised and outside of that window fitness is reduced. An understanding of the physiological mechanisms driving responses to climate change is therefore important when predicting population wide changes in light of exploitation. The philopatric South African linefish species; *Chrysoblephus laticeps* is a good candidate species to investigate the effects of both exploitation and climate change as it is subjected to variable spatial levels of exploitation and is distributed in a climate change "hotspot". A multi method approach involving otolith increment width analysis, thermal respirometry and mechanistic modelling will be used to assess the vulnerability of *C. laticeps* to climate change. By comparing specimens from one of the oldest marine protected areas (MPA) in Africa (Tsitsikamma MPA) and a nearby exploited population (Algoa Bay) I hope to elucidate the effects of exploitation on the thermal physiology of *C. laticeps*.

Work has started on historical otolith collections from the 1980's and 1990's. The thermal respirometry and mechanistic modelling components will start in 2016 after relevant permits have been obtained. Respirometry experiments will be conducted at the DIFS Port Alfred Marine laboratory.

Key words: marine; ecology; physiology; red roman; climate change; exploitation; vulnerability

10h10-10h40: Tea break

Fisheries Management (Chair: Richard Peel)

10h40-11h00: Elethu Duna (MSc student) - Progress in implementation of ecosystem approach to fisheries (EAF) in South Africa: principles and practice

Supervisor/s: Prof. KL Cochrane (k.cochrane@ru.ac.za); Prof. WHH Sauer (w.sauer@ru.ac.za)

Effective fisheries management needs to consider humans as an integral part of an ecosystem. The ecosystem approach to fisheries (EAF) differs from other management approaches in that it combines ecosystem management, which strives to conserve ecosystem structure, maintain diversity, productivity and integrity with fisheries management that strives to meet human food and economic needs. The South African Sustainable Seafood Initiative (SASSI) is a consumer outreach and awareness programme, utilising principals of EAF. It aims to address sustainability concerns in the seafood value chain, encourage consumers to buy sustainable species and promote compliance by stakeholders to the Marine Living Resources Act, (MLRA) and the South African Policy for Small Scale Fisheries (SSFP) regulations. The assessment process evaluates 14 questions in3 categories: (1) stock status, which is divided into 3 tracks depending on availability of data, (2) ecological impacts and (3) management measures. Draft assessments are first conducted by a fisheries expert. The process allows for concerned stakeholders to comment, these are reviewed by a panel consisting of different fisheries experts who make a final decision. Of the 65 species assessed, 18.4% are listed as Green, 50.8% are listed as Orange and 30.8% are listed as Red. This study aims to assess how South Africa is progressing in implementing EAF and if there are challenges, determine what they are. To address this aim, the scores of 65 assessments conducted in 2013 and 2014 were obtained from SASSI. Two methods were used to analyse the data; nonmetric multidimensional scaling (NMDS) and cluster analysis, in the statistical program R. NMDS is a multivariate ordination technique that determines community similarity or dissimilarities by making use of a distance measure. Cluster analysis links samples together based on similarities. Analysis of the SASSI assessments indicated that there has been progress made in implementing EAF since the World Summit on Sustainable Development in 2002. The high number of Orange and Red listed species however also indicated that major sustainability issues exists. Commercially important species enjoy a lot of research and management attention compared to other species, including bycatch species, this is reflected by a high proportion of Green rated commercially important species. The inshore trawl was the worst performing fishery with all bycatch species listed as Red. The same species are also targeted by the linefishery and were listed as Orange, indicating the linefishery had less ecological impacts and more effective management measures. The assessments also showed that management measures of pelagic longline and offshore trawl fisheries declined in effectiveness in 2014. Tuna pole was found to have the least ecological impacts. Based on these results, 4 fisheries were chosen for further analysis to determine challenges that exist using ecological risk assessments, DAFF scientific working groups information and published literature.

Key words: marine; fisheries management; EAF; SASSI

11h00-11h20: Tia Jordan (MSc student) - An assessment of the small-scale fisheries in the Kogelberg district of the Western Cape

Supervisor/s: Prof. KL Cochrane (k.cochrane@ru.ac.za); Prof. WHH Sauer (w.sauer@ru.ac.za)

Small-scale fisheries play a critical role to communities through their contribution to food security, poverty alleviation and providing income. The study was aimed at the Kleinmond small-scale fishery and estimated the current economic value of the fishery and potential for increasing this and also whether it is being utilized in a way that ensures sustainable harvesting of the marine resources. It is important to evaluate the ecological, economic and social dimensions of the fishing community in order to address the problems the community are facing. The study looked at previous research done in the area. Information was collected to update and complement the previous research and address the objectives. In order to understand the catch contribution in the area, DAFF data was obtained for the fisheries. Questionnaires were then developed and completed in interviews with the various stakeholders in the value-chain. Interviews were also conducted with other stakeholders through phone calls and focus groups to help supplement the information already gained. Simple economic models were developed for the fisheries working out of the Kleinmond harbour. These models were used to estimate the gross and net economic value of catches for individual right holders, as well as the Kleinmond area as a whole.

The economic models used in this study estimated that the lobster fishery was the primary source of income to the small-scale fishers. This was due to lobster being sold to the export market as a high valued commodity, whereas the linefish are being sold to the local market as a lower valued commodity. However, linefish was found to be more of a culture commodity to the community and a portion is kept for personal consumption. The linefishers have shown concern in that the last couple of years as snoek *Thrysites atun,* has not been found in the area, and the fishing effort has shifted to a resident species Cape bream *Pachymetopon blochii*. Whereas the rock lobster *Jasus lalandii,* is considered to be being harvested sustainably under the current total allowable catch, concern was shown for the future of the fishery because of the illegal fishing taking place in the area and nationally. Small-scale fisheries in Kleinmond community are largely dependent on their fishing resources, even though the industry is only marginally profitable. It is thus paramount through management measures and optimising the value-chain avenues to provide sustainability of the resources and improve the livelihoods for the community. The next step forward will be to address the management suggestions and the way forward to enhance the value-chain, in particular in the linefishery.

Key words: marine; fisheries management; small-scale fishery; Kleinmond

11h20-11h40: Nomonde Ndlangisa (MSc student) - Stock enhancement and ranching of abalone in a rural coastal village, with community development in mind: A pilot study at Hamburg, Eastern Cape, South Africa

Supervisor/s: Prof. P Britz (p.britz@ru.ac.za); Prof. M Roodt (m.roodt@ru.ac.za)

Along the South African coastline, the harvesting of various molluscs and bivalves is important to food security and the livelihoods of those who utilise these resources. In rural small scale fishing communities, stock enhancement and ranching of species such as abalone *Haliotis midae* has the potential to improve the state of the resource while also acting as a driver of rural community development. The objectives of this study were to assess the state of the inshore abalone resource along the coast line at Hamburg Eastern Cape, develop tools to implement a co-management arrangement between the community, industry and government institutions and develop a business model that links the project into value and distribution chains, optimising socio-economic gain from the project.

There were two main components to this study; the first was to assess the state and potential of the resource. This was done by conducting biological surveys which were compared to a previous study at the same location. Reefs supporting abalone with the potential for abalone stock enhancement were identified and mapped using satellite imagery and local knowledge. The second component of this study was to make use of participatory action research to determine ways to build capacity among all the relevant stake holders involved in this partnership. In the small scale fisheries policy promulgated in 2012, co-management is identified as the way forward for effective management of small scale fisheries. Through observations at government and community meetings, interviews and focus groups, concepts for an implementation strategy for co-management, particularly through public-private partnerships were derived.

The biological survey produced similar results to the study conducted in 2006. A low density of juvenile abalone was observed in the infralittoral zone and no emergent abalone were found in any of the quadrats suggesting heavy harvesting pressure by small scale fishers. The PAR confirmed that public private partnerships are a useful tool to drive co-management. With low capacity observed at the community level, poor implementation at the government level and a desire from industry to increase their role in development, rural small scale fisheries provide an ideal environment for partnership. The current policy informing small scale fisheries which has shifted from being purely biological in focus, remains a hindrance to this process as it still employs a top-down management approach, not based on community needs. Public private partnerships create a platform for co-management through skills transfer as they are inclusive, purpose driven and value adding, rather than the rigid cooperative model we see blue printed in the regulations to small scale fisheries released this year.

Key words: marine; fisheries management; participation; development sovereign

Mariculture (Chair: Richard Peel)

11h40-12h00: Adejoke Adesola (PhD student) - Apparent digestibility comparison in dusky kob *(Argyrosomus japonicus)* assessed using three methods of faecal collection and three digestibility markers

Supervisor/s: Dr CLW Jones (c.jones@ru.ac.za); Dr TA Shipton (t.shipton@ru.ac.za)

Funder/s: Marifeed (Pty) Ltd; Technology and Human Resources for Industry Programme (THRIP); MASSIF; Department of Agriculture Forestry and Fisheries (DAFF)

A precise method for estimating digestibility of nutrients is necessary when developing diets suitable for aquaculture species. The objective of the present study was to evaluate the use of three dietary markers (chromic oxide, titanium dioxide and acid insoluble ash), and three methods of faecal collection (modified Guelph system, stripping and dissection method) for the estimation of apparent nutrient digestibility in dusky kob. The three external markers were evaluated at 0.5 % dietary concentrations respectively. Three replicate groups of the fish were used for testing each diet. The duration of the digestibility trial was twenty eight days. Diets were fed to apparent satiation between 08:00h and 10:30h. Each day, 60 minutes after the second feeding, tanks were flushed and the effluent pipes cleaned to remove any residual particulate matter such as faeces and uneaten feed. The following morning, prior to feeding, faecal matter which settled overnight in settlement tank (modified Guelph system) were collected into plastic bottles from the digestibility tank. The strip treatment was performed daily, 6 h following the morning feeding. Digesta were collected by dissection on the last day of faecal collection. For all treatment groups, daily faecal collection were pooled and stored at -20°C until further processing. Apparent dry matter, lipids, energy, crude protein and ash digestibility coefficients were calculated on the basis of the individual markers tested.

Key words: marine; aquaculture; dusky kob; diet

12h00-12h20: Nhlanhla Ginindza (MSc student) - Effect of lipid inclusion levels in aquafeeds on carcass composition, quality change during storage and nutrient excretion in dusky kob *Argyrosomus japonicus*

Supervisor/s: Prof. P Britz (p.britz@ru.ac.za); Dr T Probyn (TrevorP@daff.gov.za)

Dusky kob *Argyrosomus japonicus* is an important aquaculture species that has drawn attention from local investors and researchers to investigate its culture on a commercial scale. This study sought to test the effect of lipid levels in aquafeeds fed to dusky kob juveniles on: (i) growth performance, proximate and fatty acid composition (ii) the chemical changes and shelf-life of refrigerated fillets, and (iii) metabolic rates and nitrogen excretion. Dusky kob juveniles (mean 35.12 g) were fed 4 feeds in triplicates with varying lipid and protein levels containing 8%, 12%, 16% and 20%, hereafter referred to as 8F, 12F, 16F and 20F, respectively. The growth experiment was conducted in a semi-recirculation system for 15 weeks. At the end of the growth trial, 8 fish fillets per treatment were stored at $6.6 \pm 1.5°C$ for 18 days and sampled at 4 day interval to determine changes in quality indicators. The 4 feeds were fed to four groups of juvenile dusky kob in a respirometer to measure excretion and metabolic rates.

Due to a factory artefact, protein content in feeds was not according to planned formulations, hence, may have influenced results. The specific growth rate (SGR) and feed conversion ratio (FCR) were best (ANOVA, $p < 0.05$) in the 8F treatment. Tissue concentration of monounsaturated and polyunsaturated fatty acids were different (ANOVA, $p < 0.05$) and showed no correlations with dietary lipid levels. Consequently, higher dietary lipid levels increased the n-3/n-6 ratios. TVBN values were different (ANOVA, $p < 0.05$) throughout storage and higher in the 16F and 20F treatments. Free fatty acids increased (ANOVA, $p < 0.05$) in all treatments and generally correlated positively with dietary lipid levels. Excreted nitrogenous metabolites were lowest at the 20F treatment although the patterns were similar. These experiments have shown that an increase in dietary lipid levels increases the concentration of tissue polyunsaturated fatty acids and lowers nutrient loss into water. However, higher dietary lipid levels shortens storage life. Further studies are thus required expand on the information obtained from this study.

Key words: marine; aquaculture; dusky kob; quality loss; nitrogen excretion

12h20-14h00: Lunch break

Freshwater Ecology (Chair: Taryn Murray)

14h00-14h20: Richard Peel (PhD Student) - Colonization and succession of fishes in Lake Liambezi, an ephemeral floodplain lake in northeastern Namibia

Supervisor/s: Prof. OLF Weyl (o.weyl@saiab.ac.za); Dr JM Hill (j.m.hill @gmail.com); Dr CJ Hay (clinton.hay@gmail.com)

Lake Liambezi is a large (300 km^2), ephemeral floodplain lake in northeastern Namibia that is fed on an irregular basis by floodwaters from the Zambezi and Kwando rivers. It undergoes cyclical phases of flooding and drying in relation to climatic wet and dry cycles. The lake dried up in 1985 and remained so until the early 2000s, when it was partially inundated and subsequently dried on several occasions before eventually filling in 2009. The floodwaters brought with them a diverse fish fauna that quickly colonised the newly flooded environment, and has undergone significant changes as the lake has matured. The aim of this research is to describe and understand the colonisation process and species successions by i) comparing the recruiting fish fauna from 2001, 2004 and 2007, and describing trends in species composition since inundation in 2007, ii) assessing the life-histories of eight important species representative of different strategies and iii) analysing the food web using stable carbon and nitrogen isotopes.

The colonising fish communities differed significantly between 2001, 2004 and 2007, with numerous species contributing to the dissimilarity between years. This suggests colonisation patterns are largely the result of stochastic dispersal processes on the Zambezi floodplains. The colonising fish community in 2007 was dominated by cyprinids, primarily *Barbus paludinosus* and *Barbus poechii*, and the clariid catfishes *Clarias gariepinus* and *Clarias ngamensis*. The abundance of these species declined rapidly in the first two years after inundation. After refilling in 2009 the barbs were replaced by two small alestids, *Rhabdalestes maunensis* and *Brycinus lateralis*. Larger, slower growing species such as the predatory *Serranochromis macrocephalus* and *Hepsetus cuvieri* have increased more gradually in abundance since refilling. The stable lake conditions favour equilibrium strategists such as cichlids which have thrived. Periodic strategists such as *Schilbe intermedius* show large recruitment pulses in years of inflow from neighbouring floodplains, but poor recruitment in non flood years. Opportunistic strategists have shown mixed responses to increasing stability. Cyprinids have disappeared in the absence of predictable, seasonal flooding while alestids have thrived. Food web analysis showed that the food chain is short and influenced primarily by bottom-up (productivity related) factors. Consumer δ^{13}C values indicate that algal primary production contributes most to consumer biomass, while C$_3$ macrophytes and detritus contribute relatively little. Low levels of isotopic niche overlap between cyprinids and alestids suggests competition was not an import factor in their succession. Competition may, however, have played a role in the succession from *R. maunensis*, which initially replaced the barbs, to *B. lateralis* which now dominates experimental gillnet catches.

Key words: freshwater; ecology; community structure; life history; food web analysis

14h20-14h40: Geraldine Taylor (PhD student) - Comparative fish ecology in three floodplain rivers

Supervisor/s: Prof. OLF Weyl (o.weyl@saiab.ac.za); Dr JM Hill (j.hill@ru.ac.za); Dr CJ Hay (clinton.hay@gmail.com)

Lowland river floodplains are characterised by predictable, seasonal flooding, creating complex habitats and nutrient rich nursery areas for diverse fish communities (Flood Pulse Concept). As a result, floodplain systems are known for their productive multispecies fish faunas which support subsistence and artisanal fisheries providing food, employment, income and livelihoods for riparian communities. The Zambezi and East Kavango Regions of Namibia are home to three large floodplain river systems: the Zambezi, Kavango and Kwando rivers. The aim of this research is to contribute to understanding African floodplain fish ecology by investigating the differences in: physicochemical properties, fish assemblage structure, fish diets, food web structure, and fish growth rates between the three rivers.

