

Department of Ichthyology and Fisheries Science



Photograph by Olaf Weyl ©

Research Report Series 19



RHODES UNIVERSITY

Department of Ichthyology and Fisheries Science
P.O. Box 94, Grahamstown 6140

October 2007
(Final Version)

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

**Aquafarm Development (Pty) Ltd.
Belgische Stichting Roeping
Benguela Environment Fisheries Interaction and Training Programme
(BENEFIT)
Department of Environmental Affairs and Tourism (DEAT)
Department of Biochemistry, Microbiology and Biotechnology,
Rhodes University (RU)
Deutscher Akademischer Austausch Dienst (DAAD)
East Cape Parks Board
Eastern Cape Development Corporation
ECRAM
EnviroFish Africa
Ernst & Ethel Eriksen Trust
Espadon Marine (Pty) Ltd.
Freestate Nature Conservation
Fresh Tuna Exporters Association
Frontier Programme – Marine & Coastal Management (MCM)
HIK Abalone Farm (Pty) Ltd.
Irvin & Johnson (Pty) Ltd.
Joint Research Council (Rhodes University)
Marifeed (Pty) Ltd.
Marine & Coastal Management (MCM), DEAT
Marine Growers (Pty) Ltd.
Marine Living Resources Fund, MCM
National Research Foundation (NRF)
ORCA (Ocean Research Conservation Africa) Foundation
Research Council of Norway
Roman Bay Sea Farm (Pty) Ltd.
SASMIA
South African Environmental Observation Network – Elwandle Node
South African Institute for Aquatic Biodiversity
South African National Parks
THRIP (NRF)
Water Research Commission (WRC)
Western Indian Ocean Marine Science Association
World Wildlife Fund – South Africa**

**Department of Ichthyology
and Fisheries Science**

Research Report Series 19

October 2007

Edited by: C.L.W. Jones & P. Patrick

Schedule of Events/Table of Content

Wednesday 3 October 2007	1
08h50-09h00: Welcome by Prof. P. Britz (Head of Department)	1
Honours seminars (Chair: Dr O. Weyl)	1
<i>09h00-09h20: Matthew Richardson (BSc Hons. student) – Using stable isotope analysis and gut content analysis to determine trophic position and diet of fishes in the Great Fish River.</i>	1
<i>09h20-09h40: Rosanne Thornycroft (BSc Hons. student) – Diet and trophic position of four fish species in Glen Melville Reservoir.</i>	2
<i>09h40-10h00: Timothy Richardson (BSc Hons. student) – Rapid assessment of the fishery potential of Xonxa Dam near Queenstown, Eastern Cape.</i>	3
<i>10h00-10h20: Michelle Mollatt (BSc Hons. student) – An analysis of subsistence line fishing activity in selected areas of the Wild Coast, South Africa</i>	4
<i>10h20-10h40: John Filmlalter (BSc Hons. student) – The suitability of otoliths, vertebrae and opercular bones as hard parts for ageing yellowfin tuna (<i>Thunnus albacares</i>).</i>	5
<i>10h40-11h00: Fabien Forget (BSc Hons. student) – The genetic structure of the resident sparid <i>Chrysoblephus laticeps</i> in South Africa.</i>	6
11h00-11h25: Tea break	6
Honours seminars continued (Chair: Dr O. Weyl)	7
<i>11h30-11h50: Alice Johnson (BSc Hons. student) – The effect of age and size on cultured abalone (<i>Haliotis midae</i>) gut enzyme activity in early weaning.</i>	7
<i>11h50-12h10: Matthew Naylor (BSc Hons. student) - The effect of diet on growth and enzyme activity of the east coast rock lobster, <i>Panulirus homarus rubellus</i>.</i>	8
<i>12h10-12h30: Keagan Halley (BSc Hons. student) – The effect of the anaesthetic AQUI-S[®] 10 and salinity on ammonia production in juvenile dusky kob (<i>Argyrosomus japonicus</i>).</i>	9
<i>12h30-12h50: Nicholas Nicolle (BSc Hons. student) – The effect of the anaesthetic Aquil-S[®] 10, water temperature and salinity on oxygen levels during transport of two size classes of juvenile dusky kob (<i>Argyrosomus japonicus</i>).</i>	10
<i>12h30-12h50: Rowan Timmer (BSc Hons. student) – The effects of the intensity and colour of light on aggressive behaviour of Dusky kob (<i>Argyrosomus japonicus</i>) under culture conditions.</i>	11
Thursday 4 October 2006	12
Humphry Greenwood Guest Speaker (Chair: Prof. P.J. Britz)	12
<i>08h35-09h20: Samantha Petersen – The realities of implementing an ecosystem approach to fishery management in South Africa.</i>	12
Freshwater ichthyology and fisheries (Chair: E. Thompson)	13
<i>09h20-09h40: Bruce Ellender (MSc student, first year) – A quantitative assessment of the subsistence and recreational fisheries in Lake Gariep, South Africa.</i>	13
<i>09h40-10h00: Henning Winker (PhD student, first year) – What can be learnt from angling competitions in large South African dams?</i>	14
<i>10h00-10h20: Graham Traas (MSc student, first year) – Distribution and relative abundance of the freshwater fishes in the Sundays River System.</i>	15
<i>10h20-10h40: Vusi Mthombeni (MSc student, first year) – The biology of <i>Austroglanis</i> catfishes from the Clanwilliam Olifants river system, South Africa.</i>	16

10h40-11h05 Tea break	16
Marine Fisheries (Chair: H. Winker)	17
<i>11h10-11h30: Amanda Northrop (MSc student, second year) – How important are various data sources and assumptions in stock assessment?</i>	17
<i>11h30-11h50: Russell Chalmers (PhD student, second year) – Assessment of linefish resources within the proposed Greater Addo marine protected area (MPA).</i>	18
<i>11h50-12h10: Bruce Donovan (MSc student, second year) – A re-assessment of the Port Alfred/Kenton-on-sea/Boknes commercial and recreational deep-sea linefishery, with respect to changes in the fisheries management environment in South Africa.</i>	19
<i>12h10-12h30: Hylton Cecil Newcombe (MSc student, first year) – Contribution to the development of a management plan for the baitboat and sport fishery for tuna in South Africa.</i>	21
<i>12h30-12h50: Jessica Escobar-Porras (MSc student, second year) – Movement patterns and a first estimate of population size base on mark- recapture of selected catsharks (Scyliorhinidae) in South African waters.</i>	22
<i>12h50-13h10: Terence Stonier (MSc student, second year) – Microsatellite analysis of chokka squid (Loligo reynaudii) from different spawning aggregations around the South African coast.</i>	23
13h10-14h15 Lunch break	23
Estuarine studies and marine larvae (Chair: R. Chalmers)	24
<i>14h20-14h40: Bronwyn O’Connell (MSc student, second year) – Home range and area use patterns of spotted grunter, Pomadasys commersonnii, in an intermittently open estuary, using acoustic telemetry.</i>	24
<i>14h40-15h00: Phanor Montoya-Maya (MSc student, second year) – Dynamics of ichthyoplankton and zooplankton from selected cool temperate estuaries in South Africa.</i>	25
<i>15h00-15h20: Paula Patrick (MSc student, second year) – Composition, abundance, distribution and seasonality of larval fishes in the shallow nearshore zone of the proposed Greater Addo Marine Reserve, Algoa Bay, South Africa.</i>	26
<i>15h20-15h40: Peter Watt-Pringle (MSc student, third year) – Post-settlement movement behaviour of blacktail (Diplodus sargus capensis), zebra (Diplodus cervinus hottentotus) and white musselcracker (Sparodon durbanensis).</i>	27
Friday 6 October 2006	28
Mariculture (Chair: G. Paulet)	28
<i>09h20-09h40: Alistair Green (MSc Student, second year) – The development of a high temperature maintenance diet for the South African abalone Haliotis midae.</i>	28
<i>09h40-10h00: Caryn McNamara (PhD student, second year) – Haematology of the South African abalone, Haliotis midae.</i>	29
<i>10h00-10h20: Rowan Yearsley (MSc student, second year) – Water quality and growth on a South African abalone Haliotis midae farm and the potential for integrated mariculture.</i>	30
<i>10h20-10h40: Andrea Bernatzeder (MSc student, second year) – Salinity induced physiological responses of dusky kob, Argyrosomus japonicus (Family: Sciaenidae).</i>	31
10h40-11h05 Tea break	32
Mariculture (Chair: C. McNamara)	32
<i>11h10-11h30: Maryke Musson (MSc student, first year) – Prediction of larval viability based on various egg and larval quality characteristics in dusky kob, Argyrosomus japonicus.</i>	32

<i>11h30-11h50: Lindsey Woolley (MSc Student, first year) – The development of an artificial feed for the South African finfish industry by adapting local technologies developed for the abalone industry, using dusky kob as a model species.</i>	33
<i>11h50-12h10: Paul Collett (MSc student, second year) – Early rearing technology of juvenile dusky kob, <i>Argyrosomus japonicus</i>.</i>	34
<i>12h10-12h30: Guy Paulet (PhD student, second year) – Towards the development of a suitable pelleted diet for the East Coast rock lobster, <i>Panulirus homarus rubellus</i>.</i>	35
<i>12h30-12h50: Ernst Thompson (PhD student, third year) – Characterization of alkaline digestive enzymes in fish larvae – implications for nutritional studies of larval finfish</i>	36
Marine fisheries continued (Chair: C. McNamara)	37
<i>12h50-13h10: Serge Raemaekers (PhD student, fourth year) – Fisheries Governance of two high value resources in the Eastern Cape, South Africa.</i>	37
Non-presenting students	38
<i>Rhett Bennett (MSc student, third year) – Optimisation of a sampling protocol for long-term monitoring of temperate reef fishes.</i>	38
<i>Naomi Richardson (MSc student, third year) – A preliminary investigation into the use of biomarkers and a fish community index to assess estuarine health in selected Eastern Cape estuaries.</i>	39
<i>Albert Esterhuizen (PhD student, second year) – The development of an artificial weaning diet for the South African abalone, <i>Haliotis midae</i>.</i>	40
<i>Michael Markovina (MSc, third year) Flatfish sperm physiology.</i>	41
<i>Justin Kemp (MSc student, second year) – The effect of temperature on the growth and survival of juvenile wild-harvested <i>Panulirus homarus rubellus</i> in a partial-recirculating system.</i>	42
Index: funder, supervisor and author	43

Wednesday 3 October 2007

08h50-09h00: Welcome by Prof. P. Britz (Head of Department)

Honours seminars (Chair: Dr O. Weyl)

09h00-09h20: Matthew Richardson (BSc Hons. student) – Using stable isotope analysis and gut content analysis to determine trophic position and diet of fishes in the Great Fish River.