Temperature, flood regime, nutrients, water quality, and fish assemblage structure were compared between rivers. Temperature and water quality were very similar, varying seasonally. The Zambezi River had the largest flood (6.14 m), followed by the Kavango (3.8 m) and Kwando rivers (0.65 m). Nutrient levels (nitrate and ammonium) varied seasonally in the Zambezi and Kwando rivers. Total nitrogen levels were highest in the Kwando (0.72 mg/l), followed by in the Zambezi (0.32 mg/l) and Kavango rivers (0.29 mg/l). Fish assemblage structures varied seasonally in the Zambezi and Kavango rivers, where they were most similar, differing greatly from the Kwando River assemblages.

The diets of *Brycinus lateralis, Clarias gariepinus, C. ngamensis, Hepsetus cuvieri, Schilbe intermedius* and *Serranochromis macrocephalus* were described and compared between rivers. *C. gariepinus, C. ngamensis,* and *S. intermedius* were mainly piscivorous in the Zambezi and Kavango rivers, and omnivorous to insectivorous in the Kwando River where sampling occurred during the summer flood. *H. cuvieri* and *S. macrocephalus* were piscivorous in all rivers, with little variation in diets. *B. lateralis* was insectivorous in the Kwando River and maceration greatly inhibited prey identification. Whole ecosystem carbon and nitrogen stable isotope samples were collected from the three rivers, and will be used to describe and compare their food web dynamics. Predator species core niche widths will also be compared between rivers using standard ellipse areas.

The age and growth of the six study species have been compared between rivers. *B. lateralis, H. cuvieri,* and *S. macrocephalus* grew fastest in the Zambezi and Kavango rivers, and slowly in the Kwando River, whereas the growth rates of *S. intermedius*, *C. gariepinus*, and *C. ngamensis* were more variable. Faster growth rates were attributed to larger floods.

In conclusion flood regime was most likely the driving factor influencing fish ecology.

Key words: freshwater; ecology; flood regime; nutrients; diet; food web analysis; growth

14h40-15h00: Lubabalo Mofu (MSc Student) - Reproductive and feeding ecology of the River Goby *Glossogobius callidus* (Teleostei: Gobiidae) from irrigation impoundments in the Sundays River Valley of the Eastern Cape, South Africa

Supervisor/s: Prof. OLF Weyl (o.weyl@saiab.ac.za); Dr DJ Woodford (darraghwoodford@hotmail.com)

The River Goby *Glossogobius callidus* is naturally distributed along the Eastern Seaboard of the South African coastline, between Northern Mozambique and the Cape region of South Africa. In the Eastern Cape region of South Africa *G. callidus* are particularly abundant in both estuarine and freshwater environments, often dominating fish abundances. In the Sundays River system, *G. callidus* is indigenous and is currently distributed in the headwaters of all the major tributaries as well as the main river channel and its in-stream impoundments. In addition, the species has now established in many off-stream artificial impoundments of the region, through natural colonization and inter-basin transfers. Despite the abundance of the species, very few studies have assessed aspects of the biology and ecology of *G. callidus*, with no published information available on the age and growth, reproductive and feeding of adult River Goby.

G. callidus were sampled monthly from August 2013 till March 2015, from the Sundays River Valley Irrigation ponds in the Eastern Cape Province of South Africa. The gonadosomatic index (GSI) was used to assess the breeding season of *G. callidus* (GSI = Gonad mass/ Eviscerated mass x 100). Eggs were counted with the aid of a stereomicroscope to estimate fecundity. Both macroscopic and histological assessments of gonad stage were performed. Stage data was also used to calculate age at 50% maturity for males and females. In total 2054 fishes ranging in length from 21.1 mm to 137.2 mm were sampled. Of the sampled 698 were males and 627 were females and 699 were undetermined sex. Prey items were removed from the stomachs, identified and sorted to obtain the index of relative importance (%IRI) dietary information for each prey group. Of all 571 examined *G. callidus* stomachs 97% contained food items, with only 3% being empty. Analysis of the stomach contents revealed a total of 20 prey items belonging to ten taxonomic groups, with most identified to a broad taxonomic level.

This study revealed that the River Goby are multiple spawners with GSI peaking late spring and midsummer. Logistic ogive described maturity at first 50% as $L_m50 = 70$ mm for females and $L_m50 = 72$ males which rather illustrated late maturity. Individually fecundity ranged between 100 and 950 eggs and was significantly correlated with fish size ($r^2 = 0, 74$). Total fecundity was TF = -3173.8 + 45.577*Length represented positive correlation between total fecundity and length. Furthermore aquatic invertebrates formed the bulk of *G. callidus* diet, this highlights the benthic nature of the later life history stages of the species, a trait well observed in the Gobiidae. The diet of the River Goby seems to therefore represent that of a generalist feeder with insects being the primary prey groups of the later life-history stages in the Sundays River Irrigation ponds.

Key words: freshwater; ecology; Gobiidae, Sundays River Valley Irrigation ponds

15h00-15h20: Modiegi Bakane (MSc student) - Biology and management of Threespot tilapia *Oreochromis andersonii* (Castelnau, 1861) in the Chobe District, Botswana

Supervisor/s: Prof. OLF Weyl (o.weyl@saiab.ac.za): Mr. D Tweddle (d.tweddle@saiab.ac.za)

The threespot tilapia *Oreochromis andersonii* (Castelnau, 1861) is one of the fish species common in commercial fishermen's catches, recreational catches and aquaculture production in the Chobe District of Botswana. Regionally it is widely distributed in the Cunene, Okavango Delta, Kafue and upper Zambezi. In the Chobe district of Botswana it inhabits the main channels, backwaters, lagoons, side channels of Chobe river and associated floodplains, Zibadianja Lagoon and Savuti river and Marsh albeit in low numbers especially in the Chobe River due to heavy fishing. However healthy populations still exist in abundance in protected areas of Zibadianja Lagoon and Savuti marsh where fishing is minimal /prohibited since it is not compatible with park management activities. Generally the cichlids are the most targeted and exploited species and highly regarded as food in the Chobe District of Botswana. The major threat to *O. andersonii* is introduction of alien *Oreochromis niloticus* as a result of aquaculture in the Kafue and upper Zambezi. Furthermore increased population growth hence fishing pressure, use of destructive fishing methods and climate change further leads to rapid declines in fish stocks of Chobe District. Therefore in a quest for sustainable conservation measures the study explores the biology and management of *O. andersonii* by investigating its biology, age, growth and relative abundance in fish communities in the Chobe district then employ management recommendations based on the findings.

Various gears were employed between September 2014 and April 2015 for sampling four habitats/stations. Experimental gillnet catch data demonstrated that the Chobe River differs from Zibadianja Lagoon and Savuti Marsh by having lower CPUE but being most species rich (31 species) as opposed to (25 species) and (24 species) respectively. Future research will assess age and growth and maturity of *O. andersonii* in these habitats.

Key words: freshwater; fisheries management; Cichlidae; biology; *Oreochromis andersonii*

Friday 9 October 2015

Humphrey Greenwood Guest Speaker (Chair: Prof. Warwick Sauer)

08h30-08h40: Welcome and introduction by HOD

08h40-09h30: Judy Mann Error! Bookmark not defined. **– Hold on tight to your dream…**
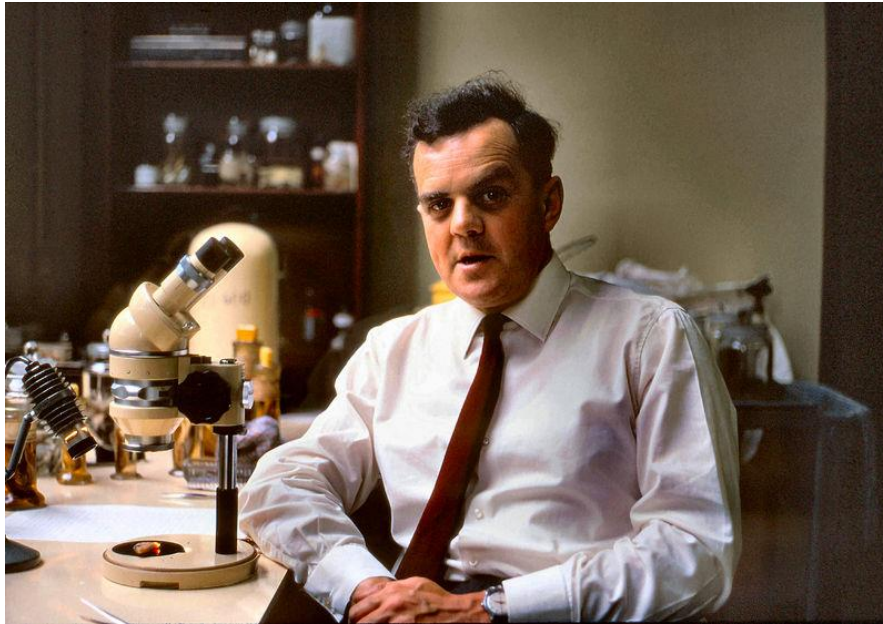
Marine and Estuarine Ecology (Chair: Geraldine Taylor)

09h30-09h50: Taryn Murray (PhD student) - The wanderings of leervis *Lichia amia* (Carangidae), an estuarine-dependent piscivore

Supervisor/s: Prof. PD Cowley (p.cowley@saiab.ac.za); Dr A-R Childs (a.childs@ru.ac.za); Dr RH Bennett (rhettroman@gmail.com)

Leervis *Lichia amia* (Carangidae) is a sought-after estuary-dependent fishery species targeted by recreational, line- and spearfishers and coastal subsistence fishers throughout its local distribution. Increasing levels of juvenile exploitation in estuaries highlight the need to better understand spatial and temporal aspects of estuarine dependency, and connectivity with the neighbouring marine environment. Conventional mark-recapture data obtained from a dedicated tagging study in the Swartkops Estuary was used to investigate movement patterns in the estuary, the degree of estuarine fidelity, and dispersal and habitat connectivity of juvenile leervis. Recapture information provided baseline knowledge on their movement behaviour, however, a more robust assessment of estuarine movements was required. Therefore, passive acoustic telemetry was used to assess area use, movement patterns, residency and multiple habitat connectivity of juvenile leervis. Thirty-eight individuals (233–608 mm fork length), surgically equipped with coded acoustic transmitters, were monitored for one year in the Kowie (n = 21) and Goukou (n = 17) estuaries, situated approximately 620 km apart. Most tagged fish revealed a strong diel rhythm in movement behaviour with others displaying weaker circatidal activity patterns. Certain individuals were also recorded utilising longer stretches of the estuary, specifically over spring tide periods, and movements appeared to be strongly influenced by temperature. One third of the leervis tagged in the Kowie Estuary remained resident during the monitoring period, while others were recorded on receivers deployed in estuaries between 80 km north-east (Tyolomnqa Estuary) to 247 km south-west (Kromme Estuary) of their capture estuary. In contrast, one quarter of the leervis tagged in the Goukou Estuary remained resident, with only four fish (24%) moving to other estuaries 150 km east (Knysna Estuary) to 61 km west (Breede Estuary) of their capture estuary. These telemetry studies also yielded insights into the vulnerability of juvenile leervis as the recapture and subsequent reporting of the transmitters provided estimates of mortality rates. In the Kowie Estuary 33% of tagged individuals were recaptured, while 12% of the juveniles tagged in the Goukou Estuary were recaptured. Findings of this study have provided new insights into the movement behaviour and vulnerability of this recreationally important fishery species.

Key words: estuarine; ecology; mark-recapture; acoustic telemetry; movement behaviour

09h50-10h10: Alexander Winkler (PhD student) - The long shore migratory patterns and inshore habitat use of the Leerfish, *Lichia amia* (Teleostei: Carangidae), in southern Angola using a multimethod approach.

Supervisor/s: Dr WM Potts (w.potts@ru.ac.za); Dr A-R Childs (a.childs@ru.ac.za)

Lichia amia (Linnaeus, 1758), or leerfish, is an important recreational, subsistence and commercial fishery species throughout its cosmopolitan distribution. It is highly abundant in southern Angola where it attracts large numbers of foreign anglers and contributes to the local economy. Despite its economic value, very little is known about the regional connectivity and movement patterns of the species. Current molecular evidence as well as conventional tag recaptures in Namibia from Angola suggests seasonal longshore migrations between these two regions and isolation from the South African population. This population structuring is thought to be a consequence of the cold Benguela Current which forms a biogeographic barrier between the South African and Angolan populations. The aim of this study is to investigate the movement behaviour of sub-adult, and adult *L. amia*, using a multi-method approach (population genetics, tag recapture, catch and effort, acoustic telemetry) in an attempt to understand their habitat utilization and circannual movement patterns in relation to environmental cues.

A total of 2070 *L. amia* were captured during 14137 angler-hours between 2005 and 2014 in southern Angola. Of these, 1667 were tagged with conventional tags. Genetic samples were collected and analysed from individuals captured in southern Angola (n = 20) and central Namibia (n = 11). Thirty nine acoustic listening stations where deployed in September 2013 along a 150 km stretch of coastline in southern Angola covering exposed coastline (Flamingo Lodge (FL)), a large coastal embayment (Baia dos Tigres (BT)) and a small coastal embayment (Tombwa bay (TB)). Twenty mature (670 mm – 1020 mm FL) *L. amia* where tagged internally with coded VEMCO V 16 (2 year battery life) acoustic transmitters in the immediate vicinity of Flamingo Lodge, southern Angola between August and September 2013. Twenty-two underwater temperature loggers were also deployed throughout the array. An additional batch of ten fish (570 mm - 886 mm FL) were tagged in June/July of 2014 with VEMCO V 13 (1 year battery life) acoustic transmitters. The acoustic receivers were serviced in June 2014 and July 2015.

The shared haplotypes of fish captured in Angola and Namibia, a tag recapture in Namibia and seasonal reductions in CPUE in southern Angola provided evidence that the leervis are one population and migrate into Namibia in summer. Ninety-three percent of the acoustically tagged fish were detected on the array, with 26 fish being detected at FL, 19 detected in and around BT and two in TB. Migration, ranging and station keeping behaviour were observed in 60.7 %, 21.4 % and 10.7 % of the individuals, respectively. A large proportion of the migratory fish travelled south through BT from October and returned to FL from May, which coincides with rising and falling water temperatures, respectively. Based on a previous biological study it is likely that the winter spawning event occurs in the FL area. Besides providing critical ecological information, this study has also provided an opportunity to assess the efficacy of different methods for understanding fish movement patterns.

Keywords: marine; ecology; conventional tagging; acoustic telemetry; West Africa

10h10-10h30: Matthew Parkinson (PhD student) - Understanding migration patterns and inshore habitat use of west coast dusky kob *Argyrosomus coronus* in southern Angola using acoustic telemetry techniques

Supervisor/s: Dr WM Potts (w.potts@ru.ac.za); Prof. AJ Booth (t.booth@ru.ac.za)

West coast dusky kob *Argyrosomus coronus* is a warm-temperate coastal sciaenid (occurring to a maximum depth of 100 m) found in northern Namibia and Angola. It is exploited by many fisheries (artisanal, recreational and commercial) during most of its life history stages and, although there is biological information available, information on their movement patterns and migrations is limited. Conventional tagging information showed that juveniles (<600 mm TL) were more resident (57 % recaptured at release site), while sub-adults and adults were more mobile (13 % recaptured at release site). Conventional tagging and catch-per-unit-effort data suggests that adults undergo a seasonal migration, following the shifting Angola-Benguela Frontal Zone (ABFZ) into Angola in winter and into northern Namibia in spring. There is no information on their fine-scale movements and habitat utilisation.

Argyrosomous coronus is closely related to the South African *A. japonicus* and are thought to have been separated from each other as recently as two million years ago during the formation of the Benguela Current. Although the life history of these species is similar, *A. japonicus* has a juvenile estuarine-dependent phase, which is most likely different to *A. coronus* since there is only one functioning estuary throughout its distribution. The aims of this study are to investigate the movement behaviour of juvenile, sub-adult, and adult *A. coronus*, to determine their juvenile habitat utilisation in the absence of estuaries, and to understand environmental triggers and the influence of environmental variables on movement patterns.

Acoustic telemetry equipment and temperature loggers were deployed in 2013 in three representative regions including sections of exposed coastline and two coastal embayments, in southern Angola. Twenty sub-adult/adult (760-1155 mm TL) fish were tagged with coded acoustic transmitters at Flamingo Lodge, southern Angola, during August 2013. A further 10 juvenile/sub-adult fish (460-765 mm TL) were tagged in June 2014.

Adult fish exhibited a partial migration pattern, whereby a proportion of the population migrated south while the majority remained in the Flamingo area. During the 2013-2014 period, three adult fish (>960 mm FL) undertook a southerly movement to Tombua Bay, and during the 2014-2015 a further three adults (>1050 mm FL) made a similar trip. The majority of the juvenile fish left the array between October 2014 and January 2015, with return trips occurring between March and April 2015. When within the Flamingo array, juveniles remained in very small core use areas, normally in the areas where they were tagged and largely restricted to the inshore zone. Adults and sub-adults exhibit greater area use, with the larger fish tending to be more likely to undertake more extensive migrations.

Key words: marine; ecology; area use

10h30-11h00: Tea break

Marine and Estuarine Ecology and Management (Chair: Murray Duncan)

11h00-11h20: Gareth Grant (MSc Student) - Movement patterns of *Rhabdosargus holubi* in the Kowie Estuary, South Africa

Supervisor/s: Prof. PD Cowley (tagfish@gmail.com); Prof. AK Whitfield (a.whitfield@saiab.ac.za); Dr RH Bennett (rhettroman@gmail.com)

Rhabdosargus holubi is a ubiquitous estuarine-dependent fishery species endemic to southern Africa. Although aspects of their recruitment dynamics from sea to estuary have received considerable research attention, little is known about their movement behaviour within estuarine systems. Fishery surveys have revealed that *R. holubi* is a dominant catch species within several temperate estuaries in South Africa. Therefore, investigating movement behaviour is fundamental to understanding its ecology and implementing effective fisheries management strategies. Making use of acoustic telemetry, this study aims to gain a better understanding of the spatial ecology of juvenile *R. holubi* within the permanently open Kowie Estuary. Previous studies have revealed that surgically implanted transmitters may have adverse effects on the physiology and behaviour of fish. Therefore, due to the small size of juvenile *R. holubi* a transmitter-effect experiment was necessary. Dummy transmitters were surgically implanted into juvenile *R. holubi* to evaluate tag retention rate and the effects of the transmitters on recovery, growth and survival. Forty two individuals were kept in three 1m^3 holding cages in the Kowie Marina. Fourteen individuals were assigned to each cage and split into two groups: 7 control and 7 individuals for dummy tag implantation. After 96 days all individuals were sacrificed to assess long-term internal and external effects of the transmitters. Tag retention was 100% with no mortality recorded for both groups. Moreover, transmitter presence did not significantly influence the growth of juvenile *R. holubi*. Apart from one individual, which did not expel its sutures and had some inflammation around the wound area, all the individuals were in a healthy condition and did not appear to be affected by transmitter presence. These results suggest that transmitter presence has little effect on juvenile *R. holubi* and that it is a good candidate for telemetry studies. Consequently, a field experiment on wild fish took place in the Kowie Estuary from 23 October 2014 to 28 February 2015. The study aimed to evaluate the space use patterns and habitat connectivity of 21 juvenile *R. holubi* tagged in three equal batches along the estuary (i.e. 7 individuals within the lower, middle and upper regions, respectively). Twenty-two Vemco VR2W acoustic receivers continuously monitored the presence or absence of tagged individuals. The proportion of time spent at each receiver was calculated for each fish. The tagged fish exhibited varying levels of residency within each release site area (lower = 0.85 ± 0.15; middle = 0.68 ± 0.32; upper = 0.23 ± 0.26). Furthermore, estuarine area use was greater for the upper batch (15.65 ± 6.49 km) compared to the middle and lower batch (7.36 ± 3.68 and 2.67 ± 2 km, respectively). In terms of habitat connectivity *R. holubi* spent the highest proportion of time within the estuarine environment (83%), with the sea (16%) and riverine (1%) environment also being utilised to a lesser extent.

Key words: estuarine; ecology; telemetry; *Rhabdosargus holubi*

Estuaries are productive habitats and biologically important ecosystems as juvenile nursery areas and feeding grounds for adults from a host of fish species. However, they are also threatened habitats, exposed to increasing human disturbance and exploitation. The stocks of several South African estuarine-dependent linefish species are considered as either overexploited or collapsed, including four of the major targeted species; spotted grunter *Pomadasys commersonnii*, dusky kob *Argysomus japonicus*, white steenbras *Lithognathus lithognathus* and leervis *Lichia amia*. It is clear that their dependence on estuaries would warrant the inclusion of these ecosystems into marine reserve planning exercises. Since traditional management strategies (e.g. bag and size limit restrictions) have proven ineffective for estuarine fisheries, there is a need for alternative management measures, such as spatial and temporal restrictions, to ensure increased survival of juveniles and recovery of adult breeding populations. Alternative management strategies that contribute to integrated and effective management of estuaries through the sustainable utilization of fishery resources and/or strategic protection or exclusion of exploited areas would have merit for estuarine-dependent fishery species. The Sundays Estuary, Eastern Cape, South Africa falls within the footprint of the Greater Addo Elephant National Park, with a proposed expansion to include a marine protected area (MPA). However the estuary itself was not considered during the planning of the proposed MPA. Using information collected on the social, biological and institutional aspects of fishery resource utilization on the Sundays Estuary, a sustainability assessment was conducted using an indicator-based approach based on the principles of sustainable development. Indicators were used to highlight the inadequacies of the fishery and provide guidance to future sustainable practices. The results from the sustainability assessment showed that present levels of exploitation, due to the poor institutional capacity by the organisations responsible for fisheries management, are unsustainable (with an overall sustainability index of 28%). An alternative management solution is imperative for future generations to continue benefiting from the Sundays Estuary. Acoustic telemetry is a technique that has been widely adopted to infer habitat and area use patterns of fish species. A better understanding of spatial characteristics of estuarine-dependent fish species such as; estuarine dependency and habitat use patterns are required for effective management. The second component of this study makes use of high resolution telemetry data collected on *A. japonicus* movements within the Sundays Estuary to conduct a scenario-based approach highlighting potential spatial management strategies.

Key words: estuarine; fisheries management; protected areas; spatial-based management

11h40-12h00: Matthew Farthing (MSc student) - Description of the larval and early juvenile ichthyofauna from the exposed beach surf zone and a nearby sheltered coastal embayment in southern Angola

Supervisor/s: Dr WM Potts (w.potts@ru.ac.za), Prof. N Strydom (nadine.strydom@nmmu.ac.za)

The importance of understanding the ecology of the early life stages of fishes is well documented. Studies in the warm-temperate waters of the Eastern Cape, South Africa have found that surf zone habitats host large numbers of larval fishes, including a limited number of "estuarine dependent" species. This study aims to investigate the other warm-temperate biogeographic region in southern Africa, namely the southern Angolan coastline. This region is unique as it contains only one functional estuary, the Cunene, and therefore it is likely that the "estuarine dependent" species may have evolved to utilize the surf zone habitats. The South African and southern Angolan warm-temperate biogeographic zones were linked prior to the formation of the Benguela Current system and consequently, they share a number of common species. Therefore comparative research in these regions can provide insight into the adaptability of several important South African fish to contrasting habitats. This study aims to describe the larval and early juvenile ichthyofauna occurring in the surf zone and a nearby coastal embayment in southern Angola and to describe their habitat preference, seasonality and prey field. This is the first work in the region to focus on fish larvae, and besides making a meaningful contribution to our understanding of the early life stages of its fishes, will also provide comparative information to similar studies in warm-temperate South Africa.

Six surf zone sites (three sandy; three mixed sand and reef) were selected along a 25 km section of coastline. Triplicate tows (25m alongshore) using a 5m x 1.5m beach seine (500μ) were conducted monthly (July 2014 – July 2015). A further eight embayment sites were sampled bimonthly in summer (January 2015) and winter (June 2015) in Tombwa Bay using the same methods. Four sites were within the shelter of the bay, and four were in the immediately adjacent surf zone. Larvae were stored in 5% formalin/seawater solution, and turbidity, salinity and temperature observations were recorded. Bimonthly zooplankton sampling was performed in both summer and winter using a long cone ring net (200μ).

The surf zone was dominated by Sparidae (67%), Gobiidae (13%) and Clupeidae (11%), while the coastal embayment was dominated by Mugilidae (39%), Ammodytidae (32%) and Clupeidae (11%). Abundance (total catch) did not differ significantly between substrate types in the surf zone ($p = 0.42$). In the embayment samples, abundance was significantly higher in the bay than in the adjacent surf zone across both seasons ($p = 0.04$), particularly for Mugilidae ($p < 0.01$), Gobiidae ($p = 0.01$), Blenniidae ($p = 0.04$) and Engraulidae ($p = 0.04$). In contrast, the abundance of Sparidae was significantly higher in the adjacent surf zone than in the bay ($p = 0.01$). The abundance of larvae in the coastal embayment was significantly higher in summer than in winter ($p < 0.01$).

Key words: marine; ecology; warm-temperate; larval ichthyofauna

12h00-12h20: Richard Llewellyn (MSc student) - The effectiveness of the De Hoop Marine Protected Area in the conservation of reef fish and as a tool for fisheries management

Supervisor/s: Dr A Götz (albrecht@saeon.ac.za); Dr A Bernard (ant@saeon.ac.za)

Fisheries are considered a primary driver of the degradation of fish populations. As a result, Marine Protected Areas (MPAs) have been widely implemented as management and conservation tools to protect the populations of exploited fish species and their habitats. Despite this, the scientific basis for an anticipated beneficial effect on fisheries needs to be strengthened. This project aimed to assess the effectiveness of the De Hoop MPA in protecting exploited reef fish stocks and reef biodiversity, as well as to detect any potential benefits from the MPA to the surrounding fisheries. To achieve this, catch data from the surrounding commercial fisheries were analysed to investigate long-term trends in catch per unit effort (CPUE) outside the MPA. In addition, baseline fish assemblage data from inside and outside of the MPA were collected using baited remote underwater stereo-video systems (stereo-BRUVs).

Fisheries catch data from the Nation Marine Line-fish System (NMLS) database for the areas surrounding De Hoop were analysed by means of Generalised Additive Models (GAMs) with integrated smoothness estimation. The results from the GAMs were then examined for any trends in CPUE data for the period from 1985 (start of the data series and implementation of De Hoop MPA) and 2012 (end of currently available data series), with focus placed on the resident reef fish in the catches. The catch data for reef fish showed a steady decline in CPUE until 2000 with a subsequent recovery in later years. The CPUEs was generally similar or higher around the MPA than away from the MPA, with the exception of carpenter. The baseline stereo-BRUVs survey was conducted in March/April 2015, with a total of 102 samples collected from areas open to fisheries exploitation (n = 53) and inside the De Hoop MPA (n = 49). Videos from the stereo-BRUVs were analysed using EventMeasure to extract species composition, abundance (MaxN) and lengths. To investigate the effect of protection *Status* (exploited or protected) on the reef fish community a two-way permutational multivariate analysis of variance (PERMANOVA) and canonical analysis of principal coordinates (CAP) were performed on MaxN and biomass per species data in Primer V6 with the PERMANOVA add-on package.

Preliminary analysis of stereo-BRUVs data indicated that *Status* has a significant effect on the community structure for MaxN ($p < 0.0047$) and biomass ($p < 0.0116$). The fish community in the exploited area was dominated by reef associated ray-finned fish species, while sharks were more prevalent within the MPA. This result is most likely due to habitat differences between the two areas. Although every effort was made to sample similar habitat types within the protected and exploited areas, very little sub-tidal reef could be located in the De Hoop MPA.

Key words: marine; conservation; MPA; fisheries management; stereo-BRUVs

12h20-12h40: Christopher Bova (PhD Student) - Evaluating a normative approach as a tool for improving angler compliance to recreational fishery regulations

Supervisor/s: Dr. WM Potts (w.potts@ru.ac.za); Prof. S Aswani (s.aswani@ru.ac.za)

The recreational fishery in South Africa outnumbers all other fisheries sectors in not only the number of fisherman, but the amount of fish harvested as well. These anglers are bound to a set of regulations that allow for the sustainable management of the fishery and include: permits, bag limits, which reduce overall catch, size limits, which allow a species to reach maturity, closed seasons, which protect certain species at a vulnerable stage of life and prohibited species. Poor compliance in the recreational fishery has been a problem in not only South Africa, but globally for decades and this undermines the objectives of these regulations, weakens the ecological stability of the coastal zone, prevents all forms of development and impairs the government's ability to promote sustainable development of livelihoods. Many methods have been applied to improving compliance in the recreational fishery with the preferred method being increased enforcement. Although increased and improved enforcement has had some success globally, it is a highly costly measure and with much of South Africa's coastline being inaccessible as well as the rampant corruption of law enforcement, this measure is not feasible. Recently, the recreational fishery of South Africa has been found to meet the criteria necessary for a normative approach to be successful. The objective of this project is to evaluate the efficacy of the normative approach to non-compliance. The normative approach uses tools that appeal to morality, legitimacy and norms associated with compliance.

Through the development and implementation of questionnaires and behavioural experiments, this study will (i) use the random response technique determine the extent of non-compliance in South African recreational rock and surf angling, (ii) measure the perceived, injunctive and descriptive behavioral norms of anglers and (iii) test the validity of a normative approach for improving compliance in the recreational fishery. These questionnaires and experiments will be administered to fisherman in three major shore angling regions of the South African coastline, which include the surrounding areas of Cape Town, Port Elizabeth and Durban. The baseline questionnaires will be administered from early 2016 until August of 2016, followed by a knowledge-attitude-behavior campaign which presents the anglers with information on the normative behavior of their peers. The campaign will run for 12 months from start to finish. After the campaign, endline questionnaires and experiments will be conducted in order to measure potential changes in the angler's normative behavior predicting that corrected perception of the descriptive norm would motivate increased compliance in the fishery.

Key words: marine; fisheries management; social norms; recreational fisheries; compliance

12h40-13h00: Shannon Wilsnagh (BSc Hons student) - Attraction of juvenile dusky kob *Argyrosomus japonicus* **to different water types for recruitment**

Supervisors: Dr NC James (n.james@saiab.ru.ac.za), Dr A-R Childs (a.childs@ru.ac.za); Mr J Kemp (j.kemp@ru.ac.za)

Estuaries are important nursery areas for the juveniles of many marine fish species. Although the recruitment of larvae and juveniles of estuary-associated marine fishes into estuaries has been well documented. Little is known about the factors that govern the recruitment response. Such information is important for the identification and prioritisation of estuaries for conservation and management, particularly for estuarine-dependent fishery species. A suite of physical factors have been proposed that may act as cues for larvae and juveniles to locate and recruit into estuaries. These factors include olfactory cues, temperature, salinity and/or turbidity gradients. It has been suggested that olfactory cues of freshwater/estuarine origin may be the primary cue responsible for the recruitment process of estuary-associated species into estuarine nursery areas. An experiment conducted on Cape stumpnose (*Rhabdosargus holubi*) found that post-flexion larvae are able to recognise water from different origins (river, estuary and seawater), probably based on odour. It has been suggested that turbidity gradients may also aid in recruitment into estuaries for species that prefer turbid water. This study will investigate the possible role of olfaction and turbidity on the recruitment process for dusky kob (*Argyrosomus japonicus*), an iconic overexploited estuarine-dependent fishery species. Field studies have shown that dusky kob are predominantly found in turbid estuaries. The aim of this study was to assess the ability of post-flexion dusky kob larvae to differentiate between various water types, based on turbidity and olfactory cues.