Supervisors: Prof. A. Booth (t.booth@ru.ac.za) and Dr O. Weyl (o.weyl@ry.ac.za)

A sufficient understanding of trophic relationships is vital to a wide range of ecological studies. Past techniques used to determine trophic interactions have included gut content analysis and stable isotope analysis. Gut content analysis focuses on the short-term, describing instantaneous diet composition but failing to elucidate long term assimilation. Stable isotope analysis, by contrast, can be used to identify trophic levels, and elucidate longer-term pathways and origins of carbon and nitrogen so as to reveal direct and indirect trophic interactions between producers and consumers.

The objectives of this study were to use gut content analysis (GCA) and stable isotope analysis (SIA) to get an understanding of the food web structure within the Great Fish River. Six fish species commonly found within the river system were investigated. Fish were caught using fyke nets, gill nets, a larval seine and by hook and line.

The gut content analysis comprised an occurrence method, an indirect volumetric method and a gravimetric method. Muscle tissue samples were taken from all fish, as well as for all potential food sources that were collected in and around the river.

The GCA focussed on catfish and yellowfish due to low catches of the other species. Although 17 mosquitofish were caught, stomach contents were unidentifiable. Of the identified food types, simuliids and aquatic beetles were the most common in the catfish stomachs, while fruits and seeds contributed the largest volume. In the yellowfish stomachs, simuliids and aquatic insects from the order Hymenoptera were most frequently recorded, but again, fruits and seeds constituted by the main volume of their diet. A relative importance index (RI) showed that for catfish, fruits and seeds, aquatic beetles, and frogs were the most important, whereas caddisflies, and simuliids were most important for the yellowfish

The stable nitrogen ratios from the isotope analysis suggested the presence of three main trophic levels: (1) the primary producers consisting of phytoplankton, detritus, particulate organic matter (POM), land vegetation and riparian vegetation; (2) aquatic insects and small mosquitofish; (3) yellowfish, catfish and remaining mosquitofish. The carbon ratios of many of the producers and consumers were highly variable, which made it difficult to link consumers to any specific carbon source. Aquatic insects and detritus, however, seemed the most likely food sources of the yellowfish, which was consistent with the findings from the gut content analysis. The number of potential food sources for catfish were more diverse than for yellowfish, which suggest a catholic diet. Riparian vegetation, detritus and aquatic insects appeared to be the main carbon sources of the mosquitofish. Diet within species were relatively constant, however there was indication of a change in diet with length for catfish.

In summary, results of both GCA and SIA provide evidence of a complex food web structure, comprising multiple potential primary carbon sources with a large degree of variation. This variation and complexity is characteristic of lotic systems, where spatial variation in habitat is far more pronounced allowing for greater diversity in carbon sources.

09h20-09h40: Rosanne Thornycroft (BSc Hons. student) – Diet and trophic position of four fish species in Glen Melville Reservoir.

Supervisors: Dr O.L.F. Weyl (o.weyl@ru.ac.za) and Prof. A.J. Booth (t.booth@ru.ac.za)

Stable isotope analyses (SIA) are becoming increasingly common in dietary studies in aquatic systems. SIA allows for both the elucidation of trophic position and potential food sources. When used in conjunction with traditional gut content analyses, SIAs can provide an additional insight into the variation in fish diets over long-term periods as gut content analyses provide a short-term snapshot of food sources.

To better understand the trophic ecology of Glen Melville Reservoir, a 76 ha water supply reservoir near Grahamstown, Eastern Cape, both gut content and SIA were conducted on four fish species. These were *Clarias gariepinus*, *Cyprinus carpio*, *Labeobarbus aeneus* and *Labeo umbratus*. Ninety-three fish were sampled between May to July of 2007 using gillnets, fyke nets and hook and line. Muscle tissue was collected from 36 specimens and gut content analysis was undertaken on 53 specimens. Gut contents were preserved for analysis and muscle tissue was removed from the fish and dried in a 60°C oven to constant mass for stable isotopic analysis.

Stable isotope ratios of $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ were used to quantify trophic position (TP) of consumers and primary producers. Four distinct trophic levels were noticeable from the $\delta^{15}\text{N}$ analysis. Epilithic algae, phytoplankton, Cyanophytes and terrestrial plants were considered primary producers, and zooplankton, aquatic insects and tadpoles were primary consumers, *C. carpio* and *L. umbratus* were secondary consumers. Tertiary consumers included leeches, *C. gariepinus* and *L. aeneus*.

$\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ ratios for length class showed that catfish obtain their carbon from the same source as length class increases however enrichment takes place raising their mean $\delta^{15}\text{N}$ with an increase in size. *C. carpio* and *L. umbratus* show $\delta^{13}\text{C}$ depletion with increasing length class whereas *L. aeneus* shows $\delta^{13}\text{C}$ enrichment with increasing length class.

Detritus and mud dominated the total volume of *C. carpio* and *L. umbratus* diets at 60.7% and 30.3%, respectively. *Labeo umbratus* also consumed a high proportion of algae (26.3 %). *L. aeneus* guts were volumetrically dominated by zooplankton (72.8%) and plant matter (16.6%). *C. gariepinus* stomach contents contained 67 % plant matter and 17% fish remains. In terms of frequency of occurrence, different consumer patterns were evidence. Insects occurred in 71 % of *L. aeneus*, 67 % of *C. carpio* and 25 % of *C. gariepinus* stomachs. Zooplankton was present in 71 % of *L. aeneus* stomachs. Grass seeds were present in 64 % and 63 % of *L. aeneus* and *C. gariepinus* stomachs, respectively. Algae was present in 12.5% of *L. umbratus* stomachs. An index of relative importance (IRI) was calculated and converted to a percentage. IRI showed that detritus and mud were the most important component in the diet of *C. carpio* (IRI = 82%) and that zooplankton was the most important component in the diet of *L. aeneus* (IRI = 87%). Plant matter was the most important in the diet of *C. gariepinus* (IRI = 63%). There was no clearly important dietary component in *L. umbratus* with algae, detritus and plant matter having an IRI of 34%, 30% and 15%, respectively. Variation between results from SIA and gut content analysis could be due to the different temporal patterns of diet represented by the two techniques.

09h40-10h00: Timothy Richardson (BSc Hons. student) – Rapid assessment of the fishery potential of Xonxa Dam near Queenstown, Eastern Cape.

Supervisors: Dr O.L.F. Weyl (o.weyl@ru.ac.za) and Prof. A.J. Booth (t.booth@ru.ac.za)
Funder: EnviroFish Africa; Benguela Environment Fisheries Interaction and Training Programme (BENEFIT)

In Africa, small reservoirs have been identified as having considerable importance for the provision of food security. Most inland rural communities of South Africa lack a fishing history and dams in such areas are often underutilized from a fisheries perspective. Fish resources of inland water bodies in the Eastern Cape have been identified as a renewable natural resource that, if utilized effectively, could be developed for local economic gain to aid in countering the high levels of poverty and unemployment. Xonxa Dam in the Eastern Cape was originally constructed for irrigation purposes with no attention being paid to the potential utilization of fish resources in the system. The objective of this study was to investigate the fishery potential of Xonxa Dam and make management recommendations to ensure that the resources are used in an effective and sustainable manner. Three short sampling trips to Xonxa Dam were undertaken in 2007. The fish population was sampled using experimental gillnets, longlines, fyke nets and a seine net. The total catch of each gear set was recorded by mass and number. Each fish was weighed, measured and sexed, and when possible, otoliths were removed. Fish were aged by counting growth zones on the otoliths, under the assumption that these zones are deposited annually. A total of 677 fish were sampled over the study period and included smallmouth yellowfish, *Labeobarbus aeneus*; African sharptooth catfish, *Clarias gariepinus*; common carp, *Cyprinus carpio*; and longfin eel, *Anguilla mossambica*. *Cyprinus carpio* and *A. mossambica* were not caught in sufficient numbers to support a fishery and thus their potential could not be assessed. *Labeobarbus aeneus* was the most abundant species by number but *C. gariepinus* was the most abundant species by mass. The average length of *L. aeneus* sampled was 230mm FL and the average length of *C. gariepinus* 845mm TL. Average CPUE for *L. aeneus* caught in gillnets was 4.9 kg.fleet⁻¹.night⁻¹ and 29.1 fish.fleet⁻¹.night⁻¹. Average CPUE for *C. gariepinus* caught on longlines was 11.2 kg.10 hooks⁻¹.night⁻¹ and 2.1 fish.10 hooks⁻¹.night⁻¹. The weight-at-age (W_t) for *L. aeneus* and *C. gariepinus* was estimated as $W_t = 0.000012(FL_t)^{2.99}$ and $W_t = 0.0000064(TL_t)^{3.00}$ respectively. A three parameter Von Bertalanffy growth function was used to describe the growth of the two dominant species in the dam. The parameter estimates were $L_\infty = 276.25$ mm FL, $K = 0.25$.year⁻¹ and $t_0 = -0.63$ years for *L. aeneus* and $L_\infty = 1121.34$ mm TL, $K = 0.20$.year⁻¹ and $t_0 = -0.24$ years for *C. gariepinus*. Natural mortality (M) was estimated at 0.30 year⁻¹ for *L. aeneus* and 0.18 year⁻¹ for *C. gariepinus*. Length and age-at-50% maturity were assumed to be knife-edged for both species and were estimated at 204mm FL and 4.78 years for *L. aeneus*, and 330mm TL and 1.49 years for *C. gariepinus*. Length and age-at-50% selection was estimated for the 40mm stretched mesh gillnet and it was found that *L. aeneus* was selected at 200.1 mm FL corresponding to an age of 4.57 years. Selectivity for *C. gariepinus* on longlines was assumed to be knife-edged at 800mm TL and 6 years. A yield and spawner biomass-per-recruit analysis was applied to the two most abundant species in the dam. For *L. aeneus*, F_{max} was estimated at 2.18.year⁻¹. However, this would result in a reduction in spawner biomass to 2.3% of pristine levels. The target reference point, F_{SB40} , was estimated at 0.3.year⁻¹. This would result in the fishery only being harvested at 56% of its maximum yield-per-recruit. For *C. gariepinus*, the target reference point of $F_{0.1}$ is 0.26.year⁻¹. This would reduce spawner biomass to 52.9% of pristine levels. Thus, the *C. gariepinus* resource can be utilized in a sustainable manner under higher fishing pressure.

This indicates a considerable fisheries potential for Xonxa Dam. It was, however, identified that the major obstacle in developing a fishery at the dam is a market for the catches. Work is thus needed to establish effective marketing mechanisms which will allow the community at Xonxa Dam to utilize the fish resources prior to the initiation of a fishery.

10h00-10h20: Michelle Mollatt (BSc Hons. student) – An analysis of subsistence line fishing activity in selected areas of the Wild Coast, South Africa

Supervisors: Prof. P. Britz (p.britz@ru.ac.za) and Mr S. Raemaekers (s.raemaekers@telenet.be)

The Marine Living Resources Act of 1998 defined subsistence and small-scale commercial fishers for the first time, giving them formal access to natural resources, which some of them had previously been forced to harvest illegally. Marine & Coastal Management (M&CM) have been mandated to ensure goals of the Act are met, through the process of issuing rights to subsistence fishers to ensure marine resources they collect are harvested on a sustainable basis. This has been done by employing community catch monitors since January 2006 (two per village) who walk along the coastline and identify, count, measure and record fish species (as well as other marine organisms) harvested.

There was a need to analyse the findings of these questionnaires, in order to assess the feasibility and value of this monitoring to M&CM. Of key importance of this monitoring to M&CM is the need for information on illegal fishing levels, and hence the urgency for directed compliance and effort control, in order to protect remaining fish species, especially those with threatened stocks. The project's aims were hence to assess the extent of illegal fishing, quantify and characterise line fish species targeted by the line fishermen, and report this to M&CM for management purposes. Of the 53 communities monitored, four geographically representative communities were chosen. Two of these are important tourism nodes. These communities were Hluleka, Port St Johns, Coffee Bay and Lumphoko.

To capture and analyse the data, a database was created in Microsoft Access ©. An analysis of the efficacy of monitors working along the coast was also carried out by interpreting the data quality.

Results showed that illegal fishers made up most of those fishing (Range: 27% to 88%), with highest levels occurring in Lumphoko, Port St Johns and Hluleka (all at 88%). Legal fishers (unspecified, but having a permit number or exemption type) made up a smaller portion of fishers (Range: 8% to 11%).

Commonly targeted linefish were shad/elf (*Pomatomus saltatrix*) at Hluleka and Coffee Bay (28% and 74% respectively). Blacktail (*Diplodus sargus capensis*) made up 29% of catches at Lumphoko and bronze bream (*Pachymetopon grande*) formed 39% of catches at Port St Johns. Of all measured blacktail (*Diplodus sargus capensis*) caught at Hluleka, 11,5% were undersize. At Lumphoko, 50% of the spotted grunter (*Pomadasyss commersonnii*) measured were undersize. made up 20% shad/elf (*Pomatomus saltatrix*) catches measured at Port St Johns were found to be undersize. Coffee Bay had the most number of undersize species – 33.3% of measured galjoen (*Coracinus spp.*), 12.5% of measured kob (*Argyrosomus spp.*) and 3.5% of measured shad/elf (*Pomatomus saltatrix*). Of major concern is that bronze bream (*Pachymetopon grande*), a protected species, were caught and kept at all locations.

Of the 25 species found in the four locations, greatest species diversity (72% of these species) occurred at Hluleka. Coffee Bay had the lowest representative proportion (40% of these species). Overall, this information illustrates the generally high species diversity of the region and therefore need for implementing effective control and monitoring strategies in all areas.

There was a large variation in data quality and accuracy, and thus caution must be taken when interpreting results. The analysis has, however, pointed to the conclusion that the monitoring system is still inadequate and prompts recommendations made to increase capacity at both the monitoring and management levels.

10h20-10h40: John Filmlalter (BSc Hons. student) – The suitability of otoliths, vertebrae and opercular bones as hard parts for ageing yellowfin tuna (*Thunnus albacares*).

Supervisors: Dr O.L.F. Weyl (o.weyl@ru.ac.za) and Prof. W. Sauer (w.sauer@ru.ac.za)

Funders: Fresh Tuna Exporters Association, BENEFIT

Yellowfin tuna are a high value species and are the target of a growing fishery in South Africa. Very little basic biological information exists regarding the South African stocks, including potential stock separations, migration patterns, reproduction and age and growth. This project is the first of an extensive research program which will attempt to answer some of these unknowns.

Because each fish is of such high value (up to R3000 per fish) the development of an ageing method which makes use of discarded material would be most helpful for future studies on the age structure of the stock. Much work has been done on the age and growth of yellowfin tuna throughout the world, with most of the work focusing on otolith microstructures, however spines have also been successfully used. The use of vertebrae for ageing has been successfully applied to bluefin tuna *Thunnus thynnus thynnus* (L.), blackfin tuna *Thunnus atlanticus* and bigeye tuna *Thunnus obesus*, while the examination of opercular bones has not been used for ageing any tuna species.

The objectives of this research were to assess whether growth increments were visible on otoliths, vertebrae and opercular bones of yellowfin tuna from the Western Cape region, and to compare the precision of determining the number of growth increments in each of these structures. Otoliths, vertebrae and opercular bones were collected from 46 fish at sea on board commercial vessels during December 2006. Each fish was measured to the nearest 0.5cm (FL) and the caudal peduncle (containing vertebrae), otic capsules and opercular bones were stored frozen in marked plastic bags. Vertebrae and opercular bones were cleaned by boiling and soaking in enzyme active commercial detergent. Otic capsules were defrosted, the sagittal otoliths removed using fine forceps, washed in fresh water and detergent, dried and stored in marked ependorf vials. Otoliths were examined either whole (immersed in methyl calceylate) or sectioned (to a thickness of 0.3 mm) and viewed using a binocular dissecting microscope. Vertebrae and opercular bones were examined without magnification. Growth increments on each structure were counted at least twice by one reader and a third time by a second reader. Intra- and inter-reader precision was assessed by calculating the average percent error (APE). Counts from different structures were compared using simple linear regression and testing whether the resultant slope differed from 1. Mean length-at-age was calculated for each method and compared using an ANOVA.

Preliminary examination of opercular bones showed no readily countable structures and opercular bones were thus excluded from further analysis. Otoliths and vertebrae showed clearly discernable growth increments. Inter-reader precision was found to be highest for vertebrae (APE = 9.8 %) and lowest for sectioned otoliths (APE = 34.9 %) while intra-reader precision was highest for whole otoliths read from inside the sulcus acusticus (APE = 8.9 %) and lowest for sectioned otoliths (APE = 15.2 %). Counts between structures did not differ significantly from each other ($p > 0.05$) for vertebrae vs. sectioned otoliths, whole otoliths read from inside the sulcus vs. sectioned otoliths, whole otoliths read from inside the sulcus vs. vertebrae and for whole otoliths read on the interior surface vs. sectioned otoliths. There was no significant difference in mean length of fish that were “aged” as 4 or 5 between different methods.

These results suggest that both whole otoliths, sectioned otoliths and vertebrae yield similar growth increment counts and could be used to estimate age for yellowfin tuna after the periodicity of growth zone formation has been validated. The choice of a suitable structure for ageing will depend on the level of difficulty associated with the extraction, preparation, reading and precision of the relevant hard structure.

10h40-11h00: Fabien Forget (BSc Hons. student) – The genetic structure of the resident sparid *Chrysolephus laticeps* in South Africa.

Supervisors: Dr P. Cowley (p.cowley@ru.ac.za) and Dr P. Teske (p.teske@ru.ac.za)

Due to the increasing amount of fishing pressure many of the linefish stocks have now collapsed and only exist as a fraction of their pristine stocks. The current management strategy of the linefish fishery involves bag limits and size restriction of the fish species. However, these are unlikely to be efficient in managing the fishery considering the status of the stocks and thus unlikely to be an effective strategy rebuilding the stocks. One of the other management approaches for the linefish fishery is the use of 'No Take Zones' within Marine Protected Areas (MPAs). The principle of MPAs as a management strategy is that 'spillover' from the no take zones would 'seed' the surrounding areas and improve fishing. Extensive studies on the movement of a sparid with commercial importance, *C. laticeps*, and the information available from tagging programs and telemetry studies within MPAs have shown that *C. laticeps* is extremely resident. Thus, it is presumed that most of the gene flow occurring along the coast in the *C. laticeps* occurs by larval dispersal. Oceanic currents have been studied in attempt to elucidate the patterns of larval dispersal. However, recent research on larval behaviour suggests that this assumption cannot be made as larvae are able to orientate themselves towards cues, maintain their position in the water column or even self-recruit to their native reefs. It is thus hypothesised that the resident *C. laticeps* could consist of discrete stocks and the identification of those stocks will provide a better understanding of the population dynamics of the species and valuable information for the more efficient management of the stock.

The objective of this study was to determine whether the resident *C. laticeps* consists of discrete stocks along the South African coast using a mitochondrial molecular marker. This was achieved by investigating the genetic structure of *C. laticeps* throughout its distribution range, comparing levels of genetic diversity between sampling sites and by estimating the amount of long term gene flow between sampling sites. Samples were collected at five locations along the coast of South Africa spanning the distribution of *C. laticeps*. Analysis using partial DNA sequencing of the control region revealed no significant genetic differentiation ($P < 0.05$) between the locations and no significant ($P < 0.05$) directionality in the gene flow. The result of the study cautiously suggest that adopting a single stock-stock model is appropriate for the management of the important roman resource. More rigorous genetic testing using higher resolution markers such as microsatellites are recommended to further elucidate any stock substructure.

11h00-11h25: Tea break

Honours seminars continued (Chair: Dr O. Weyl)

11h30-11h50: Alice Johnson (BSc Hons. student) – The effect of age and size on cultured abalone (*Haliotis midae*) gut enzyme activity in early weaning.

Supervisors: Mr A. Esterhuizen, Dr C.L.W. Jones (c.jones@ru.ac.za)
and Prof. P.J. Britz (p.britz@ru.ac.za)

Funders: THRIP, Marifeed (Pty) Ltd, Aquafarm (Pty) Ltd and HIK Abalone Farm (Pty) Ltd and Joint Research Council, Rhodes University.