Water from the Kariega Estuary, Great Fish Estuary and seawater were collected for comparison. Attraction to a particular water type was measured using a choice chamber. The presence or absence of two physical factors (turbidity and/or olfactory cues) set the differences between each water type. A Students t-test was performed to test the difference in the mean number of dusky kob selecting each particular water type. Preliminary analysis has shown that dusky kob selected Great Fish water over Kariega water and artificially turbid seawater over clear seawater. Experiments based on olfaction (clear Great Fish water against clear Great fish water with no organic odour; and clear Great Fish water against artificial seawater) were inconclusive. These results suggest that post-flexion larval dusky kob use turbidity gradients to locate estuary nursery areas. The results also indicate that turbid estuaries play a critical role in the successful recruitment of dusky kob and hence should be considered in the conservation and management of riverine catchments and of this overexploited fishery species. More information is required on the recruitment mechanisms for other estuary-associated marine species to further understand the recruitment mechanisms and cues responsible for the location of estuaries for recruitment.

Key words: estuarine; ecology; postlarval recruitment; olfactory cues; choice chambers

13h00 DIFS Photograph

Mike Dames (MSc student) - Factors effecting multiple habitat connectivity of *Pomadasys commersonnii* (Haemulidae) in open estuaries in South Africa

Supervisor/s: Prof. PD Cowley (tagfish@gmail.com); Dr A-R Childs (a.childs@ru.ac.za); Dr RH Bennett (rhettroman@gmail.com)

Funder/s: South African-Norway programme for research co-operation (SANCOOP); National Research Foundation (NRF); South African Institute for Aquatic Biodiversity (SAIAB); Save Our Seas Foundation (SOSF)

Spotted grunter, *Pomadasys commersonnii* (Haemulidae), is an iconic linefish species targeted by the recreational and subsistence fisheries in South Africa. Previous studies on the movement behaviour of spotted grunter suggest that they display high residency to their estuarine nursery habitats. However, information on multiple habitat connectivity, for example, multiple estuaries and the degree of connectivity with the marine environment is lacking. To address this knowledge gap, this study aimed to investigate aspects of the spatial and temporal ecology of spotted grunter with emphasis on multiple habitat (estuaries and the marine realm) connectivity. Passive acoustic telemetry was used to track 46 sub-adult and adult spotted grunter (281 – 670 mm TL) tagged in four permanently open estuaries, the Kariega, Bushmans, Sundays and Goukou estuaries. Longshore and "estuary jumping" movements were recorded using data obtained from the Acoustic Tracking Array Platform, with acoustic listening power in many estuaries, ports and embayments along the South African coastline. Preliminary results from fish tagged in the Kariega and Bushmans revealed that they spent the majority of their time in their respective tagging estuaries (55.1 ± 39.4% and 84.7 ± 30.1%). Despite high levels of site fidelity, sea trips were undertaken by 80% and 50% of fish tagged in these estuaries, respectively. Spotted grunter tagged in the Kariega Estuary, on average, made 6.1 ± 3.9 (range: 1 – 13) sea trips while fish from the Bushmans Estuary made 4.9 ± 4.9 (range: 1 – 13) sea trips. Overall, sea-going fish mainly visited estuaries to the west of the tagging estuaries, namely Swartkops and Sundays, and one estuary to the east (Kowie), while the Ngqura port had the most visitations (n = 33). The time spent in other estuaries was, however, low and only contributed 16.9 ± 24.4 % and 0.4 ± 0.8% of the total time monitored, for Kariega and Bushmans fish, respectively. The minimum total distance covered during the monitored period was greater for Bushmans Estuary fish (mean: 244.8 ± 164.8 km, range: 114 – 529 km) than Kariega Estuary fish (mean: 212.7 ± 158.3 km, range: 4 – 519 km). To date, the results suggest that spotted grunter exhibit high fidelity to a single estuary, but also display high levels of connectivity with the marine environment and other estuaries. The findings of this study can assist with the formulation and implementation of effective management strategies to conserve this important fisheries species.

Keywords: estuarine; ecology, acoustic telemetry, connectivity

Stephen John Dünser (MSc student) - The effect of stocking density on the behaviour of farmed South African Abalone, *Haliotis midae*

Supervisor/s: Dr CLW Jones (c.jones@ru.ac.za); Prof. H. Kaiser (h.kaiser@ru.ac.za)

Abalone farming is the largest sector of mariculture in South Africa (DAFF, 2010). Only starting in the 1990s it is relatively young compared to the farming of other haliotids across the world and is growing continually. It is therefore important to identify optimal stocking densities for *H. midae* to increase productive outputs and maximise profits (Rönnbäck, 1999). Farmed South African Abalone (*Haliotis midae*) are space-limited and are currently stocked at 18% of total available surface area. Higher stocking densities lead to decreased growth across all sizes of abalone (Nicholson, 2014). This is known for a number of haliotid species. However, little is known about the behaviour in farmed *H. midae*. This includes grazing on biofilm and feeding on AbFeed® as well as intraspecific behaviour. Other behaviour-related information such as the average time spent locomoting and resting at high and low densities is also unknown.

This research aims to explain why stocking density influences growth of *H. midae* through the study of abalone behaviour. Behaviour will be described and compared at high and low stocking densities using direct and indirect forms of observation. Comparisons drawn from this may lead to advancements in the current farming practices of *H. midae* which will later be tested. These include basket designs and feeding techniques.

Key words: marine; aquaculture; abalone; growth rate

Department of Agriculture, Forestry and Fisheries – Marine Aquaculture Annual Farm Operations Report 2010.

Nichilson GH. 2014. Towards understanding the effects of stocking density on farmed South African abalone, *Haliotis midae*. MSc thesis, Rhodes University, Grahamstown, South Africa.

Rönnbäck P. 1999. The ecological basis for economic value of seafood production supported by mangrove ecosystems. *Ecological Economics* 29: 235-252.

Carla Edworthy (MSc student) - A climate change perspective: the effects of CO$_2$ induced seawater acidification on the physiology and behaviour of *Argyrosomus japonicus*

Supervisor/s: Dr WM Potts (w.potts@ru.ac.za); Dr NC James (n.james@saiab.ac.za)

Climate change is a global phenomenon that is affecting our earth's biological ecosystems. A secondary effect of climate change is ocean acidification, whereby changes in ocean chemistry related to carbon dioxide concentrations in the atmosphere increases carbon dioxide concentrations in sea surface waters and reduces pH. The effect of ocean acidification on calcifying organisms is well documented; however there is a paucity of experimental studies that assess the effects on vertebrates, specifically on fish. Furthermore, the understanding of organism level, physiological responses to changes in ocean water chemistry is in its infancy, particularly in South Africa, despite the fact that such information is important to understanding species level responses to changes in ocean environments as a result of climate change.

This study aims to assess the effect of ocean acidification on *Argyrosomus japonicus* by determining baseline physiological effects. This is an important, estuarine-dependent species that has a complex life history. The larvae of this species are thought to have a predominantly pelagic larval phase after which they recruit into estuaries during the juvenile phase of their life cycle. During their estuarine phase the juveniles are subject to extremely dynamic and fluctuating physico-chemical conditions such as pH. As such, it is expected that the early life stages, which occur in a more stable pelagic environment, are likely to be vulnerable to changing water conditions, which may also influence their physiology and behaviour at a later stage in their life cycle when they enter estuaries. Data on the metabolism and behaviour of the larval stages of *A. japonicus* raised under conditions of three different projected levels of seawater CO$_2$ concentrations will be assessed at Pure Ocean in East London. Similar data will be collected for the later life stages under control conditions in the SAIAB/DIFS eco-physiology laboratory in order to determine whether early exposure to increased seawater CO$_2$ will continue to have an effect. Metabolic measurements will be taken using various sized static and flow through respirometers. Feeding behaviour and activity will be assessed using video analysis. This project is one of only a few physiology studies being conducted in South Africa and will take a novel approach to assessing the effect of climate change on fishes.

Keywords: marine; ecology; larval fish; Ecophysiology; respirometry

Chantel Elston (MSc student) - The ecology of juvenile porcupine rays *Urogymnus asperrimus* at the remote St. Joseph Atoll, Seychelles

Supervisor/s: Prof. PD Cowley (tagfish@gmail.com); Dr RG von Brandis (rainervonbrandis@gmail.com)

Very little information is available on the ecology of tropical stingrays despite concerns over their declining populations. The porcupine ray *Urogymnus asperrimus* is considered a rare species throughout most of its range, however juveniles are abundant at the St. Joseph Atoll (S 5°24.9'; E 53°17.9') on the Amirantes Bank, Republic of Seychelles. This remote atoll is hypothesized to be an important nursery area for these stingrays and in turn these stingrays are hypothesized to play a vital role within the atoll through linking trophic levels and affecting community structure through predation and bioturbation. This study aims to investigate aspects of the spatial and trophic ecology of the juvenile porcupine ray and to determine whether this atoll provides an important habitat to this species (which is listed as Vulnerable by the IUCN). Thirteen juvenile porcupine rays were caught by hand and surgically equipped with acoustic transmitters. Data on their movements were collected by an array of 88 acoustic receivers deployed in and around the St. Joseph Atoll and the neighbouring D'Arros Island. The acoustic monitoring data revealed that porcupine rays displayed a high degree of residency to the atoll (9 out of the 12 rays were detected for more than 50% of monitoring days), with no detections occurring outside the atoll. The rays occurred mostly on the sandflats of the atoll, with the receivers in this habitat recording 88% of all detections. Porcupine rays predominantly stayed in the areas they were caught and displayed small core use areas and activity spaces (mean monthly areas of $0,48km^2$ and $3,21km^2$ respectively). This provides evidence that this remote atoll is an important nursery habitat to these juvenile porcupine rays. Gastric lavage was performed on 55 rays to obtain stomach contents and sediment samples were collected to assess feeding selectivity. Stomach contents revealed that the diet of *U. asperrimus* is dominated by annelids followed by crustaceans (Index of Importance of 78% and 17% respectively). Most prey groups contributed little to the diet in terms of prey-specific volume indicating a generalist diet, but the annelid family Capitellidae was found to be a dominant prey item that the porcupine rays specialize on. Sediment sampling revealed that some annelid families were consumed with moderate preference (feeding selectivity index of $0,11 - 0.25$) while others were consumed with low preference (feeding selectivity index of $0 - 0.09$). All crustaceans, except one family, that were found in the stomach samples were not present in the sediment samples - this could indicate a high selectivity for these crustaceans or it could be a product of the sampling protocol (i.e. there is less chance of sampling deeper and more mobile crustaceans).

Key words: marine; ecology; stingrays; nursery; acoustic telemetry; diet

Bernard Erasmus (MSc student) - Assessing heightened pCO2 on the early development of dusky kob *Argyrosomus japonicus*

Supervisor/s: Dr W Potts (w.potts@ru.ac.za); Dr NC James (n.james@saiab.ac.za)

Anthropogenically-induced ocean acidification is one of the most prominent threats to marine biology and therefore humanity this century. Ocean acidification research is a relatively new field to which its affects have only recently been under investigation. Consequently potential impacts of ocean acidification on ichthyofauna remain unclear and require urgent attention. Up to now ecophysiological research has focused on the effect of heightened pCO$_2$ on externally calcifying taxa, such as echinoderms, corals, plankton and various molluscs. Reduced calcification rates in many of these invertebrate species have been found and further decline is expected as a result of increasing CO$_2$ concentrations. There is a paucity of information on the effect of ocean changes on internally calcifying organisms, including fish. However, fish are considered resilient to lowered pH resulting from carbonation due to their highly effective acid-base regulation system. Despite this, the effect of reduced saturation states of calcium carbonate and its polymorphs aragonite and calcite remain unclear but initial research suggest that the early life stages are the most vulnerable to the effects associated with ocean acidification. Up to now, the several studies have examined the impact of increasing concentrations of pCO$_2$ on growth, survival, skeletal development and otolith formation of marine fishes have produced contrasting results, suggesting that the response may be species dependent.

This study aims to test the potential effects of ocean acidification on fish by simulating future predicted pCO$_2$ concentrations in order to quantify the survival and growth rate and skeletal development and otolith development and gill histology of the early life stages of the sciaenid, *A. japonicus*. The early stages of development will be conducted at Pure Ocean Fish Farm (Pty) Ltd in East London and the long term potential effects investigated at Rhodes University Ecophysiology laboratory in the Eastern Cape of South Africa. Larvae will be randomly collected during six critical early developmental stages, exposed to heightened pCO$_2$ and their morphological and histological development studied.

Key word: marine; ecology; ecophysiology; climate change; ocean acidification; early development

Chris Gornall (MSc Student) - The effect of stocking density on the growth and behaviour of the South African abalone (*Haliotis midae*)

Supervisor/s: Dr CLW Jones (c.jones@ru.ac.za); Prof. H Kaiser (h.kaiser@ru.ac.za)

The profitability of abalone farms is influenced by production per unit grow-out space. Production is a function of abalone growth and stocking density, yet little is known about abalone behaviour. The aim of this study was to gain a better understanding of the behaviour of South African abalone, *Haliotis midae*. Two objectives were formulated. Firstly, to determine how stocking density affects the growth and use of space in the abalone basket; secondly, to characterise abalone behaviour and compare behaviour at a low (18 % of the available surface area, SA) and high (25.5% SA) stocking density.

The first objective was investigated by quantifying the position of abalone in baskets using snapshot photograph over an eight month trial. The behaviour of abalone changed over the course of the trial. The percentage of animals seen on the walls of the basket during night time observations decreased linearly over the 240 days of the experiment (HD: $y = 0.058x + 24.74$, LD: $y = 0.066x + 29.20$). Further changes in behaviour on the rack were observed. Growth was estimated as Weight $= 55.62 + 0.17$ days ($r^2 = 0.97$). The model for the LD treatment was Weight $= 55.29 + 0.19$ days ($r^2 = 0.98$). There was no significant difference in mean individual weight after eight months ($t_6 = 2.01$, $p = 0.09$). The biomass gain per basket was significantly higher (for the HD treatment (9.16 ± 0.57 kg/basket) than the LD treatment (6.82 ± 0.39 kg/basket; $t_6 = 6.74$, $p < 0.001$). This difference equates to 14 kg production in a six basket HD tank when compared to an LD tank.

The second objective was quantified using focal animal follow protocols and quadrat sampling through a clear-sided PVC tank. There appears to be a trade-off between the percentage of abalone locomoting (L) and grazing (G). The ratio of abalone L(%): G(%) was significantly higher at HD (74:18) when compared to LD (49:42) (Chi-square $= 11.14$, Chi-square (table) $= 3.841$, $p < 0.005$). When comparing the proportion of time abalone spent locomoting at night, abalone at HD spent on average 18% more time locomoting when compared to LD (T-test, $t_{46} = 2.67$, $p = 0.01$).

Results demonstrate that abalone are more active (i.e. expend more energy moving around the basket) at a higher density and that they spend less time grazing on diatoms at higher densities than at lower densities. These factors in combination have the ability to influence the growth rate of abalone. Data are currently being analysed.

Key words: marine; aquaculture; photography; observation

Sarah Halse (MSc student) - Towards standardized biodiversity monitoring; an assessment of stereo-video techniques to sample shallow and deep reef-fish assemblages

Supervisor/s: Dr A Götz (albrecht@saeon.ac.za); Dr A Bernard (ant@saeon.ac.za)

In recent years it has become evident that the management and monitoring of fish resources have been inadequate, or inappropriate, to ensure the sustainable utilization of target fish species, and biodiversity conservation. The single and multi-species approach of traditional management is now considered outdated, particularly for reef fish, and there is a drive to implement holistic ecosystem based fisheries management, such as marine protected areas (MPAs). Long-term monitoring is crucial for adaptive and effective management of MPAs and suitable methods must be comprehensive, easily standardized, non-invasive, non-destructive and without depth restrictions. Baited remote underwater stereo-video systems (stereo-BRUVs) are a tool that meet these requirements. However, as with all sampling methods, stereo-BRUVs do have inherent biases. For example, fish demonstrate species specific responses to the type of bait used. One of the main benefits of stereo-BRUVs is that the method can be used over a wide depth range. However, due to the attenuation of light with increasing depth, artificial light sources are required when conducting stereo-BRUVs surveys in the subphotic zone. Consequently the use of artificial light and the choice of light colour may bias the fish behavior. The use of lights under low-light conditions and in the sub-photic depth zone is unavoidable, however it is not a requirement when sampling in the photic zone. For this reason, a field experiment was conducted to measure the effect of artificial illumination on the observed fish community structure when sampling with stereo-BRUVs the photic zone.