Abalone (*Haliotis midae*) farms that rely on artificial abalone feeds wean their stock from diatoms onto formulated diets approximately a month post-spawning. These feeds were developed for on-growing larger abalone and, although they seem to work well during weaning, a diet specifically for weaning has never been developed and the on-growing diet that is currently used has not been optimized for weaning. At the time of weaning, there is usually a large variation in the size of the abalone. It is not known whether an artificial weaning diet should be developed for abalone of a certain size or age, since the gut enzyme activity may differ for different age and/or sized abalone. The objective of this research is to establish if changes that take place in abalone gut enzyme activity during weaning is determined by abalone size or age or possibly both or neither. The overall aim of this work was to make a contribution towards developing a weaning diet that takes the young abalone through the transition from diatoms to a formulated on-growing diet without compromising growth and survival.

Samples of gut enzyme were taken from wean-age abalone of different sizes, ages and from abalone that had spent different times inside the hatchery (i.e. time between sampling and deplating from diatom culture). Bradfords enzyme assay was used to determine amylase, lipase, pepsin and phosphatase activity.

There was no interaction between abalone age and size (multifactor ANOVA; $P > 0.05$) and between age and time since deplating (multifactor ANOVA; $P > 0.05$). On its own, abalone size had no effect on enzyme activity (ANOVA; $p > 0.05$) other than for phosphatase activity, which increased with an increase in size (ANOVA; $F_{(6, 133)} = 3.71$, $p = 0.002$). Abalone age had no effect on enzyme activity for pepsin, lipase and phosphatase (ANOVA; $p > 0.05$), however, amylase activity decreased with an increase in age (ANOVA; $F_{(1, 139)} = 10.24$, $p = 0.002$). Time in the hatchery had a significant effect on enzyme activity for all the tested enzymes (ANOVA; $p < 0.05$) with the exception of phosphatase (ANOVA; $p > 0.05$). Pepsin showed a steady decrease in activity with an increase in time from deplating (ANOVA: $F_{(6, 134)} = 6.04$, $p = 0.00001$), which indicates a decrease in protein utilization with age. Although lipase differed between times, there was no evidence of a trend. However, the relatively high lipase activity in wean-age abalone contradicts other studies where it was suggested that lipid is an unsuitable energy source for abalone.

Generally, abalone size and age do not appear to affect the activity of the enzymes tested here. The length of time that abalone spend in the hatchery after deplating had the largest effect on the activity of these enzyme activity.

11h50-12h10: Matthew Naylor (BSc Hons. student) - The effect of diet on growth and enzyme activity of the east coast rock lobster, *Panulirus homarus rubellus*.

Supervisors: Mr E. Thompson (e.thompson@ru.ac.za) and Prof. H. Kaiser (h.kaiser@ru.ac.za)
Funder: Joint Research Council

Spiny lobsters are an important marine resource for many countries. In South Africa, the grow-out of juvenile and adult lobsters in land based systems will create a market for the undersized lobsters harvested by subsistence fishermen on the Transkei coast and will ensure more selling power and higher prices for their harvest. As diet influences growth and survival of spiny lobsters, finding a suitable diet would increase the viability of a land-based grow-out operations. Spiny lobsters fed diets of fresh mussels or diets containing mussels have shown superior growth and survival compared to diets of fishmeal, shrimp feed and prawn feed. The dietary requirements of an animal are directly linked to gut enzyme activity which provides a basis for the formulation of efficient artificial diets.

Thus, the effect of diet on growth and enzyme activity of the east coast rock lobster, *Panulirus homarus rubellus* was tested using three diets; (1) a reference diet of whole frozen mussels (*Mytilus galloprovincialis*), (2) a pelleted diet comprising 66% fishmeal and 10% mussel meal and (3) a pelleted fishmeal diet. Diets 2 and 3 were iso-energetic with a gross energy content of 20.56 and 20.62 MJ/kg, respectively. The growth trial was conducted over 90 days, with lobsters being housed in individual cages and fed at a rate of 2.5% of body mass day⁻¹. Housing specimens separately prevented density dependent bias and allowed growth to be monitored for each individual. Specimens were weighed and measured at the commencement of the study and at two-week intervals. Specimens were also weighed and measured after moulting.

A significant difference in absolute weight gain was found between treatments ($F_{(10, 105)} = 1.9368$, $p = 0.048$). Mean weight gain per two week interval in grams; T1= 2.7±4.8, T2= 0.9±1.3, T3= 0.9±1.5. There was no significant difference in survival between treatments (Treatment 1 and 3 = 100%, treatment 2 = 90%). The best pH-values for all enzymes tested corresponded to ranges given in the literature. After optimizing the enzyme assay techniques, high activity was noted in the hepatopancreas for all digestive enzymes, and there was particularly low activity in the intestine. Pepsin was an exception, as no activity was detected in the hepatopancreas or intestine. Diet had no significant effect on enzyme activity, except in the case of intestinal trypsin (Kruskal-Wallis; $H_{(2,23)} = 7.582$, $p = 0.0226$) and chymotrypsin (Kruskal-Wallis; $H_{(2,23)} = 7.339$, $p = 0.0255$).

In the absence of pepsin, trypsin and chymotrypsin are the only endopeptidases for digestion of proteins. The differences in growth between treatments is probably related to the amino-acid profiles of dietary components and the percentage contribution of these amino-acids to the make up of the digestive enzymes. A limiting amino-acid in fishmeal may be the cause of the poorer growth.

In future research, the effect of pellet size and shape, the amount of mussel meal added to the pelleted diet and inclusion of protein sources high in arginine should be explored.

12h10-12h30: Keagan Halley (BSc Hons. student) – The effect of the anaesthetic AQUI-S® 10 and salinity on ammonia production in juvenile dusky kob (*Argyrosomus japonicus*).

Supervisors: Dr N. Vine (n.vine@ru.ac.za) and Prof. H. Kaiser (h.kaiser@ru.ac.za)

Funder: Marine & Coastal Management/DEAT Mariculture Frontier Programme. Fish were kindly supplied by Espadon Marine (Pty) Ltd and the Mariculture section of Irvin & Johnson (Pty) Ltd.

The dusky kob, *Argyrosomus japonicus* is a valued finfish species in aquaculture with a high market demand. Transporting techniques of juvenile fish from hatchery to on-growing farms has yet to be optimised. During transportation ammonia levels increase, which have a negative effect on fish physiology and health. By optimising conditions during transport, fish are stressed less resulting in better post-transport survival. The clove oil based anaesthetic AQUI-S® 10 has recently been used in aquaculture and is considered to be effective for transporting fish. Low salinity has also shown to reduced pH in the water, thereby reducing the fraction of NH₃ from total ammonia-N (TAN).

The aim of the study was to contribute towards optimising the conditions used in the transport of *A. japonicus*, by testing if AQUI-S® 10 and salinity have any effect on total ammonia-nitrogen (TAN), pH and toxic ammonia (NH₃). To test the hypothesis that AQUI-S® 10 would reduce the TAN and NH₃ at different salinities, individual juvenile dusky kob (with an average weight and standard length of 40.1±5.4g and 15.3±0.8cm respectively) were placed in plastic bags, at two salinities (12 and 35 ppt). AQUI-S® 10 was introduced into the bags (300 x 600cm) at a concentration of 0.04ml l⁻¹ and filled with 2L water. The pH, dissolved oxygen concentration, temperature, TAN and fish weight was measured in each bag. The remaining volume in the bag was filled with oxygen. Seven replicates and three controls (bags containing water but no fish) were used for each treatment. The bags were paced in polystyrene boxes and left for 24 hours, after which time the same water quality parameters measured at T₀ Were recorded The fraction of NH₃ was calculated using TAN, pH and temperature for each bag. A multifactorial ANOVA was conducted to compare the significance of differences among treatments at the p<0.05 confidence interval.

TAN produced (mg/kg fish) was significantly higher (mean TAN of 11.39 mg/kg fish compared to 2.49 mg/kg fish) at a lower salinity (p=0.00), however there was no difference in the TAN or NH₃ in the AQUI-S® 10 and no AQUI-S® 10 treatments for each salinity. There was a significant interaction between AQUI-S® 10 and the salinity (p = 0.029).

The concentration of 0.04-0.05 ml l⁻¹ had been determined in a pilot study as optimal for the light sedation of dusky kob. It is possible that the does not reduce the production of ammonia (TAN and NH₃) under transport conditions. The effect of salinity on the production of TAN is possibly due to the rise in salinity decreasing amino acid catabolism, hence nitrogen excretion (Gracia-lopez *et al.*, 2006). Although TAN increased, the drop in pH reduced the levels NH₃. The toxicity of NH₃ is primarily influenced by an increase in pH whereby an increase in one pH unit will increase the toxicity NH₃ 10- fold. Higher salinity reduced TAN but had no significant affect on NH₃, however both salinities had NH₃ at levels lower then the commonly accepted lethal limit (0.0125mg l⁻¹)

Based on these results, a concentration of 0.04-0.05 ml l⁻¹ AQUI-S® 10 has an effect on the TAN during the transport of dusky kob. The transporting of dusky kob at a lower salinity would be safer to use as an interaction was noted between AQUI-S® 10 and salinity. This study lays a foundation for further studies on AQUI-S® 10 and salinity for the transportation of *A. japonicus*. Further studies should investigate the use of 1) Different transport salinities; 2) the interaction between NH₃ and salinity; 3) different stocking densities under simulated transport and 4.) post-transport mortality.

12h30-12h50: Nicholas Nicolle (BSc Hons. student) – The effect of the anaesthetic AQUI-S[®]10, water temperature and salinity on oxygen levels during transport of two size classes of juvenile dusky kob (*Argyrosomus japonicus*).

Supervisors: Dr N. Vine (n.vine@ru.ac.za) and Prof. H. Kaiser (h.kaiser@ru.ac.za)

Funder: Marine & Coastal Management/DEAT Mariculture Frontier Programme. Fish were kindly supplied by Espadon Marine (Pty) Ltd and the Mariculture section of Irvin & Johnson (Pty) Ltd.

The culture of dusky kob (*Argyrosomus japonicus*) is new in South Africa as this species has a high consumer preference. Thus, there is a need to optimise transport of juvenile dusky kob from hatcheries to on-growing farms. Transport of fish can result in extensive stress on fish and reduce survival. By optimising transport conditions and various factors such as the use of an anaesthetic, temperature and salinity one can reduce metabolic rates and activity, and make handling easier and reduce the stress response. AQUI-S[®]10 is a clove oil-based fish anaesthetic that could prove useful in the transport of dusky kob.

The aim of this study was to contribute to optimising transport conditions for dusky kob with the use of AQUI-S[®]10. Two experiments were conducted to determine 1) the effect of anaesthetic and temperature on changes in oxygen levels (mg L^{-1}) and pH using two size classes of fish, and 2) the effect of the anaesthetic and salinity on oxygen levels (mg L^{-1}) and pH under simulated conditions. A pilot experiment was conducted to determine the concentration of AQUI-S[®]10 that produces light sedation. A concentration of 0.05 ml L^{-1} induced a level of anaesthesia that allowed fish to maintain equilibrium and remain reactive to external stimuli.

The first experiment tested AQUI-S[®]10 at 0.05 ml L^{-1} at two temperatures, 18°C and 25°C , on oxygen consumption in two size classes of fish ($26.1\text{g} \pm 4.2\text{g}$ and $1.8\text{g} \pm 0.38\text{g}$). This was done in closed systems filled with clean sea water and maintained at each of the two temperatures. A single fish was placed into each container and acclimatised for 2 hours. In each system, ten replicates (with fish) and six controls (without fish) were used for both the large and small containers. Oxygen (mg L^{-1} and % saturation), pH and temperature ($^\circ\text{C}$) were measured before and after the experiment. Oxygen consumption was determined as the amount of oxygen consumed per gram of fish per hour ($\text{mg g}^{-1} \text{ h}^{-1}$). There was no difference in oxygen consumption and pH between the temperature and AQUI-S[®]10 treatments. This may have been due to the fish not having been exposed to AQUI-S[®]10 for long enough.

The second experiment assessed the effect of AQUI-S[®]10 at 0.04 ml L^{-1} and two salinities (12 and 35 ppt) on the change of oxygen levels (mg L^{-1}) over 24 hours in transport bags. Seven replicates and three controls were used for each treatment. The use of the anaesthetic AQUI-S[®]10 at a concentration of $0.04\text{-}0.05 \text{ ml L}^{-1}$ had no effect on the change in oxygen levels independent of temperature. The change in oxygen levels was significantly less ($p=0.014$) in the 12 ppt salinity treatment than at 35 ppt. This may have been due to a low pH caused by an increase in CO_2 from fish respiration that reduced oxygen diffusion into the water.

Further studies should investigate 1) using AQUI-S[®]10 at concentrations that induce deeper stages of anaesthesia, 2) transport temperatures below 18°C , 3) the interaction between temperature and salinity as this was not tested in this study, 4) the effect of the anaesthetic on post-transport mortality.

12h30-12h50: Rowan Timmer (BSc Hons. student) – The effects of the intensity and colour of light on aggressive behaviour of Dusky kob (*Argyrosomus japonicus*) under culture conditions.

Supervisors: Dr K. Magellan (k.magellan@ru.ac.za) and Prof. H. Kaiser (h.kaiser@ru.ac.za)

Funder: Rhodes University Post Doctoral Fellowship, Joint Research Council

The recognition of the Dusky kob (*Argyrosomus japonicus*) as a viable aquaculture species has led to initial steps in industry being taken to farm the species on a commercial basis. *A. japonicus* is highly susceptible to stress under culture conditions and the behaviour associated with this stress frequently involves a high degree of aggression leading to cannibalism. Thus there is a necessity for research to be carried out into ways of decreasing the aggressive behaviour of this species under culture conditions in order to decrease mortality rates and increase the condition of the final farmed product.

The objective of this project was to determine whether differences in the intensity and colour of light affected the frequency of aggressive behaviour in *A. japonicus*.

First, aggressive behaviours of *A. japonicus* were identified. Then, to assess the affects of different lights on aggressive behaviour, five light treatments were used: white fluorescent light, partial shade, total shade, red light and green light. Eight clear glass tanks (45cm x 30cm x 32cm) each containing six juvenile fish of approximately equal size were used. Tanks were sequentially subjected to each of the five different light conditions for 24 hours with the order of presentation of treatments being randomised (5 days in total). Each day, a focal fish in each tank was randomly selected and observed for 10 minutes recording the frequency of aggressive behaviour towards other fish.

After each observation food was dropped into the centre of each tank and the latency between food being presented and food first being eaten was recorded.

A further set of observations was conducted under three light conditions, white light, partial shade and total shade. A new set of six fish were introduced into each tank and observations were as before.

Statistical analysis, using a non parametric Friedman test, indicated that there was a significant difference in the frequency of aggressive encounters under the various light treatments. Pairwise comparisons using Wilcoxon matched pairs tests showed that when fish were in the partial shade treatment they exhibited a lower frequency of aggression than when in total shade. Further studies quantifying the degree of cannibalism associated with aggressive behaviour and looking the optimum light intensity for minimizing aggression and cannibalism in *A. japonicus* under culture conditions would be beneficial.

Thursday 4 October 2006

Humphry Greenwood Guest Speaker (Chair: Prof. P.J. Britz)

08h35-09h20: Samantha Petersen – The realities of implementing an ecosystem approach to fishery management in South Africa.

Freshwater ichthyology and fisheries (Chair: E. Thompson)

09h20-09h40: Bruce Ellender (MSc student, first year) – A quantitative assessment of the subsistence and recreational fisheries in Lake Gariep, South Africa.

Supervisor: Dr O.L.F Weyl (o.weyl@ru.ac.za)

Funder: National Research Foundation (FA2005021600012)

This project is part of the Lake Gariep fisheries research programme, which aims to develop policy advice for the sustainable utilisation of fisheries resources. The overall objective of this project is to provide a quantitative assessment of the impact of subsistence and recreational angling on the smallmouth yellowfish (*Labeobarbus aeneus*) and the largemouth yellowfish (*Labeobarbus kimberleyensis*) in Lake Gariep. The current report is a quantification of the fishery, a critical component in meeting the overall objective of the MSc project and the overall programme. The entire 400 km shoreline of Lake Gariep falls under the jurisdiction of South African National Parks. For practical purposes, nature conservation authorities have designated open - access fishing areas along the shoreline. Two open access areas (Oviston and Gariep-EC totalling 40 km of shoreline) fall within the Eastern Cape, and two 25 km areas (Gariep Nature Reserve and Bethulie) are within the Free State. For the purposes of this study the fishing area was divided into two main areas according to lake-basin, namely: Oviston and Gariep (includes Gariep Nature Reserve and Gariep-EC). Exploratory surveys showed that the Bethulie fishing area comprised a pan that was separated from the lake during most of the year. This area was subsequently excluded from assessment. Roving Creel Surveys (RCS) were conducted using a stratified sampling procedure over 14-day periods every 2 months for a 12-month period. RCS included daily effort counts and angler interviews to ascertain angling user groups, species composition and Catch Per Unit Effort (CPUE) of two distinctive user groups, subsistence anglers (SAs) and recreational anglers (RAs). SAs are anglers that live near the lake, walk or cycle to the fishing area and rely on the resource as a primary or supplementary source of food and income. RAs utilise the resource primarily for leisure purposes but may sell some of their catch. In the Gariep area RAs were the dominant user group (76 %), while in Oviston they only comprised 24 % of anglers. Mean time spent angling did not differ significantly between user groups (Mann Whitney-U) or between assessment periods (Kruskall-Wallis ANOVA) and was estimated at 6.5 ± 2.2 hrs/angler/day (\pm standard deviation). Similarly, the number of lines used did not differ between sectors and the average angler used 2.9 ± 1.3 lines.

Mean CPUE was significantly higher in Gariep (0.27 ± 0.39 kg/line/hr) than in Oviston (0.12 ± 0.19 kg/line/hr, Kruskal-Wallis ANOVA, $p < 0.05$). In each area CPUE did not differ between RAs and SAs and data from both sectors were grouped for subsequent analyses. CPUE differed temporally (Kruskall-Wallis ANOVA, $p < 0.05$) ranging from 0.12 ± 0.19 kg/line/hr in Jun/Jul to 0.24 ± 0.41 kg/line/hr in Feb/Mar. Angler activity counts were higher in Oviston (29.4 ± 16.6 anglers/hr/day) than in Gariep (16.59 ± 14.36 anglers/hr/day). Total annual catch was estimated by Monte - Carlo simulation using the mean product of 1000 iterations of angler activity and CPUE drawn from raw data with replacement and raised by mean angling day length, number of lines per angler and number of days in assessment period. Total catch [lower, upper 95% CI] for Oviston was estimated at 28 [3, 86] t/year and 34 [4 – 97] t/year for Gariep. Catch composition did not differ between RAs and SAs. Five species were recorded in catches. These were namely, carp (*Cyprinus carpio*), mudfish (*Labeo capensis*), barbel (*Clarias gariepinus*), smallmouth yellowfish (*L. aeneus*) and largemouth yellowfish (*L. kimberleyensis*). Numerically, catches were dominated by carp (74 %), followed by mudfish (13 %) and smallmouth yellowfish (8 %). Relative abundance of smallmouth yellowfish ranged from 0 % in Dec/Jan to 21 % in Apr/May. In the following year biological data on yellowfish will be assessed and overall per-recruit model that incorporates both biological and fisheries information will be applied to assess the impact of the fishery on yellowfish.

09h40-10h00: Henning Winker (PhD student, first year) – What can be learnt from angling competitions in large South African dams?

Supervisors: Dr O.L.F. Weyl (o.weyl@ru.ac.za) and Prof. A.J. Booth (t.booth@ru.ac.za)

Funder: National Research Foundation (FA2005021600012)

Man-made dams in South Africa that provide considerable fisheries potential. The specific objective of the current study is to understand the interactions between common carp *Cyprinus carpio* as an exotic species, endemic large cyprinids and the different harvesting fisheries sectors. Specific emphasis is placed on the recreational anglers and potential commercial exploitation. Carp was chosen as a suitable candidate species as it has been largely ignored in previous assessments of large South African impoundments despite its dominance in recreational and commercial catches. This can be mainly attributed to its behavior to experimental gear as it avoids gill nets, the standard scientific sampling gear for inland water bodies. This project report summarises initial biological results and highlights the use of data derived from angling competitions as an effective and alternative sampling method for “difficult to catch” species.