The experiment was conducted at two sites in Algoa Bay with a total of 34 samples collected between a depth of 10-30m. Due to logistical constraints the sampling design was unbalanced with 19 illuminated samples and 15 non-illuminated samples collected. The illuminated samples recorded 40 species whilst the non-illuminated samples recorded 33 species. The seven species recorded only in the illuminated samples were rare, being detected only once and at low abundances. Of the more commonly detected species (those observed in >50% of the samples) most were seen at similar frequencies with the exception of *Boopsoidia inornata* and *Poroderma pantherium* which were detected 30% more frequently in illuminated samples. Results from a two-way permutational multivariate analysis of variance (PERMANOVA) showed that artificial illumination had no significant effect on MaxN (p(perm)= 0.5508; p>0.05) or average fish length (p(perm)=0522; p>0.05). A subsequent canonical analysis of principle coordinates (CAP) showed do distinct effect of artificial illumination for both the MaxN and average length data. This suggests that deep-water sampling can be conducted with blue illumination only when needed and without biasing sampling results and data will remain comparable to data sampled without illumination.

Key words: marine; ecology; monitoring; stereo-BRUVs; method

Roxanne Juby (MSc student) - The effect of the diel cycle and depth on a warm-temperate rocky reef fish community, South Africa

Supervisor/s: Dr A Götz (albrecht@saeon.ac.za); Dr A Bernard (ant@saeon.ac.za)

Diel variation in fish assemblages has been documented in marine habitats, however, possible fish movement patterns that drive these observed differences have received less attention. To investigate whether fish movement is a result of photic preferences alone, this study aims to compare fish assemblages between day and night at multiple shallow photic (10-30m) and deep aphotic (60-100m) sites along two continuous and homogenous rocky reef habitats employing baited remote underwater stereo-video systems. The near-shore reef sites chosen for this study include Cape Recife and Riy Banks which are situated in Algoa Bay. Sampling was carried out in June and July 2015, and will continue in March and April 2016.

From this year's results, depth was found to have a significant effect on the observed assemblage with catfish (*Galeichthys* spp.) and small shoaling sparids (Sparidae) dominating the deep and shallow reefs, respectively. Diurnal and nocturnal assemblages were significantly different at the shallow photic zone, with richer assemblages and higher abundances dominated by sparids, an important family in the commercial and recreational local line fisheries. In contrast, there was no significant difference between the diurnal and nocturnal assemblages in the deep aphotic zone. Many of the large top predatory sparids including *Chrysoblephus cristiceps, Cymatoceps nasutus, Polysteganus praeorbitalis* and an apex predator, *Petrus rupestris,* indicated a preference for light as these species were recorded only in the shallow depth zone during the day. In contrast, top predatory shark species, including *Mustelus mustelus, Triakis megalopterus* and *Squalus* sp. showed a dissimilar pattern suggesting their preference for low light conditions. *Squalus* sp. was recorded at the deep aphotic zone throughout the diel cycle and at the shallow zone only at night. It is therefore suggested that this species undergoes diel movement into the shallow depth zone in response to reduced ambient light.

Key words: marine; ecology; stereo-BRUVs; monitoring; diurnal patterns; reef fish

Thomas Keet (MSc student) - Larval-rearing techniques for *Argyrosomus japonicus*, with specific focus on a novel feeding regime

Supervisor/s: Dr T Shipton (ihts@imaginet.co.za); Prof. H Kaiser (h.kaiser@ru.ac.za)

One of the biggest limiting factors in marine finfish aquaculture in RSA is the low survival rate of early stage larvae. Most mortalities can be ascribed to the poor nutritional value of live feeds, cannibalism, and various stressors that result in swim bladder hyperinflation and/or starvation during the larval stage. Opinions in the relevant literature on the best water quality parameters for good survival and growth rates in dusky kob larvae vary. The main objective of this trial is to improve survival rates.

The main experiment will focus on a new feeding regime during the weaning of larvae onto an artificial diet. This is based on findings and recommendations made by Musson & Kaiser (2014). Histological preparations of the development of the gastrointestinal tract of dusky kob larvae from day 1 to 30 after hatching indicate that larvae possess a fully developed fundic stomach and pyloric caeca around 16 DAH. This enables longer feed storage time, more extensive mixing of feed with digestive enzymes and an increased absorption area. An earlier weaning period should increase survival and growth rates, while reducing the labour costs associated with a lengthy period of live feed cultivation.

The relatively short time period needed to conduct the experiment, 30 days, enables replicate trials. Throughout these replications, parameters such as stocking densities, water turbidity, photoperiod and light intensity can be manipulated to find a set of parameters that maximise survival and growth rates. These inter-trial comparisons are an auxiliary outcome of the main experiment. Ten identical round tanks with conical bottoms will be used for the trial. Five randomly selected tanks will be subjected to the standard marine finfish larvae feeding regime currently used in the industry, while the remaining five will be subjected to a new feeding regime that seeks to take advantage of the findings of Musson & Kaiser (2014). Feed availability and quantity will be as comparable as possible between the two treatments. The difference between the two treatments will lie in the timing of first introduction of *Artemia salina* nauplii and then the artificial weaning diet. All other parameters under artificial control will be maintained at a uniform level throughout all 10 experimental units.

Key words: marine; aquaculture; larviculture

Musson M, Kaiser H (2014) Development of the digestive system in dusky kob, *Argyrosomus japonicus*, larvae. Aquacult Int 22: 783-796

Nyiko Mabasa (MSc student) - The effect of carbohydrates on *Argyrosomus japonicus* fed complete pelleted diets

Supervisor/s: Prof. PJ Britz (p.britz@ru.ac.za); Dr CLW Jones (c.jones@ru.ac.za)

The dusky kob, *Argyrosomus japonicus* is an important marine aquaculture candidate species in South Africa. Its aquaculture attributes include factors such as fast growth rates, tolerance to sibling density and easy adaptability to intensive aquaculture conditions. Feed, the largest running cost in any aquaculture operation is the primary economic limiting factor in dusky kob production. In South Africa farmers either have to import high quality aquaculture feed (which is expensive), or use a locally produced feed with poor feed conversion and water stability which may compromise water quality and the growth and health of the fish. The focus of the present project is the development of locally produced, least cost and sustainable feed for dusky kob. Protein/energy requirements for kob have been established in earlier research, and was then used as the basis for the development of a product that compared positively with the international feed. Recent research and experience on farms has revealed that the ability of kob to utilise the starch used to bind the pellets is limited as they lack carbohydrates enzymes.

The aim of this study is to determine the efficiency of dusky kob to carbohydrate in pelleted diets. Specific objectives will be to determine the effect graded levels of carbohydrate on i) growth performance and feed utilization, ii) the effect on post prandial blood glucose and iii) on health and liver glycogen. Juvenile dusky kob will be fed diets containing different levels of pregelatinised maize starch (PGMS). Five diets containing 5, 10, 20 and 30% PGMS will be formulated with fishmeal as the main protein source. A 4 month growth trial will be conducted in an aquaculture recirculating system where the fish will be fed formulated diets twice daily, to satiation. Fish response will be monitored to determine the effect of the diets on growth and feed utilization. At the end of the growth trial some of the fish will be sacrificed and liver dissected for histology and glycogen content analysis. Blood samples will be drawn from the remaining fish at intervals after feeding to determine the rate of glucose clearance from the blood. Insulin levels will also be tested. A glucose challenge will be performed where a known concentration of glucose will be injected into the fish and rate of clearance monitored over time. This is so that rates can be compared to other species that have been given the same concentration of glucose.

Key words: marine; aquaculture; carbohydrate; pregelatinised maize starch

Sisanda Mayekiso (MSc student) - Population genetic structure and biogeography of three wrasse species within the Western Indian Ocean

Supervisor/s: Dr G Gouws (g.gouws@saiab.ac.za); Dr M Mwale (monicam@nzg.ac.za)

The biogeography of the wrasses within the Western Indian Ocean (WIO) is poorly understood, with regard to genetic differentiation or connectivity among the regions of the WIO. This region is a good model for studying the influence of physical complexities and biogeographic breaks in shaping patterns of differentiation in wrasses. Three reef-associated fish species, *Cheilio inermis Thalassoma hebraicum* and *T. lunare* were selected to examine the factors that have influenced patterns of differentiation across the WIO. A molecular genetic approach was used to provide insight into patterns of contemporary and historical connectivity of the three species.

The objectives of this study were to examine genetic differentiation and the relationships among the different geographic regions in the WIO for each target species, and to determine whether the physical complexities of the environment or biological processes of the species affect genetic differentiation of each species. Samples were collected from various localities of the WIO, the Red Sea and Indo-West Pacific Islands. DNA sequence data were generated from two mitochondrial genes (ATPase 6 and cytochrome *b*) and one nuclear locus (first intron of the ribosomal protein S7 gene). Traditional population genetic analyses were used to calculate genetic diversity indices within species, which were then compared among species. Population structure was analysed using AMOVA and pairwise Φ_{ST} to compare and calculate differentiation among the WIO regions. Median joining networks were constructed to examine relationships among haplotypes and alleles.

Overall haplotype or allelic ($h = 0.88$ to 0.98) and nucleotide diversities ($\pi = 0.002$ to 0.014) were high for all species for all gene fragments. The pairwise Φ_{ST} values revealed little to great ($\Phi_{ST} = -0.02$ to 0.67) genetic differentiation between localities, across all species for the three gene fragments. However, AMOVA of the three genes did not find variation among the defined locality group. The widespread and monotypic *C. inermis* revealed genetic differentiation within the WIO. *Thalassoma hebraicum* indicated little genetic differentiation across the WIO. The observed differentiation could be caused by oceanographic features, physical barriers across the species range and the dispersal capabilities and life history features of the species. *Thalassoma lunare* revealed genetic isolation within the WIO, as well as between the WIO and the Red Sea, which is probably due to the shallow strait Bab al Mandab and cold upwelling cells in Somalia.

Key words: marine; ichthyology; molecular genetics; regional differentiation; connectivity

Emily Moxham (MSc student) - Spatial and trophic ecology of bonefish (*Albula sp.*) in the St. Joseph Atoll, Seychelles

Supervisor/s: Prof. PD Cowley (tagfish@gmail.com); Dr R von Brandis (rainervonbrandis@gmail.com); Dr J Bijoux (judebijoux@gmail.com).

Bonefish (*Albula spp.*) support valuable recreational and artisanal fisheries worldwide. In particular, tourism-based flyfishing contributes significantly to the economy of many isolated tropical islands and atolls. Despite their economic value, little is known about the biology, ecology and taxonomic status of bonefish in the Indian Ocean. The overall aim of this project is to contribute to the understanding of bonefish ecology in the Indian Ocean. Specific objectives include (i) understanding the space use patterns and movement behaviour of bonefish using acoustic telemetry and (ii) gaining an insight into the trophic ecology of bonefish using stable isotope analysis. The study is being conducted at the St Joseph Atoll (S 5°24.9'; E 53°17.9') in the Amirantes archipelago of Seychelles. Habitats include sand flats, mangroves, ribbon reefs and sea grass beds surrounding a shallow lagoon approximately 7 km wide. An acoustic telemetry array of approximately 90 Vemco VR2W receivers deployed in and around the atoll provides a platform to monitor the habitat use patterns, site fidelity, fine scale movements and migrations of 30 bonefish surgically equipped with Vemco V13 transmitters during a fieldtrip undertaken in May 2015. The tagged fish will be monitored for 12 months and aspects such as environmental, spatial and temporal movement will be focused on during data analysis. In addition, scales and muscle tissue were collected from 32 bonefish for subsequent stable isotope analysis to investigate the trophic ecology of bonefish at this Indian Ocean atoll.

Key words: marine; ecology; *Albula*, acoustic telemetry; stable isotope analysis

Rachel Mullins (MSc student) - Examining the population structure of yellowfin tuna (*Thunnus albacares*) in southern Africa using a next-generation DNA sequencing technique

Supervisor/s: Prof. WHH Sauer (w.sauer@ru.ac.za); Prof. P Shaw (pws3@aber.uk.za)

Yellowfin tuna (*Thunnus albacares*) is a commercially important oceanic fish species that occupies the tropical and subtropical waters of the world's three oceans. Globally, *T. albacares* is the second most important tuna species in terms of both catch volume and weight. The largest contribution to this catch is taken in the Pacific Ocean, however *T. albacares* also supports important fisheries in the Atlantic and Indian Oceans, including the region surrounding southern Africa. The population structure of *T. albacares* in this region is, however, unclear. Globally, *T. albacares* is considered to consist of four genetically distinct, reproductively isolated populations, with a relatively shallow genetic divergence. Southern Africa's *T. albacares* stocks are currently considered to be comprised of two populations: an Atlantic Ocean population, whose fisheries are regulated by the International Commission for the Conservation of Atlantic Tunas (ICCAT) and an Indian Ocean population regulated by the Indian Ocean Tuna Commission (IOTC). A recent genetic study, upon which this research is based, however found evidence to suggest that South Africa's *T. albacares* may be composed of a single panmictic population. This study, using mitochondrial DNA (mtDNA) markers, found no significant genetic variation among South African *T. albacares* samples, and indicated that individuals from the eastern Atlantic Ocean (southern Africa's west coast) have a higher genetic variation to Atlantic Ocean samples than to Indian Ocean samples; The *T. albacares* stocks in the Atlantic waters of southern Africa may therefore not form a part of the Atlantic Ocean population, but may be an extension of the Indian Ocean population. If this is the case, South Africa's *T. albacares* stocks may be managed as a whole by the IOTC.

It is important for fisheries management that stocks are managed as biological, reproductively isolated population units; it is therefore important to the sustainability of the *T. albacares* fisheries in the South African waters that the species' population structure in this region is further investigated. This study therefore aims to expand on the previous study. The power to detect small but potentially significant differences between Atlantic and Indian Ocean components of the South African *T. albacares* stocks was limited by the shallow depth of the mtDNA marker networks and the small number of nuclear gene loci used in previous studies. To rectify this, this project will include samples from a greater number of locations in the Atlantic and Indian Oceans, and utilise a relatively new next-generation DNA sequencing (NGS) technique that has not previously been used in examining the population structure of *T. albacares*, to identify more variable genome-wide genetic markers, single nucleotide polymorphisms (SNPs).

Key words: marine; fisheries management; *Thunnus albacares*; population structure

Daniel Nkosinathi Mazungula (MSc student) - Morphological and molecular variation in *Amphilius natalensis* (Teleostei: Siluriformes) in southern Africa

Supervisor/s: Dr Albert Chakona (a.chakona@saiab.ac.za)

Amphilius natalensis exhibits a considerable morphological and colour variation across its broad geographical range spanning several geographically isolated river systems that drain an archipelago of mountains from KwaZulu Natal (Umkomaas system), the eastern highlands of Zimbabwe (Lower Zambezi), and to the Ruo River (largest tributary of the Shire river of southern Malawi and Mozambique). The allopatric distribution of populations of this species, suggest that *A. natalensis* may include cryptic species diversity. Sound knowledge of species-level taxonomy and their geographical distribution is required to better manage and conserve remnant populations of freshwater fishes that are threatened by multiple impacts.