Five angling competitions were sampled during which a total of 7.7 tons of fish were caught. Participant numbers ranged from 10 to 120 anglers. Anglers fish behind a straight line that is drawn from the first to the last fishing team. Each angler fishes with two rods for the same, strictly controlled, period of time (usually 8 hours). Large numbers carp and mudfish *Labeo capensis* were donated by competition anglers for biological analysis. The fork length (FL) of 2903 fish was measured (nearest mm), the reproductive stage of 1459 fish was determined macroscopically and otoliths were collected from 1373 specimens for age estimation.

Carp (60.1 %) and mudfish (38.1 %) were the most frequently caught species. In contrast to angling competitions, mudfish (65 %) and smallmouth yellowfish *Labeobarbus aeneus* (30 %) were the most abundant species in experimental gill net catches with carp accounting for only 1.9 % by number. First estimates of the von Bertalanffy growth function (VBGF) parameters were obtained for carp by applying three length frequency analysis methods to seasonal length frequencies from angling competitions. Estimated VBGF parameters were $L_{inf} = 69.6$ cm FL and $K = 0.42$ (SLCL), $L_{inf} = 64.6$ cm FL and $K = 0.50$ (ELEFAN), and $L_{inf} = 65$ cm FL and $K = 0.22$ (PROJAMAT). These estimates will be compared to results from hard part analysis using otoliths. The November 2006 competitions fell within the spawning season for both species. Length-at-50% maturity was estimated at 32.1 cm FL for female and 32.6 cm FL for male mudfish. Female carp matured at a larger size (32.8 cm FL) than males (28.9 cm FL). Mean CPUE (kg/rod/hour) of carp was significantly different ($p < 0.01$ Kruskal Wallis non-parametric ANOVA) between November 2006 (0.91; L, U 95% CI = 0.79, 1.04) and January 2007 (0.42; 0.28, 0.57). Mean FL of carp also decreased significantly ($p < 0.01$) from 40.3 cm in November to 28.4 cm in January and 29.7 cm in April. The length frequency in April clearly showed a recruiting cohort into the population. Mudfish CPUE similarly decreased ($p < 0.01$) between the November 2006 (mean = 0.23, 95% CL = 0.20 – 0.26) and January 2007 (mean = 0.11, 95% CL = 0.07 – 0.15) competitions.

These results suggest that both species accumulate in higher densities in the shallows during spawning season, where they were more prone to be caught by angling.

10h00-10h20: Graham Traas (MSc student, first year) – Distribution and relative abundance of the freshwater fishes in the Sundays River System.

Supervisors: Prof. A.J. Booth (t.booth@ru.ac.za) and Dr O.L.F. Weyl (o.weyl@ru.ac.za)
Funder: South African National Parks (2007-07-25OWEY), National Research Foundation (FA2005021600012)

Freshwater fish are considered to be the most imperiled vertebrate group globally. This situation is as a result of habitat destruction, pollution and the effects of alien species. South Africa's freshwater ichthyofauna is no different. Conservation of South Africa's freshwater fish is poor and less than 5% of rivers fall within protected areas. Conservation of the headwaters of a river system is of particular importance as it is commonly thought to be the best approach to conserving the ichthyofauna of a river system.

The Sundays River System supports an ichthyofauna comprising 17 species; seven of which are alien and two are IUCN Red Listed as threatened. Since the headwaters of some tributaries of the Sundays River fall within the Addo Elephant National Park, there is an opportunity to conserve the indigenous fish of this system, including the IUCN Red Listed *Pseudobarbus afer*. Information on the distribution of both alien and indigenous fish in the system is extremely poor, and an extensive ichthyological survey is needed to determine the extent of invasion by alien species and the current distribution of the indigenous species of the Sundays River System.

The dams in the Sundays River System will be sampled using a fleet of gill nets, fyke nets, longlines, seine nets and fish traps. In addition, an electrofisher will be used to sample smaller sections of the Sundays River. The tributaries will be sampled with an electrofisher and small longlines. Indigenous species will be measured to the nearest millimetre and released, while alien species will be sacrificed, sexed, visually staged and have their otoliths removed. Length frequencies will be used to determine the population status of each of the species sampled in the system. Community assemblage models will be used to determine the underlying biological processes occurring in the Sundays River System community.

To date, four sampling events have been conducted. A total of 1992 fish have been captured from 32 sampling sites, of which 137 were aliens. A total of 1354 *P. afer* were captured from the Klein Uie, Groot Uie and Wit rivers. Length frequencies for this species indicate that the population is breeding. Parasite infection rates for *P. afer* ranged from 11.86% to 16.43%. A total of 45 *Barbus pallidus* were captured from the Klein Uie, Groot Uie and Wit rivers. A total of 141 *Glossogobius callidus* were sampled from the Wit and Sundays rivers. Length frequency analysis indicates that the *G. callidus* population is breeding. *Clarias gariepinus* were found to be the most successful invaders, having penetrated 11.9km up the Klein Uie River. *Micropterus salmoides*, where present, have changed the species composition of the Wit River from *G. callidus*, *B. pallidus* and *P. afer* to just *G. callidus*.

Barriers to the migration of *C. gariepinus* up the Klein Uie River and *M. salmoides* up the Wit River need to be assessed as a matter of priority in order to maintain the current populations of *B. pallidus*, *G. callidus* and *P. afer*. Further sampling of the Kabouga, Uie and Wit rivers needs to be conducted and the Krom River needs to be assessed to determine the presence or absence of any alien species.

10h20-10h40: Vusi Mthombeni (MSc student, first year) – The biology of *Austroglanis* catfishes from the Clanwilliam Olifants river system, South Africa.

Supervisors: Dr O.L.F. Weyl (o.weyl@ru.ac.za) and Mr I.R. Bills (r.bills@ru.ac.za)

Funder: Water Research Commission (K8 592), Rhodes University Joint Research Council

The indigenous freshwater fishes of the Western Cape Province of South Africa are becoming increasingly rare due to anthropogenic factors which include agricultural malpractices and introduction of alien invasive fishes. Sixteen of the 19 native species are endemic to the region, while 15 are threatened. The Olifants is the most diverse river system, containing 9 indigenous and 8 endemic and endangered fish species. The ichthyofauna is dominated by the Cyprinidae which comprise 6 species, 1 currently recognized species of Galaxiidae and two species of Austroglanididae. The two *Austroglanis* species *Austroglanis gilli* and *Austroglanis barnardi* are IUCN-listed as vulnerable and endangered, respectively. The lack of biological information on these *Austroglanis* populations and on other freshwater fishes of the region constrains the development of species-specific conservation and management programmes.

The main objective of this study is to provide comparative biological information for both species and develop management recommendations necessary for their conservation.

To meet this objective, the current study investigated age and growth, reproductive biology and feeding biology based on 341 *A. barnardi* and 197 *A. gilli* from the Noordhoeks River and 298 *A. gilli* from the Rondegat River which were collected by the South African Institute for Aquatic Biodiversity (SAIAB) during various fish surveys. Ageing was based on reading sectioned otoliths obtained from 151 *A. barnardi* and 39 *A. gilli* specimens from the Noordhoeks River and 114 specimens of *A. gilli* from the Rondegat Rivers. The number of growth increments of *A. gilli* and *A. barnardi* indicate that longevity is in the region of 9 to 14 years, respectively. However, periodicity of growth increment formation still needs to be validated. Maturity was determined by fitting a logistic function to the proportion of reproductively active female fish and length-at-50% maturity was estimated at 70.4 mm TL for *A. barnardi* and 69.4 mm TL for *A. gilli* from the Noordhoeks River and at 94.4 mm TL for *A. gilli* from the Rondegat River. Spawning season was determined by GSI and visual staging and the proportion of ripe individuals and GSI showed a summer peak. Macroscopic assessment of the ovaries showed different sized oocytes in both species and suggests multiple spawning. This, however, remains to be validated histologically. To date, the gut contents from 96 stomachs of *A. barnardi* from Noordhoeks and 102 stomachs of *A. gilli* from Rondegat Rivers have been examined. Preliminary results show that benthic invertebrate larvae of the ephemeroptera (Baetidae), diptera (Simuliidae) and trichoptera dominated the diet of *A. gilli*. The diet of *A. barnardi* was dominated by the larvae of trichoptera and diptera (Chironomidae).

Research in 2008 will focus on attempting to validate growth increment deposition rate by marginal zone analysis and through corroboration with daily growth increments. Histological validation of macroscopic staging of gonads will be conducted and differences between life-history characteristics will be assessed between species and populations.

10h40-11h05 Tea break

Marine Fisheries (Chair: H. Winker)

11h10-11h30: Amanda Northrop (MSc student, second year) – How important are various data sources and assumptions in stock assessment?

Supervisors: Prof. A.J. Booth (t.booth@ru.ac.za) and Prof. S. Radloff (s.radloff@ru.ac.za)
Funder: National Research Foundation (SFH2005081100020)

There is sufficient evidence available to show that world's fisheries are imperiled. Catches and catch rates are declining with most stocks considered overfished. Amelioration of these situations requires the development of a workable management plans and their implementation. One important component of each management plan is the annual determination of the current status of the stock and what catch levels would be sustainable over a specified time-frame. These estimates are determined using stock assessment approaches.

Stock assessment methods are quantitative and complex; they rely on specific assumptions and require large data sets that are expensive to collect. Questions therefore arise as to what form of data to collect, how much data to collect and how much will the data cost? Ideally there will be an optimal solution whereby the correct data are collected such that accurate advice is provided at a specified level of uncertainty. Data commonly available include a time-series of catches, catch rate, research survey abundance, and catch-at-age information from both surveys and commercial sources.

Simulation studies are useful tools for assessing data quality and stock assessment model performance. The modeler can create a hypothetical resource with known parameters and generate hypothetical data sources. The data are then modeled and the difference of the sample statistics compared against the known parameters. The parameters are generated by an operating model, while the sample statistics are estimated by more than one assessment model.

This study investigated the following questions: (1) can a biomass model be used as an evaluative tool for a stock that exhibits a distinct age-structure, (2) what is the relative accuracy and precision of various model outputs, and (3) what the combination of datasets yields the best fit to the data.

An age-structured operating model was used to simulate 100 pseudo- datasets under underlying assumptions about the population structure, process and observation error and autocorrelated recruitment patterns. Age-independent and age-dependent assessment models were then used to estimate various commonly used management outputs. These included, *MSY*, *MSYR*, *MSYL* and *Depletion* (the ratio of current biomass to unexploited levels).