The present study therefore aims to re-evaluate the taxonomic status, to investigate the Phylogeography and phylogenetic relationships of *A. natalensis* throughout its distribution in southern Africa, using molecular and morphological data. All specimens were caught using an electro-fisher and were anaesthetized using clove oil and a small piece of muscle tissue or fin clips were sampled and preserved in 99% ethanol in 2 ml eppendorfs with clearly labelled tissue numbers in the field. The voucher specimens were first fixed in 10% formalin in field and were then transferred through a series of washes in alcohol (10%, 50% and lastly 70% for long term storage) in the National Fish Collection at SAIAB. Morphological measurements were done using digital calipers on the left side of the specimen, and recordings were made to the nearest 0.1mm. Morphological data was log transformed to eliminate size effect in the analysis. Preliminary analyses suggest low morphological divergence between populations currently assigned to *A. natalensis*. Sequence data is being generated to determine the degree of genetic divergence between and within populations.

The end results of the study will help resolve the taxonomy of *A. natalensis*, by giving a more accurate understanding and mapping of the distribution ranges of unique lineages within *A. natalensis* in southern Africa. Furthermore, findings from this study will have significant conservation implications as it will identify priority areas to conserve, putting in focus all levels of diversity.

Key words: freshwater; conservation; *Amphilius natalensis*; cryptic species; taxonomy

Phumza Ndaleni (MSc student) - Distribution, biology and ecology of bluegill sunfish *Lepomis macrochirus* populations in the Kariega River system, South Africa

Supervisor/s: Prof. OLF Weyl (o.weyl@saiab.ac.za); Dr RJ Wasserman (ryanwas21@gmail.com); Dr BR Ellender (bru.ellender@gmail.com)

This study focusses on providing a better understanding of the biology and ecology of Bluegill *Lepomis macrochirus* Rafinesque 1819, which is native to Central and North America but was introduced into South Africa in 1939. *Lepomis macrochirus* are listed as category 1b alien invasive in the NEMBA Alien Species Regulations (2014). As a result there is a need for management of this species. Such management requires a sound understanding of the biology and ecology of this species. While the biology and ecology of this fish is well understood in its native range, there is no published information on the biology and ecology of this species in South Africa. This thesis will: (1) assess the distribution and relative abundance of the species in the Kariega system, Eastern Cape; (2) determine growth, maturity, reproduction and diet; and (3) use functional response experiments (e.g. Alexander *et al.* 2014) to assess whether this species has heightened predation effects when compared to *Tilapia sparrmanii*, *Micropterus salmoides* and *Pseudocrenilabrus philander*.

Regarding distributions, sampling has been done on the headwaters of the river and its tributary (Assegaai River) using fyke nets, gill nets, electrofishing and seine netting. All species sampled were identified, counted and measured. Distributions (presence/absence) and relative abundance (catch per unit effort) will then be mapped and assessed in relation to habitat, water quality and the presence or absence of barriers to migration. A total of 239 fyke net nights, 34 gill net nights, 28 sites of electrofishing each with two passes, 25 seine net pulls and 3 tries of hook and line fishing was done. To date, for the biological component of the study, for the age and growth component of the thesis, a minimum of 100 bluegill have been collected for the Winter season and are still under analysis. Spring, Summer and Autumn samples will be collected during 2015 and 2016. The functional response (FR) experiment has already been run whereby the FR's of *L. macrochirus*, *M. salmoides*, *T. sparrmanii* and *P. philander* were compared. *Tilapia sparrmanii* (18%), *P. philander* (7.5%), *Labeobarbus marequensis* (0.4%), *Barbus anoplus* (6.3%), *M. salmoides* (11.7%), *L. macrochirus* (24.3%), *Glossogobius callidus* (7.1%), *Anguilla mossambica* (0.8%) and *Labeo umbratus* (0.8%) have been sampled from the headwaters. There are no results for the biology data as the data is still being analysed. Functional response results revealed that *M. salmoides*, *P. philander* and *L. macrochirus* had the same attach rate. *T. sparrmanii* had the lowest attack rate. *M. salmoides* had the highest handling time followed by *P. philander*, *L. macrochirus* and *T. sparrmanii*.

Key words: freshwater; ecology; *T. sparrmanii, M. salmoides*, *L. macrochirus; P. philander*

Nicholas Schmidt (MSc student) - Optimising detection of fine-scale relationships between reef fish and invertebrate communities using remote imagery sampling techniques

Supervisor/s: Dr ATF Bernard (ant@saeon.ac.za); Dr A Götz (albrecht@saeon.ac.za)

The degradation and modification of reef habitats as a result of modern fishing practices can have long-term effects on benthic invertebrates and the fish species associated with them. Benthic habitats are known to influence the diversity of demersal fish communities, and little is known about how the variability in benthic community structure influences fish distributions. Therefore, understanding the habitat requirements of commercial harvested species can facilitate meaningful management decisions supporting the long-term sustainability of economically important fish species. Often habitat information collected by baited remote underwater stereo video systems (stereo-BRUVs) is used to explain variation in reef fish community structure. This is because stereo-BRUVs provide a measure of the habitat where fish are seen and no additional sampling effort is required. However, using habitat information from stereo-BRUVs ignores the fact that bait can attract fish from neighbouring habitats which may not be visible in the video footage. This has the potential to hide the exact relationship between fish and their habitats.

Data for the study are in the process of being collected at two locations in South Africa; Tsitsikamma National Park MPA and Bird Island MPA. At each location, a 1200m x 1200m study area, from the shallow subtidal (7 m) to approximately 40m depth, was chosen from existing bathymetric maps. At each study area a geo-referenced fine-scale habitat map, documenting bottom type and macro-benthic invertebrate assemblage structure, will be developed from benthic photo-quadrates taken with a Jump Camera. In addition, geo-referenced reef fish assemblage structure will be measured with both unbaited remote underwater stereo video systems (stereo-RUVs) and stereo-BRUVs. The photo quadrats and video footage will be analysed to determine (i) the relationship between reef fish and their habitat, (ii) the effect of bait on this relationship and (iii) if the habitat information obtained from the stereo-B/RUVs can be used to explain fine scale relationships between fish and their habitats.

Initial data collection in Tsitsikamma took place in September 2015 and the outstanding work will be completed by March 2016. Data collection for Bird Island is scheduled to take place in November 2015 and April 2016.

Key words: marine; ecology; marine protected area; monitoring; stereo-BRUVs

Yonela Sithole (MSc student) - A taxonomic re-evaluation of *Gymnothorax undulatus* (Family: Muraenidae) in the Western Indian Ocean

Supervisor/s: Dr M Mwale (monicam@nzg.ac.za); Dr T Miya (t.miya@saiab.ac.za)

The family Muraenidae (moray eels) comprises of 16 marine genera that have approximately 200 described species. However, the group is poorly studied from a phylogenetic perspective with morphological inconsistency within genera mainly due to overlap among characters. Therefore, it is difficult to ascertain the taxonomy of most moray eels. Currently, moray eel species are differentiated by colour pattern, differences in dentition and vertebral counts. The genus *Gymnothorax* Bloch, 1795, is the largest genus of moray eels with about 123 species of which only 20 are found in southern Africa. This genus has been widely used as a catch-all genus for most moray eels that do not fit any of the more specialized recognised genera, with some species of this genus being known only from a single inadequately described species.

The taxonomy of most species *Gymnothorax* is therefore uncertain and in need of revision. For example, the undulated moray *Gymnothorax undulatus* (Lacepède, 1803), an Indo-Pacific coral reef species that is distributed from the Western Indian Ocean (WIO) to the Eastern Central Pacific has notable variations its distribution range. This is also confounded by the absence of information on the type specimen as well as type locality used in its description. Recently, variation in colour pattern of the specimens from some of the mainland areas such as South Africa and oceanic islands in the WIO has been reported. Therefore, this study aims to re-evaluate the taxonomy of *Gymnothorax undulatus* and to clarify its status in the WIO. Morphological data will be used to compare specimens from WIO continental land masses and islands and also to compare the taxonomy of these specimens to those from other biogeographic regions such as Red Sea. Genetic data will be used to examine the levels of genetic variation among localities of *G. undulatus*. Morphometric and meristic characters of 75 specimens housed at SAIAB and Smithsonian museum have been examined for four mainland countries and four island countries in the WIO and four specimens from the Red Sea. Additional specimens from other localities will be included (Natural history museum (Paris, France). Results from this study will help to identify other distinguishing characters that will be useful in the field to separate the species other than the colour pattern.

Key words: marine; ecology; taxonomy; morphology; moray; coral reef; phylogenetic

Timothy Smith (MSc student) - Investigation into the morphological and genetic variation of southern African *Nannocharax* species

Supervisor/s: Dr Albert Chakona (a.chakona@saiab.ac.za), Dr E Vreven (emmanuel.vreven@africamuseum.be)

Nannocharax are a genus of small characins distributed across tropical sub-Saharan Africa. At present, four species of *Nannocharax* are known to occur within the southern African region. These four species have wide distributions across several unconnected river systems, and contact between populations of different river systems is unlikely. Collections of the southern African species have shown noticeable morphological and colour pattern variation, and preliminary molecular analyses indicate that the group is more diverse in this region than previously realised. Investigation into this variation has been undertaken in order to determine the extent of the diversity the southern African representatives of this genus. The purpose of this study is a taxonomic revision of the group in this region.

Specimens and genetic samples housed and accessioned at the Southern African Institute for Aquatic Biodiversity are being used. Specimens were chosen from as many river systems as possible to capture most possible variation. Genetic variation is being determined by investigating the mitochondrial cytochrome oxidase I gene region as well as a nuclear gene region. Morphological analysis is being done using traditional and geometric morphometric techniques and comparison of meristic characters. Other external characters, such as colour pattern and dermal structures will also investigated. Internal structures will be observed and compared using digital x-ray and staining and clearing techniques. Genetic data will be analysed using PAUP. Morphometric and meristic data will be analysed with principal component analyses and discriminant function analyses. Internal morphological characters will be compared visually.

This project hopes to resolve the questions surrounding the taxonomic diversity of *Nannocharax* occurring in southern African river systems, as well as to bring further recognition to the unrecognised diversity occurring within this region.

Key words: freshwater; systematics; morphology; genetic analysis; cryptic species diversity

Warren Witte (MSc student) - Growth of stock enhanced abalone at Cape Recife in the Eastern Cape

Supervisor/s: Prof. P Britz (p.britz@ru.ac.za)

South Africa has legislated a policy of abalone ranching and stock enhancement as a potential means of rebuilding abalone stocks depleted by illegal fishing. Experimental abalone ranching rights have been granted to private companies, who are required to work with research service providers to undertake abalone seeding and assessment of growth and survival. We report on large scale seeding experiments undertaken at Port Elizabeth, South Africa during 2014/15. Commercial-scale surface-scatter seeding of half a million (10 tons) of cultured abalone (25-87mm shell length) was undertaken at 51 sites. In parallel with the seeding experiment, private security was used protect the seeded resource resulting in no detectable illegal fishing. Average survival rates ranged from 29-44% 250 days post-seeding. The effects of two habitat types (coralline versus foliose algae dominated), seeding density and abalone size were investigated in a controlled trial using 36 small-scale experimental plots. After 8-9 months, a lower average growth rate was recorded in the coralline algae dominated habitat ($0.99mm.month^{-1}$ shell length increment) than the foliose algae dominated habitat ($1.78mm.month^{-1}$). Given the promising seeding results, it appears that ranching may be a viable alternative to current fisheries management approach, whereby giving exclusive, long-term access rights will incentive rights holders to invest in stock rebuilding and protection.

Key words: marine; mariculture; abalone ranching; restocking

Chénelle Lesley de Beer (PhD student) - An assessment of the biology and fishery of *Loligo reynaudii* in southern Angola

Supervisor/s: Dr WM Potts (w.potts@ru.ac.za); Prof. WHH Sauer (w.sauer@ru.ac.za); Dr M Lipinski (mrlipinski@nashuaisp.co.za)

Loligo reynaudii, commonly referred to as Lula, plays a critical role in the livelihoods of subsistence and artisanal fishermen in southern Angola. There have also been several unsuccessful attempts in recent years to develop a commercial fishery for this species using fishing techniques developed for the South African squid fishery. Unlike South Africa, the Angolan fishery has not yet been described in any detail, and is currently unmanaged. Comparative morphological and molecular investigations on *L. reynaudii* from southern Angola and South Africa indicate a single genetic population despite the presence of three distinct morphological stocks (Angola, the South African west coast and South African south coast). As a semelparous species, *L. reynaudii* are highly susceptible to environmental fluctuations, with the Angola Benguela Frontal Zone (ABFZ) providing a highly dynamic environment, subject to large-scale interannual and decadal fluctuations. Currently there is no information on the life history and reproductive behavior of Lula in southern Angola, providing an ideal opportunity to examine the life history and reproductive characteristics of this species in this dynamic region.

Preliminary results show Lula to be present only in the south of Angola and undergoing an annual migration; arriving inshore on the fishing grounds in May as sea temperatures become cooler, and departing as temperatures increase in October. Initial results from biological samples collected from the two primary fishing localities (Namibe and Tombua) indicate males to reach maturity at 245.9 mm, and females at 173.2 mm, with a peak in maturity for both sexes coinciding with the movement of squid away from the fishing grounds in October. Interviews with local fisherman, exploratory dives and searching for spawning aggregations using echo sounders in the three primary fishing areas, produced no signs of spawning squid or egg masses; it therefore appears that squid utilize these areas for feeding. Further analysis of the biological and environmental data collected is underway. Questionnaire interviews with fishermen are planned for late 2015, and will provide social and economic information on the importance of the fishery for the livelihoods of those dependent on Lula in southern Angola.

Key words: marine; fisheries management; ecology; *Loligo reynaudii*

Fabien Forget (PhD student) - The associative behaviour and trophic ecology of rainbow runner (*Elagatis bipinnulata*) and oceanic triggerfish (*Canthidermis maculatus*) at floating objects

Supervisor/s: Dr L Dagorn (laurent.dagorn@ird.fr); Prof. PD Cowley (p.cowley@saiab.ac.za)

In the open ocean, numerous pelagic fish species associate with floating objects and regularly form large multi-species aggregations. Tropical tunas including skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*) and bigeye tuna (*T. obesus*), regularly aggregate around floating objects or Fish Aggregating Devices (FADs) in tropical and sub-tropical regions, and are targeted by large purse seine fishing vessels. However, this fishing practice has resulted in 2.8-6.7 times more bycatch (ocean dependant) than when fishing on free swimming tuna schools. Owing to this higher bycatch rate, there is a clear need to investigate bycatch reduction methods in the FAD-based purse seine fishery. In an attempt to address this concern, acoustic telemetry was used to study the behavioural ecology of two major bycatch species, namely the oceanic triggerfish (*Canthidermis maculatus*) and the rainbow runner (*Elagatis bipinnulata*) at floating objects in the western Indian Ocean. The findings indicated that both species displayed moderately long residence periods at FADs with an average of 26.3 days for rainbow runner and 31.1 days for oceanic triggerfish. Additionally, both species displayed a distinct diel pattern in associative and vertical behaviour. During the day, tagged individuals of both species increased their home range by performing excisions away from the FAD and also increased their vertical activity. However, at night the two species remained near the surface, closely associated with the FAD. Aspects of the reproductive biology and trophic ecology of these two species were also investigated. Biological data revealed that most individuals associated with FADs were sexually mature, while dietary analyses indicated that both species feed extensively on pelagic crustaceans and molluscs. The findings of this study suggest that FADs play a key role in the life cycle of oceanic triggerfish and rainbow runner. The vulnerability of these dominant bycatch species in the tropical tuna purse seine fishery should be considered within an ecosystem based approach to the management.

Key words: marine; ecology; bycatch; acoustic telemetry; FADs

Catherine Greengrass (PhD student) - Potential for freshwater crayfish farming in South Africa focusing on *Cherax cainii* aquaculture development

Supervisor/s: Prof. P Britz (p.britz@ru.ac.za)

Funder/s: Agriculture Research Council

Farming of the Western Australian crayfish, Smooth Marron *Cherax cainii*, has been practiced in Australia over 40 years and has spread to several countries, including South Africa. Despite its high value (US$ 37.60 / kg), international production is still low (66 t). Research on farming technology for Marron is considered 'developmental' globally, requiring further research on production related aspects. Farming in South Africa has been practiced since the 1970s on a small-scale – peaking around 2006 with 20 farmers (30 – 40 tonnes) but declining to one farmer producing 3-4 tonnes per year. Marron presents an opportunity for diversification of aquaculture species and development of a high-value niche product. A PhD research project at the Agricultural Research Council is underway, focusing on i) feeding behaviour - feeding time, duration, handling/ingestion associated with different diet treatments (pelleted, organic matter with/without biofilm) and preference between combinations of diets treatments, ii) impact of provision of shelter on growth and survival and potential to use shelter to scale up production capacity in tank culture, iii) impact of supplementation of pelleted feed in communal tank culture with organic matter with/without biofilm on growth and survival, iv) development of a local pelleted feed and benchmarking growth and survival, iv) using findings to generate and test a production model for tank culture and vi) economic feasibility of pond and tank culture within the context of the South African value-chain, including potential for reuse of waste water for hydroponic/aquaponic plant production. Findings of trials conducted to date will be presented.

Key words: freshwater; aquaculture; Marron; feeding behavior; growth; pelleted feed

Philip Haupt (PhD student) - Characteristics and distribution patterns of benthic biotopes and fish assemblages at Aldabra atoll, Seychelles

Supervisor/s: Dr A Bernard (ant@saeon.ac.za); Dr JR Turner (j.turner@bangor.ac.uk)

The aim of the study is to characterise coral reef biotopes, and to quantify the relative abundance and distribution of fish to better understand relationships between habitat and fish assemblages on Aldabra Atoll, Seychelles. This will provide a baseline for coral reef ecosystem structure on a pristine tropical atoll as well as the foundation for marine monitoring and spatially explicit management recommendations for Aldabra Atoll.

The study comprises four research themes:

- Characterise and map the biotopes of the Aldabra Seaward Reef

Reef habitat classes were derived using image processing techniques applied to GeoEye satellite imagery of Aldabra. Ground truthing data were collected using SCUBA and a towed benthic camera. Benthic biotopes will now be characterised from the ground truthing data at a finer scale than habitat classes, and the effect of estimated sediment and exposure gradients will be assessed using multivariate analysis.

- Characterise fish community diversity and relative abundance

Baited and Unbaited Remote Underwater Video systems (B/RUVS) were deployed on reef sites at multiple locations surrounding Aldabra Atoll. Video imagery was assessed to estimate fish diversity and relative abundance (MaxN), using SeaGIS's EventMeasure software.

- The effect of the tides and time of day on the fish assemblage

B/RUVs were deployed during high and low tide, during a spring tide, to determine the effect of tide and time of day on fish assemblages. To discern the effects of time of day, fish assemblage data were compared for the same site during the morning and afternoon hours, on days when two high tides occur. Five replicates across three depths, shallow, medium and deep were collected.

- The relationship between the fish community and biotope

The data derived from the preceding research themes will be used to answer questions concerning the fish and biotope association. Multivariate statistics will be used to detect the patterns of fish community groupings nested within biotopes, in order to understand and characterise the relationship between biotope and fish communities. The key discriminating factors of biotope (e.g. structural complexity, benthic cover) and spatial distribution of artisanal fishing pressure will be analysed to determine the driving forces for fish assemblages within a biotope. Data are currently being processed, and the results are due in the course of 2016. Up to now 300 towed benthic videos were collected, and 30 sites were dived to collect high resolution benthic data, and image analysis. Eleven habitat classes were derived from ground truthing data and an accuracy assessed habitat map was derived. Two hundred B/RUVs videos were collected to characterise the fish community, and an additional 80 for the tidal study.

Key words: marine; ecology; reef; benthic; Aldabra atoll; habitat mapping; biotopes

Justin Kemp (PhD student) - Nutrient utilisation in abalone: Insights from feeding combination diets in the South African abalone *Haliotis midae*

Supervisor/s: Prof P Britz (p.britz@ru.ac.za)

Abalone are generalist herbivores in their natural rocky shore environment, consuming a variety of brown, red and green seaweeds. However, the rapid development of abalone culture in South Africa (300 tons in 2005 to 1070 tons in 2010) was based initially on a single species of wild-harvested kelp *Ecklonia maxima* and is now dominated by the use of formulated feeds. Despite the significant research on nutritional formulations, we know surprisingly little about abalone digestive process, particularly the utilisation of seaweed.

When compared to formulated feed, seaweed appears to be as a nutrient-poor food source in terms of gross protein and energy content. Despite this, abalone have been shown to grow particularly well on a diet of mixed seaweeds under culture conditions. Furthermore, protein utilization of formulated feed has been shown to improve with fresh seaweed supplementation. A growth trial assessing the role of fresh seaweed supplementation into the diet of animals fed a formulated feed was conducted under controlled conditions at the Port Alfred Marine Research Laboratory. Five graded supplementation levels of a "mixed bag" of fresh seaweed (*Ulva sp.*, *Gracilaria sp.* and *E. maxima*) were tested over a 12 month growth-period. In addition to assessing standard production outcomes including growth, feed efficiency and canning yields; a multi-technique approach was adopted in an attempt to gain insights into aspects of nutrient digestion, intermediary metabolism and assimilation under differing dietary regimes.

Under this experimental design, abalone were exposed to multiple nutrient sources in their baskets, ranging from multiple macroalgae classes through terrestrially derived plant products to marine fish-based proteins. This provided an interesting scenario to investigate the use of stable isotopes, a technique usually associated with food web ecology, as a tracing tool to evaluate nutrient deposition in abalone. Analysis on foot muscle samples showed significant differences in the δC^{13} and δN^{15} values for abalone from differing dietary treatments. These data were incorporated into a bayesian mass balance mixing model (SIAR) in order to estimate the contribution of dietary components to muscle deposition. In addition, metabolic studies investigated the energetic costs of digestion, glucose metabolism and protein utilization using intermittent-flow respirometry and appropriate post-prandial sampling techniques. Finally, a time-series histological study assessed diet-driven structural shifts in abalone digestive morphology using standard staining as well as corrosion casting techniques. Analysis of these data are ongoing.

Key words: marine; aquaculture; combination diets; formulated feed; metabolism

Jade Maggs (PhD student) - An evaluation of movement patterns of important fishery species in coastal waters of southern Africa

Supervisor/s: Prof. PD Cowley (p.cowley@saiab.ac.za)

Movement of fishes is an integral part of their daily life, but has significant implications for fishery management. In South Africa's multi-user, multi-gear, multi-species fishery, management is challenging. To complicate matters further, many of the targeted species exhibit complex movement behaviour. Individuals may be highly resident for extended periods before dispersing long distances over short periods of time. Many species also participate in annual migrations, sometimes covering thousands of kilometres along the South African coastline. It is hypothesized that, in this region, certain commonalities exist in fish movement patterns. Understanding these commonalities will aid in the planning of future spatial and temporal management initiatives. This study will synthesize what is currently known of fish movement and migration patterns in South Africa, will investigate the connection between movement patterns and certain life-history characteristics and environmental factors, will generate a classification of movement patterns and discuss fishery management in the context of fish movement behaviour. Firstly, a review of South African fish movement research has already been undertaken, including 101 marine and estuarine fish movement studies from southern Africa published over 87 years from 1928 to 2014 with the aim of synthesising research trends and findings. From 2000 onwards fish movement research featured more often as the primary topic of a publication in contrast to the previous periods where it was more often included as an auxiliary topic within biological or ecological publications. Studies focused on the subtropical and warm-temperate region between Cape Point and Kosi Bay. Some 63% of studies covered only the marine environment, 17% only estuaries and 15% covered both environments, with the remaining 5% confined to laboratory studies. Mark-recapture techniques featured in 69% of studies, while acoustic telemetry, a more recent technological development, featured in only 31%. Most studies were focused on osteichthyes (65%), 33% on elasmobranchs and only two (2%) studies covered both groups. Overall, 26 families were identified in the literature, with endemic sparids featuring in 32% of publications, followed by carcharhinids (16%). Ten movement themes were identified in the surveyed literature, including broad-scale movement patterns, which featured in 68% of studies, followed by fine-scale habitat usage (33%) and protected areas (26%). Major knowledge gaps include a classification of movement types and factors influencing movement behaviour. Secondly, data from the Oceanographic Research Institute's Cooperative Fish Tagging Project, is currently being analysed to look for commonalities in fish movement behaviour so that a classification system can be developed. Mark-recapture data is showing that nearly all 30 species analysed in this study exhibit a varying degree of partial migration, which describes the occurrence of resident and migratory behaviour within a coexisting animal population. These results have significant implications for advancing management effectiveness.

Key words: marine; ecology; management; fish movement behaviour; mark-recapture

Moqebelo Morallana (PhD student) - Assessing and managing the environmental impact of abalone ranching and stock enhancement of the abalone, *Haliotis midae* at Cape Recife

Supervisor/s: Prof. PJ Britz (p.britz@ru.ac.za)

Abalone fishery began in 1949 in Gansbaai and soon expanded to Cape Columbine and Quin Point, where it supported commercial fishery for over 60 years. The entire fishery is dependent on one species, *Haliotis midae*, locally known as "perlemoen". These are highly prized marine molluscs in the Far East. Abalones live in shallow waters less than 10 metres deep, and their sedentary nature make them ideal candidates for commercial exploitation. Throughout the years, unsustainable commercial, recreational and illegal harvesting, coupled with an increasing demand for the resource, led to a significant decline in stocks. The continuous increase in poaching prompted the government to close the commercial fishery in 2008 to allow stocks to recover. Nevertheless, poaching persisted, with over 1 700 tonnes of abalone harvested between 2010 and 2012, this was over ten times the legal total allowable catch. Currently, government's interventions at combating poaching were and are still unsuccessful.

To rebuild declining stocks, the Department of Agriculture, Fisheries and Forestry gazetted and issued experimental abalone ranching and stock enhancement permits to re-seed over-exploited areas along the coast. This study will assess and manage the environmental impact of abalone ranching and stock enhancement on wild abalone populations. The study will be in three components, ecological, genetic and socio-economics. Generally, the ecological component will determine current spawning biomass since re-seeding, conduct stock recruitment and abundance surveys, monitor the survival of hatchery populations, and the potential yield. Genetic component will focus on population dynamics, phylogeography, parentage assignments and monitor the overall health of the stock. Socio-economics will focus on resource governance, poverty alleviation, monitoring of harvesting trends (both legal and illegal), and how to make the fishery more accessible particularly to previously disadvantaged communities. Eventually these components will allow making recommendations regarding long-term sustainability of the fishery.

Key words: marine; fisheries management; abalone; poaching, stock enhancement

Bosupeng Motshegoa (PhD student) - Systematics and biogeography of the mountain catfishes of the genus *Amphilius*, in southern Africa

Supervisor/s: Dr A Chakona (a.chakona@saiab.ac.za); Dr FDP Cotterill (fcotterill@gmail.com)

Mountain catfishes of the genus *Amphilius* (sub-family Amphilinae) are found throughout much of the African continent where they occur in several major river systems. The distribution of these fishes has been divided into two broad groups, the Low African and High African morphological groups. Recent molecular and morphological studies have revealed that the diversity of mountain catfishes in the Low African morphological group has been underestimated, and many of the species that were previously thought to have broad geographical ranges have been shown to be narrow range endemics. A similar scenario is likely to be uncovered for the High African group where only three species (*A. uranoscopus, A. natalensis* and *A. laticaudatus*) are currently recognised. *Amphilius uranoscopus* and *A. natalensis* have unusually broad distribution ranges for freshwater limited taxa, because they occur across multiple isolated river systems from southern to eastern Africa.

The present study is using molecular and morphological data to: (i) investigate the possible existence of cryptic species within mountain catfishes in the High African group, (ii) determine their evolutionary relationships, and (iii) assess the process the drove diversification and shaped contemporary distribution patterns of these fishes.

Comprehensive field surveys were conducted to collect voucher and tissue samples from river systems that represent the entire geographic ranges of *A. uranoscopus*, *A. natalensis* and *A. laticaudatus*. Additional samples will be loaned from other research groups that are working in other parts of Africa. Standard laboratory protocols were followed for DNA extraction, amplification and sequencing. A total of 250 mtDNA COI sequences (500 base pairs) have been generated to date.

Preliminary results indicate high levels of structuring within the currently recognised species. A phylogenetic tree (neighbour joining) obtained from analysis of the COI gene supports the hypothesis that there is hidden diversity within the mountain catfishes of southern Africa. Additional genetic markers (both nuclear and mitochondrial) and morphological data will be generated to determine the taxonomic integrity of the genetic lineages that have been identified from the COI data.

Key words: freshwater; molecular systematics; population structure; species complex

Aldi Nel (PhD student) - A characterization study to investigate the effects of a kelp supplement in the artificial feeds of cultured South African abalone (*Haliotis midae*) on abalone gut microbiota, gut morphology and digestive enzyme activity

Supervisor/s: Prof. P Britz (p.britz@ru.ac.za); Prof. B Pletschke (b.pletschke@ru.ac.za)

Seaweed supplementation promotes growth in locally farmed South African abalone and farms incorporate the kelp *Ecklonia maxima* in the formulated feeds of abalone. However, there is no information available on the effect of kelp level on abalone growth. A combination of seaweed's contribution of micronutrients and bioactive compounds and modulation of the gut microbiota through seaweed has been suggested to promote abalone growth, but these effects need to be established. Seaweed acts as a prebiotic in humans and pigs, and a favourable modulation of the abalone gut microbiota could prevent the invasion of pathogens and yield exogenous digestive enzymes to aid in the abalone's digestive processes.

The aim of this study was to analyse and compare abalone gut bacterial communities, digestive enzyme activities and gut morphological parameters between two groups of farmed South African abalone fed two formulated feeds: a base diet (26 % protein, 0 % kelp; "control diet") and a kelp-supplemented base diet (26 % protein; 0.88 % kelp dry mass; "prebiotic diet"). The commercial value of kelp supplementation in abalone artificial feeds at relatively low levels was established by testing for an interaction between protein and kelp levels on growth by aiming to optimize the level of kelp inclusion.

Farmed abalone (19.4 ± 4.5 g S.D.) were fed twelve experimental diets with graded kelp levels of 0.44, 0.88, 1.77 and 3.54 (% dry mass) at three protein levels of 22, 24 and 26 % in a 2 x 2 factorial experimental design (*N = 6*) for eight months. A reference diet (26 % protein, 0 % kelp) was included for comparison. There was no interaction between kelp level and protein level on abalone mass gain (%) (p = 0.74), and growth (%) increased with protein level (26 > 24 > 22 %; p < 0.00001). No optimal level of kelp inclusion was found within the 26 % protein level, as only the reference diet (41.9 ± 7.3 %) displayed significantly lower mass gains (%) than the kelp-containing diets (65.7 – 74.5 %) ($F_{4,25}$ = 8.4, p = 0.00019). Abalone fed either a prebiotic or control diet for 45 days on-farm displayed no significant differences in amylase, alginate lyase, laminarinase, fucoidanase and protease activities for whole digestive tract extracts (M-W $U_{6,6}$ = 12 - 18, z = -0.88 – 0.72, , p = 0.24 – 1).

In summary, the favourable effect of kelp supplementation on abalone growth was not dose-dependent. Digestive enzyme activity levels did not differ between a kelp-supplemented and a non-supplemented diet for the inclusion level under study, which possibly reflects similarity in diet quality. Results for histology and bacterial comparisons are currently being analysed.