Preliminary results show that the BDM underestimates parameters such as *MSY* and *Depletion*, giving a more conservative view of stock status. In general, the relative error for the model is small, and thus it can be used as an evaluative tool for stocks that have a pronounced age-structure. For example, *MSY* had at most a 5% relative error value. In cases of extreme autocorrelated recruitment the BDM outperformed the ASPM model, though in general the ASPM model gave smaller confidence intervals for the relative error of all parameter and management outputs. The ASPM model is extremely sensitive to aging error within the catch-at-age data, underestimating *MSY* by as much as 25%.

11h30-11h50: Russell Chalmers (PhD student, second year) – Assessment of linefish resources within the proposed Greater Addo marine protected area (MPA).

Supervisors: Prof. W.H.H. Sauer (w.sauer@ru.ac.za)

Funders: South African National Parks, World Wildlife Fund – South Africa (ZA1434), Western Indian Ocean Marine Science Association (No3/2006), South African Environmental Observation Network – Elwandle Node

Marine protected areas (MPAs) have long been advocated as a viable alternative to conventional fisheries management and biodiversity conservation. A new MPA has been proposed in Algoa Bay, adjoining the terrestrial Greater Addo Elephant National Park (GAENP). Due to the large size and location of the proposed MPA it will be the first in South Africa to incorporate a bay environment, exposed rocky headlands and offshore islands. A survey was initiated in 2006 to describe key habitats, assess their level of exploitation and evaluate their importance for conservation planning in order to design a spatially orientated management plan. The objective of this component of the study was to assess the spatial and temporal distribution, community structure, relative abundance and population size structure of linefish within the proposed MPA.

Controlled angling surveys and underwater visual census (UVC) assessments were randomly stratified across area, season, depth and reef profile within the proposed boundaries of the MPA. Depth, bottom temperature, substrate type and GPS position was recorded at each site. Overall linefish density differed significantly between study areas ($F_{3,202}=3.1$; $p<0.03$) with the St Croix area having significantly lower densities than the Bird Island and Woody Cape areas. Roman, the selected indicator species, showed significantly higher densities in the Bird Island area as compared to the Woody Cape, Cape Padrone and St Croix areas ($F_{3,206}=39.9$; $p<0.0000$). There was no significant difference in roman density between seasons in any areas. Analysis of the linefish community structure using ANOSIM indicated significant differences in species composition between areas ($p<0.004$). A SIMPER analysis revealed that santer, fransmadam and roman were dominant species within the Bird Island (48%; 30%; 20% respectively), Woody Cape (79%; 12% respectively) and Cape Padrone (42%; 41%; 16% respectively) areas, while white seacatfish (42%), silver kob (29%) and santer (20%) dominated in the St Croix area. Reef depth and profile did not influence the relative abundance of santer ($F_{2,59}=0.44$; $p>0.6$), roman ($F_{2,65}=0.02$, $p>0.9$) and steentjie ($F_{2,59}=0.005$; $p>0.9$) while depth had a significant effect on the relative abundance of fransmadam ($F_{2,59}=3.9$; $p<0.03$) with abundance increasing with decreasing depth. Although depth did not influence roman density, the population size structure differed significantly between depth classes ($F_{2,228}=3.4$; $p<0.04$) with size increasing with decreasing depth.

These results will be used to assess the importance of the different key habitats in the conservation of exploited reef species within the proposed MPA and design a zoning scheme and management plan. In addition the potential use of the sampling design as a long-term linefish monitoring tool will be evaluated.

11h50-12h10: Bruce Donovan (MSc student, second year) – A re-assessment of the Port Alfred/Kenton-on-sea/Boknes commercial and recreational deep-sea linefishery, with respect to changes in the fisheries management environment in South Africa.

Supervisors: Prof. T. Hecht (t.hecht@ru.ac.za) and Dr O.L.F. Weyl (o.weyl@ru.ac.za)

Funder: Marine & Coastal Management (2007), National Research Foundation through SANCOR (2006)

Following a detailed study of the Port Alfred/ Kenton-on-sea/Boknes fishery in 1984/5 there have been significant changes in the fisheries management environment, accompanied by a noticeable shift in fishing effort from commercial to recreational deep-sea line-fishing. During the mid 1980's Port Alfred was the third largest line-fishery in the country (excluding snoek and yellowtail) with 28 vessels operating commercially on a full-time basis. The fishery was the third most important industry in Port Alfred. Currently there are 10 licenses issued for area between Cape Padrone and Great Fish point, of which only 3 are operating out of Port Alfred on a full-time basis.

The project aims to evaluate the biological and socio-economic effectiveness of fisheries management strategies over a 20 year period using the Port Alfred fishery as a model; and to understand the social and economic behaviour of stakeholders in response to the changes in the management environment.

In addition to traditional biological fishery assessment methods (using data collected over a two year period and available historical data), more contemporary methods of assessing fishing induced changes in community structure are used. These include multivariate analysis to assess long term changes in size compositions; and dominance structures using K-dominance curves, size spectra analyses and abundance biomass curves. The outcomes will provide a rigorous statistical basis upon which to describe the population changes that have occurred during the preceding 21 years and upon which recommendations can be made.

Socio-economic aspects of the fishery are being investigated by means of questionnaire surveys and structured interviews with past and present commercial operators, crew members, recreational fishers and on-shore fisheries related operations. The aim is to quantify: 1) the changes that have taken place in commercial and recreational effort over time, and evaluate the underlying causes of such changes; 2) the changes to fishery based employment and income; 3) the coping strategies of the fishermen related to changes in the management environment; 4) the economic returns of boat owners and fishers; and 5) the fishers perceptions with respect to rights allocation in light of the perceived changes in the fishery.

Initial results show a general decrease in the abundance of previously targeted species (notably panga, *Pterogymnus lanarius*) in the commercial and recreational catch with an increase in other redfish species such as santer (*Cheimarius nufar*). The decrease in silver kob (*Argyrosomus inodorus*) catches may be attributable to the increase in the size limit for this species in April 2005 and not related to actual species abundance. This appears to be evident from a comparison of current and historical length-frequency distributions.

Effort for the main access-point to the fishery is monitored by a motion activated digital camera. The average monthly effort for commercial fleet is 150h05min (\pm 48h59) while total recreational effort is higher with 269h16min (\pm 97h43) on average every month. The commercial CPUE is higher than the recreational CPUE, viz. 12.71 kg/hour against 3.25 kg/hour per vessel respectively. Preliminary comparisons show that these CPUE values are *ca.* 38% lower than the (1984/5) historical values for both sectors.

For commercial operators, rising fixed costs (fuel, bait and labour) and reduced catches of size-limited target species have created an economically marginal market. In the same light, there are an increasing number of fishers with recreational licenses operating fishing charters to cover the overhead costs of trips.

12h10-12h30: Hylton Cecil Newcombe (MSc student, first year) – Contribution to the development of a management plan for the baitboat and sport fishery for tuna in South Africa.

Supervisors: Dr. W. Sauer (w.sauer@ru.ac.za) and Dr O. L. F. Weyl (O.Weyl@ru.ac.za)
Funder: Fresh Tuna Exporters Association

The tuna industry is one of the few fisheries sectors in South Africa that is still in a development phase. The baitboat component has changed from landing fish of fairly poor quality to one which is able to compete in the lucrative demand for a sashimi quality product. This fishery fits neatly into the objectives of government for the development of the small to medium commercial sector. The recent development of this sector requires a sound management strategy, where the participants are able to work closely with the Department of Marine & Coastal Management. There is little knowledge of the poling and recreational component of the fishery, which contributes substantially to the total catch. As tuna stocks are highly migratory, knowledge of the South African component is crucial in terms of obtaining quota's, insuring the sustainability and resilience of off - shore tuna stocks and input from both a management and conservation/scientific perspectives in discussions with international working groups such as ICCAT. A sound scientific and management approach is also required to acquire Marine Stewardship Council affiliation. Hence a comprehensive management plan for this fishery is required.

The objectives of this project are to provide a qualitative and quantitative assessment of the size and shape of the tuna fishing industry; including total catch, effort, cpue, socio-economic and economic information. Trends will be investigated between market value and body fat composition of yellowfin tuna. Data collection will take place in the Western and Eastern Cape. Both landing sites and processing factories will be targeted using a variety of methods including questionnaires for onboard observations; landing sites (targeting tuna pole, linefish and recreational fishers); and buyers (exporters and local suppliers). Questionnaires will be conducted at the various sites via random stratified sampling. Molecular experiments will be conducted within the laboratories at the Department of Biochemistry, Biotechnology and Microbiology at Rhodes University. Chromatography techniques to assess the fatty acid make-up of tissue extracts from yellowfin and their prey are being investigated.

The project has concentrated on the Eastern Cape for the first phase of data collection; tuna are present in the area in autumn and winter. Preliminary results show that this is a recreational fishery of some 100 ± 25 vessels. Vessel types vary, from expensive fly-bridge cruisers to less expensive ski-boats, averaging in price of R692, 000.00 \pm R483, 000.00. Each vessel is equipped with between six to 12 rod and reel outfits. Joint outfit prices vary for each vessel according to the number of sets used, averaging R43, 000 \pm R29, 000. The recently held Algoa Bay Standard Bank Tuna Classic 2007, had 68 vessels entered, with 43 percent of entrants not residing from Port Elizabeth. This competition is the largest of its kind held within the Eastern Cape. Half the predicted Eastern Cape sport fishers entered, with total vessel net worth in excess of R47, 000, 000 at sea each day. Data collection in the Western Cape is underway.

12h30-12h50: Jessica Escobar-Porras (MSc student, second year) – Movement patterns and a first estimate of population size base on mark- recapture of selected catsharks (Scyliorhinidae) in South African waters.