Key words: marine; aquaculture; digestive physiology; gastropods; prebiotics

Lungelwa Nomxego (PhD student) - Spawning patterns of the shallow water hake (*Merluccius capensis*) in the south coast of South Africa

Supervisor/s: Dr M. Lipinski (mrlipinski@nashuaisp.co.za); Prof. WHH Sauer (w.sauer@ru.ac.za)

The focus of the current study is to investigate spawning patterns of the shallow water hake (*Merluccius capensis*) on the south coast of South Africa. One aspect, the development of a revised maturity scale for *Merluccius capensis* in South Africa is described here. A large number of keys for maturity staging have been devised and described in the scientific literature, and the current key used by the Department of Agriculture, forestry and Fisheries is taken from the Botha scale, which consists of five macroscopic maturity stages which have not been validated though histology. This section of the study aims to develop a revised maturity scale. The study area is between 34°- 39 'South and 16°- 28 'East. Samples were collected by both research and commercial vessels during 2014 and 2015 and are currently being processed and analyzed. Non parametric tests are being used to analyze the data; Chi - square tests for identification of % error between macroscopic vs microscopic readings; Spearman rank tests for correlations between dependent parameters; Factorial ANOVAs to analyze stages; t- tests for the difference between two means. Stages are characterized by the most advanced oocytes present. Results indicate six morphological stages validated through histology. Histological assessment included identification of primary growth cells (oogonia and perinucleolar) for stage one; these were also present in all other stages as *M. capensis* is a serial and indeterminate spawner. Stages two to six were identified by the presence of advanced characteristics which included cortical alveoli and primary vitellogenesis (stage 2); secondary to tertiary vitellogenesis and nucleus migration (stage 3); formation of platelets and hydrated oocytes (stage 4,5); numerous postovulatory follicles; thick ovarian wall, muscle bundles and atretic follicles, mostly beta atresia (stage 6). Interestingly the study showed that it is not possible to accurately stage *M. capensis* using only morphological characteristics, with a disagreement of 70- 80% between macroscopic and microscopic results, also supported by other previous studies. Results emphasize the need for the use of validation through histology, although it is both costly and time consuming.

Key words: marine; ecology; histological validation; vitellogenesis; postovulatory follicles

Denham Parker (PhD Student) - An evaluation of sampling and statistical methods for long-term monitoring of subtidal reef fishes: a case study of Tsitsikamma National Park marine protected area

Supervisor/s: Dr A Götz (albrecht@saeon.ac.za); Dr H Winker (henning.winker@gmail.com)

Tsitsikamma National Park (TNP) is the oldest, and one of the largest (350km^2) 'no-take' marine protected areas (MPAs) in Africa. A long-term monitoring (LTM) programme to observe the subtidal reef fishes in the TNP MPA was established in 2007. To date, 243 angling replicates have been completed, and a total of 2751 fish belonging to 41 different species have been caught and released. This dataset already represents the longest and most comprehensive subtidal reef fish abundance estimate in Southern Africa.

Angling data revealed definitive spatial structuring, in the form of spatial autocorrelation, and a shift in viewing spatial dependency as a statistical obstacle to a source of ecological information created a new avenue of data inference. The effectiveness of Generalized Linear Mixed Models (GAMMs) to account for spatial autocorrelation was highlighted, and evidence that disregarding spatial dependencies in temporal analyses can produce erroneous results was illustrated in the case of dageraad (*Chrysoblephus cristiceps*).

Temporal analyses demonstrated that after 50 years of 'no take' protection the TNP MPA ichthyofauna exhibits a high level of stability. However, the inadequacy of angling as a method for monitoring a broad spectrum of the fish species was highlighted, due to its selectivity towards large predators. A novel sampling technique known as Stereo Baited Remote Underwater Videos (stereo-BRUVs) was introduced to the LTM programme in 2013. Stereo-BRUVs enabled sampling of 2640 fish belonging to 52 different species, from 57 samples collected in less than two years. A comparison of the sampling methods concluded that, compared to angling, stereo-BRUVs provide a superior technique that can survey a significantly larger proportion of the ichthyofauna with minimal length-selectivity biases. In addition, stereo-BRUVs possess a higher statistical power to detect changes in population abundance.

To provide a more rigorous method evaluation, simulation testing was employed to assess the ability of angling and stereo-BRUVs to accurately describe a decreasing population. The advantage of this approach is that the simulated population abundances are known, so that each sampling method can be tested in terms of how well it tracks these known abundance trends. The study established that stereo-BRUVs provided more accurate data when describing a distinct population decline of roman (*Chrysoblephus laticeps*) over 10- and 20-year periods. In addition, spawner-biomass was found to be a more accurate population estimate than relative abundance (CPUE and MaxN) due to the inclusion of population size structure information, highlighting the importance of length-frequency data. The study illustrated that an evaluation framework that utilizes simulation testing has the potential to optimize LTM sampling procedures by addressing a number of methodological questions.

Key words: marine; ecology; stereo-BRUV; controlled angling; long-term monitoring

Mpho Ramoejane (PhD student) - Evolution and conservation of Southern African *Labeo* fishes in relation to water management

Supervisor/s: Prof. OLF Weyl (o.weyl@saiab.ac.za); Dr E Swartz (ernst.swartz@gmail.com); Dr B Sidlauskas (brian.sidlauskas@oregonstate.edu).

Labeos are an important food source in developing countries and are used occasionally for angling, spear fishing and in commercial and subsistence fisheries. *Labeos* are known for their specialized sucker lip mouths with which they feed on algae and detritus, thereby playing an important role in controlling the abundance of algae in ecosystems. Four *Labeo* species groups are found in Southern African. The four groups are the South African *Labeo umbratus* group (*L. umbratus*, *L. capensis*, *L. seeberi* and *L. rubromaculatus*) and three Pan-African groups, namely the *Labeo niloticus* (*L. altivelis*, *L. rosae* and *L. ruddi*), *Labeo coubie* (*L. congoro*) and *Labeo forskahlii* (*L. cylindricus*, *L. molybdinus*, *L. lunatus* and *L. ansorgii*) groups. Very little is known about how Southern African *Labeos* relate to each other except for the morphological study of Reid (1985). Understanding how these species relate to each other would not only help in the understanding of the systematic diversity of this genus in Africa but would also help in understanding the vulnerability of its species to hybridisation. Some of the species are under threat due to predation by alien fishes, habitat alterations, man-made barriers to migration and hybridisation with closely related introduced species.

Objectives of the study are:
- To construct a phylogeny of the Southern African *Labeo* species
- Test if the morphological groups proposed by Reids (1985) or if the two major divisions of the African *Labeo* species (Tshibwabwa & Teugels 1995) are monophyletic using southern African taxa
- To assess the validity of the *Labeo umbratus* group as a new genus

To construct the phylogenetic relationships two mitochondrial DNA (cytochrome *b* and cytochrome c oxidase subunit 1) and one nuclear DNA (recombination activating gene 1) genes were sequenced for 275 specimens. Maximum likelihood and parsimony were performed and phylogenetic trees constructed to illustrate species relationships and groups. Phylogenetic relationships between the Southern African *Labeo* species was reconstructed and percentage divergence estimated. Proposed *Labeo* groups have a paraphyletic relationship due to poor support among them but relationships between species within proposed groups have strong support. *Labeo congoro* grouped with *Niloticus* group instead of the *Coubie* group. *Labeo ruddi* does not cluster with *Niloticus* group but is closely related to *L. vulgaris*, which it forms a separate clade with. "*Umbratus* group" is proposed to be a new genus with the name *Abrostomus*, because it is distinct from other *Labeo* groups. Unidentified specimens from Angola are closely related to the *Forskahlii* group. These could be other undescribed species that belong to this group. Estimates of percentage divergence between *Labeo* species revealed that species within monophyletic clades (the proposed *Labeo* groups) have low genetic divergence between them and thus are vulnerable to hybridisation.

Key words: freshwater; conservation; fish; phylogeny, mitochondrial DNA, nuclear DNA.

Ngoako William Selapa (PhD Student) - Effect of selected water quality parameters on production of dusky kob *Argyrosomus japonicus* in aquaculture recirculation systems of South Africa

Supervisor/s: Prof. PJ Britz (p.britz@ru.ac.za); Dr CH Fouche (ChrisF@daff.gov.za)

The challenges facing the dusky kob *Argyrosomus japonicus* in industry include the regulation of water quality parameters that is mainly due to inefficient recirculation aquaculture systems (RAS). In addition, the individual water quality parameter requirements, tolerance and respective effect in the production of dusky kob have not been studied. This study aims to determine the effect of selected critical water quality parameters in production of dusky kob in RAS. The specific objectives of the study are to (i) to quantify the effect of unionized ammonia (NH_3-N) on growth and health of dusky kob (ii) to determine the dissolved oxygen (DO) requirement levels and effect on growth and health of dusky kob (iii) to determine the carbon dioxide tolerance levels and effect on growth and health of dusky kob, at the university's experimental scale. Further objectives at the commercial farms level are to (iv) establish the effectiveness of the components of the commercial dusky kob RAS models in regulating the levels of the selected water quality parameters and (v) determine, *via* production, the relationship between collected water quality parameter data and correlated effect on growth performance of dusky kob. The results of this study will provide an understanding of the dynamics and relationships between water quality parameters through production. The data will be utilized to develop a commercial dusky kob biometric calculator that could be used in planning future dusky kob RAS and will assist current operating dusky kob farms to upgrade the RAS accordingly for dusky kob culture.

Key words: marine; aquaculture; dusky kob; water quality; recirculating systems

Michelle Soekoe (PhD student) - Allopatric variation in *Triakis megalopterus* populations isolated by the Benguela Current

Supervisor/s: Dr WM Potts (w.potts@ru.ac.za); Dr MJ Smale (msmale@bayworld.co.za)

The formation of the cold Benguela Current approximately 2 million years ago led to a marked change in the distribution and abundance of fishes along the west coast of southern Africa. Warm temperate fishes were restricted to either side of the Benguela Current as its cold water formed a barrier to gene flow between these populations. With the timing of the allopatry similar across species, it is possible to quantify the rate of adaptation of the populations in response to the disparate environmental conditions across a range of marine species. Thus, it is possible to better understand the evolutionary processes affecting regional biodiversity by quantifying and comparing the differences in the genotypic and phenotypic adaptation of these species. With a characteristically slow rate of phenotypic change and evolution, Elasmobranch species provide a baseline with which other marine organisms can be compared. Therefore, the aim of this study is to examine the genotypic and phenotypic variation between southern Angolan (AN), Namibian (NA) and South African (WC = Western Cape, EC = Eastern Cape) *Triakis megalopterus* (spotted gully shark) populations. The results presented in this report concentrates on the genetic connectivity of *T. megalopterus* across its southern African distribution.

Triakis megalopterus showed low to moderate levels of genetic diversity based on the haplotype ($h \leq 0.524$) and nucleotide ($\pi \leq 0.0014$) frequencies as well as heterozygosities ($H_E \leq 0.578$). Historical mitochondrial DNA data (median joining network & phylogenetic analysis) showed a southern Benguela vs. northern Benguela subsystem genetic structure with evidence of an EC separation. Contemporary microsatellite data (FCA, F_{ST} and Bayesian clustering analysis) showed a distinct trans-oceanic (Atlantic vs. Indian Ocean) genetic structure. Unfortunately, the lack of a mutation rate estimate for *T. megalopterus* hindered the exact dating of population segregation events. It is, however, hypothesised that the EC separation coincides with the exposure of the Agulhas Bank during the Pleistocene and the extended periods of reef habitat reduction of *T. megalopterus* during the Last Glacial Maximum (LGM). Global biogeographic patterns and well known barriers to gene flow (Cape Agulhas and Cape Point) do not seem to play a role in the population structure of *T. megalopterus*. This difference in structuring may also be indicative of limited female dispersal due to philopatry and contemporary male-mediated gene flow amongst WC-NA-AN. Interestingly, the nDNA F_{ST} data shows a link between WC-NA and WC-AN but not AN-NA. As the NA population inhabits the colder waters of the Benguela Current and the AN population in the warmer waters of the Angolan Current, it may be plausible that *T. megalopterus* consists of a warm and cold water lineage. A pattern also observed in two species of kob (*Argyrosomus japonicus* and *A. inodorus*) from southern Africa.

Key words: marine; ecology; genetics; morphology; elasmobranch; spotted gully

Ralph Watson (PhD Student) - Movement behaviour and feeding ecology of two endemic catsharks (Scyliorhinidae) from South Africa

Supervisor/s: Prof. PD Cowley (tagfish@gmail.com); Dr E Gennari (e.gennari@oceans-research.com)

Nowhere else in the world is the endemism of catsharks (Scyliorhinidae) higher than off the coast of southern Africa. Despite having over 16 species of catsharks, of which 10 are endemic, knowledge of these animals is severely lacking. The purpose of this study is to contribute to the understanding of the spatial and trophic ecology of two common sympatric inshore benthic species, namely the pyjama catshark (*Poroderma africanum*) and the leopard catshark (*Poroderma pantherinum*). More specifically, the study will investigate the relative abundance, movement behaviour, habitat (reef) connectivity, diet and niche overlap of these two co-occurring species in Mossel Bay. The marine fish assemblages and relative abundance of these catshark species will be studied using Baited Remote Underwater Video Systems (BRUVS) that will be deployed at selected reef sites in the bay. Movement behaviour will be studied using acoustic telemetry methods. The existing network of acoustic receivers under the auspices of the Acoustic Tracking Array Platform will be complemented with an additional five receivers that will be deployed at strategic shallow reef sites in the bay. A total of 30 individuals (divided between species and sex) will be internally tagged with V16 coded transmitters and be tracked over a three year period. Stomach contents will be collected through gastric lavage and analysed using a microscope. Prey will be analysed to the lowest possible taxon and quantified by number (N), weight (W) and frequency of occurrence (F). The Index of Relative Importance (IRI) will then be calculated using IRI = (%N + %W) * %F. Using this multi-method approach, a number of research questions will be addressed to gain a better understanding of the spatial and trophic ecology of these ubiquitous, yet under studied, catshark species.

Key words: marine; ecology; acoustic telemetry; gastric lavage; BRUV

Steven Weerts (PhD student) - The influence of connectivity on the fishes of selected estuarine ecosystems in KwaZulu-Natal, South Africa

Supervisor/s: Dr AK Whitfield (a.whitfield@saiab.co.za); Prof. DP Cyrus (cyrusd@unizulu.ac.za)

Connectivity amongst freshwater, estuarine and marine systems is a primary driver of fish assemblages in estuaries and estuarine lakes. Connectivity is defined by a set of linkages that are affected by, amongst other things, the nature of an estuaries mouth, bathymetry, tidal exchange, distance from the sea, hinterland gradient and freshwater flows. These factors in turn are all affected by natural and anthropogenic influences. It is important that the relationship between connectivity and estuarine fish faunas is understood in order to better manage marine, estuarine and freshwater resources. Biological responses, however, are confounded by a multitude of species specific life histories over different time scales. While South African estuaries and their ichthyofauna are relatively well studied, surprisingly little research has been conducted into this aspect of estuarine ecology. This work addresses estuarine connectivity using datasets gathered over the last 20 years. It focusses on representative subtropical systems of KwaZulu-Natal.

Estuarine embayments: The influence of month on populations of closely related fishes with different life history strategies is investigated in adjacent estuarine embayments. Recruitment via a relatively constricted estuarine-marine connection does not limit abundance of estuarine dependent fishes. Differences in recruitment abundances are influenced more by habitat and physico-chemistry. Habitat differences play a key role in some species, especially at the early life stages, and this has impacts on abundances of older fishes. Physico-chemical differences are also important and these are affected by connectivity.

Estuarine lakes: Fish assemblages are investigated in a natural linked lake system. There are significant differences in fish assemblages in different lakes. This is reflected mostly in different abundances of species within a common set of taxa. Fish assemblages from modified coastal lakes are also investigated and a significant impact of flow barriers to the distribution of fishes is demonstrated. The influence of reduced connectivity from marine waters over geological time scales due to natural sea level fall as well as over much shorter contemporary time scales due to anthropogenic impacts (weirs and barrages) is to be explored.

Temporary open-closed estuaries: Mouth condition plays an important role in influencing populations of marine spawned fishes in estuaries and the structure of estuarine fish communities. In South Africa, where estuaries are numerically dominated by temporary open-closed systems, this is an important consideration. This aspect of estuarine connectivity is explored by investigating fish community structure in multiple systems in a single biogeographical zone that range from almost permanently open to almost permanently closed. Species most responsible for community differences are identifiable and their response to mouth closure is predictable.

Key words: estuarine; ecology; fish; connectivity; life histories

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