Supervisors: Prof. W. Sauer (w.sauer@ru.ac.za) and Dr P. Cowley (p.cowley@ru.ac.za)
Funder: National Research Foundation Core Grant, Marine & Coastal Management Provincial Grant (#61706)

Sharks are particularly vulnerable to over-exploitation. Although catsharks are an important component of the near-shore marine biodiversity in South Africa and most of the species are endemic, little is known about their movement patterns and population dynamics. With an increasing number of recreational fishers this information is crucial for management purposes. The primary objective of this project is to investigate the movement patterns of Pyjama (*Poroderma africanum*), Leopard (*Poroderma pantherinum*), and Brown (*Haploblepharus fuscus*) catsharks, while secondary aims are to evaluate abundance, seasonality and population size. Three different data sources are available, with low to high resolution spatial data. The first is from the ORI/ WWF-SA National Tagging Project with data from 1984, covering the entire South African coast. The second source is from a fish tagging and monitoring programme, initiated in 1995, within a 5 km stretch of coastline within the Tsitsikamma National Park (TNP). The final data set is from my own research over 24 months, covering 4 bays in a lightly exploited area of about 1km of coastline near St Francis Bay. Research techniques included inshore direct observations through diving, and standardised mark-recapture fishing methods using hook and line and cages. Offshore direct observations were also made for a 30 day period during the summer season. Acoustic monitoring of 5 individuals was carried out over a four month period using two Vemco VR2 receivers placed in two of the bays. The use of various methods will increase the accuracy of the information. To date 1408 sharks have been tagged (*Poroderma africanum* (761), *P. pantherium* (355), *Haploblepharus fuscus* (171) and *H. edwardsii* (121)) in the ORI/WWF-SA Tagging Project with a recapture rate of 5.61% (n= 79). In the TNP Programme 224 sharks were tagged (*P. africanum* (85), *P. pantherium* (38), *H. fuscus* (3) and *H. edwardsii* (98)), with a recapture rate of 7.14% (n=16). At St. Francis, 101 sharks have been tagged (*P. africanum* (14), *P. pantherium* (34), *H. fuscus* (50) and *H. edwardsii*(3)), with a recapture rate of 19.80% (n=20). A total of 1733 sharks have been tagged and 115 recaptures obtained for a 6.64% recapture rate. Population size estimates will be made using the mark-recapture obtained from the St Francis study site. In addition, I will attempt to correlate movements with various environmental variables such as temperature.

12h50-13h10: Terence Stonier (MSc student, second year) – Microsatellite analysis of chokka squid (*Loligo reynaudii*) from different spawning aggregations around the South African coast.

Supervisors: Dr W. Sauer (w.sauer@ru.ac.za) and Dr P. Shaw (p.shaw@rhul.ac.uk)

Funders: SASMIA, National Research Foundation

Accurate information about population (stock) structuring within any commercially exploited species plays a very important role in their management. This information is especially important with *Loligo reynaudii*, an annual species where each new generation depends entirely on the previous year's survivors. In the past this stock has been managed on the assumption that it consists of a single large population where individuals freely mix and interbreed, however recent genetic data from related squid species has suggested that geographically distinct spawning sites may be used by genetically distinct spawning groups, forming a number of genetically distinct sub populations which do not interbreed. Locally, *L. reynaudii* spawns in the shallow shelf waters along the coast, forming large, spatially separate spawning concentrations in various areas during certain times of the year, with these spawning sites appearing to be in consistent locations from year to year. While tagging studies have shown that individuals do move between these inshore spawning aggregations along the eastern Cape Coast, it is not known how these mix with offshore spawning concentrations found between Port Elizabeth and the Western Agulhas Bank, and squid found on the West Coast of South Africa.

Depending on this level of gene flow between aggregations, the current management practises adopted for *L. reynaudii* may be rendered unsuitable, with possible over-exploitation of localised, differentiated groups leading to rapid and irreversible alterations to the genetic structure and diversity of the population. The aim of this project was to enhance the current knowledge of stock structuring on a genetic level using DNA markers. Using previously developed microsatellite markers for *L. reynaudii*, samples from the different areas of distribution for this species, mostly collected over one season, were analysed for any variation in microsatellite DNA. All samples were then preserved in 80% ethanol and kept in a cool room until use. Individual DNA material from all samples was extracted following a basic CTAB extraction protocol, and five loci were selected for screening the samples. PCR's were set up and a minimum of 48 individual samples from each area were prepared for screening at the 5 selected loci. A number of extractions were made from Angolan squid samples for screening in the same manner, providing an "outgroup", for comparison to the results from the South African samples. The data was then analyzed using 2 programs, Fstat and Genepop and was examined for Hardy Weinberg Equilibrium, heterozygosity and allele frequency differences at each of the 5 loci. Preliminary analysis of these sample marker frequencies for the alongshore spawning groups showed limited microsatellite variation between spawning aggregations on the eastern Cape coast, but some variation between the Western Agulhas Bank and the eastern Cape, indicating possible stock differentiation.

13h10-14h15 Lunch break

Estuarine studies and marine larvae (Chair: R. Chalmers)

14h20-14h40: Bronwyn O'Connell (MSc student, second year) – Home range and area use patterns of spotted grunter, *Pomadasys commersonnii*, in an intermittently open estuary, using acoustic telemetry.

Supervisor: Dr P. Cowley (p.cowley@ru.ac.za)

Funders: SA/Norway Programme on Research Co-operation (National Research Foundation/Research Council of Norway), Deutscher Akademischer Austausch Dienst (DAAD)

Acoustic telemetry was used to investigate the home range and area use of spotted grunter *P.commersonnii* in an intermittently open estuary in the Eastern Cape of South Africa. Spotted grunter is an important, estuarine-dependent, fishery species. Since estuaries are essential habitats in the life history of this species, an understanding of the movement and area use patterns in an intermittently open/closed estuary such as the East Kleinemonde, with stable environmental conditions, will enhance our understanding of the ecology of this species. Furthermore, due to the increase in fishing pressure placed on estuarine systems, along with the lack of compliance and law enforcement, knowledge on the home range and area use will contribute to the management of this over-exploited fishery species. The aim of this study was to (i) collect high resolution data to quantify the home range size, (ii) investigate the factors determining home range size (e.g. season, diel, fish length, prey availability) and (iii) investigate the long-term trends in area use. Nine spotted grunter (mean: 427mm TL; min: 326mm TL; max: 489mm TL) were surgically implanted with VEMCO V8 transmitters. Tagged individuals were manually tracked for varying periods of between 1 and 6 days and nights every month from March 2004 to November 2004. Five stationary receivers (VEMCO VR2s) were moored at specific locations from the mouth to the top of the estuary to provide additional long-term monitoring. Water chemistry data was recorded daily at each of the VR2 sites. Data was analyzed using the GIS software Arcview ® and the Animal Movement Analysis Extension (AMAE). The results showed large variation in the home range size (95% UD) (range: 26 296 - 165 321m²; mean: 76 797m² ± 39 255 SD) and number (range: 2-7; mean: 3.78 ± 1.39 SD), core area size (50% UD) (range: 7 088 - 18 830m²; mean: 10 783m² ± 4 435 SD) and number (range: 1-3 ; mean: 1.44 ± 0.73 SD), and home range length (range: 0.56 -2.67 km; mean: 1.43 ± 0.90 SD) of the tagged individuals. Tagged spotted grunter exhibited varying area use patterns. One individual had an extended home range (into the upper reaches of the estuary), five fish had moderately short home ranges (extending into the middle reaches) and three fish had short home ranges (confined to the lower reaches). Many of the core areas overlapped, with highest overlap in the lower reaches of the estuary. The factors influencing home range size and the long term trends in area use will be further investigated.

14h40-15h00: Phanor Montoya-Maya (MSc student, second year) – Dynamics of ichthyoplankton and zooplankton from selected cool temperate estuaries in South Africa.

Supervisors: Dr N.A. Strydom (n.strydom@ru.ac.za) and Dr T.H. Wooldridge (tris.wooldridge@nmmu.ac.za)

Funder: National Research Foundation

The present study aims to provide baseline information on composition, abundance, and distribution of ichthyo- and zooplankton in selected (nine) cool temperate estuaries as well as provide some insight into the interactions between these organisms. The physico-chemical environment characterising these estuaries is also described. Larval fishes and zooplankton were collected by plankton towing in selected estuaries once per season a period of one year between 2003 and 2004. Principal Component Analysis and ANOSIM (Primer) showed a strong seasonal component to the physico-chemical environment in these estuaries. Similarities among estuaries of the same type and within same biogeographic region were unclear. Estuaries sampled showed specific physico-chemical conditions that could be related to changes in river flow and oceanic current systems. Ichthyoplankton sampling yielded 13 300 early stages fishes comprising 43 species belonging to 19 fish families. Clupeidae (54 %) represented by a single species, Gobiidae (34 %) represented by 10 species and Blenniidae (18 %) were the dominant fish families. Richness and density of larval fishes in all estuaries sampled show a marked variation between season and estuaries sampled but generally tended to peak in summer. The Bot estuarine lake displayed a high average fish density (729 ind/100m³) but low species richness (5) whereas the permanently open Breede Estuary shows a lower average fish density (100 ind/m³) but high species richness (28). Future work includes calculation of diversity indices (i.e. Shannon-Wiener's Diversity Index and Pielou's Evenness Index) and exploring Generalized Additive Models as a means to assess the interactions between ichthyoplankton and the physico-chemical variability in estuaries. The zooplankton component still needs to be processed and will be analysed using similar techniques to those used for ichthyoplankton.

15h00-15h20: Paula Pattrick (MSc student, second year) – Composition, abundance, distribution and seasonality of larval fishes in the shallow nearshore zone of the proposed Greater Addo Marine Reserve, Algoa Bay, South Africa.

Supervisor: Dr N.A. Strydom (n.strydom@ru.ac.za)

Funders: Marine Living Resources Fund (Marine & Coastal Management, National Research Foundation, South African Institute for Aquatic Biodiversity)

Research in the shallow nearshore along the South African coast is limited and the use of this habitat by larval fishes is poorly understood. This project aims to determine the composition, abundance, distribution and seasonality of larval fishes along two depth contours (5/6m and 15/16m) in the shallow nearshore region of the eastern sector of Algoa Bay, a proposed marine protected area between Woody Cape and Sundays Estuary. Larvae were collected by means of boat-based bongo-net tows in autumn, winter, spring and summer between March 2005 and January 2007. Salinity, temperature and turbidity were recorded. Short and long-term shallow water current profiling using an Acoustic Doppler Current Profiler was also conducted within the study area between May 2006 and April 2007. A multi-lane swimming chamber was used to test the swimming abilities of postflexion *Diplodus capensis* and *Sarpa salpa* larvae (Family Sparidae) relative to maximum current velocity observed in the study area. In total, 6045 larval fishes were collected representing 32 families and 78 species. Gobiidae and Cynoglossidae were the dominant fish families. The Gobiidae made a total contribution of 49 %, with the cynoglossids contributing 8 % to the total catch. Significant seasonal and spatial variations in larval density were observed. The highest mean larval fish density of 65 larvae/100m³ was recorded in Spring with the lowest mean density of 19 larvae/100m³ recorded in Summer. Mean larval fish densities were higher in the deeper 15/16m depth zone (40 larvae per 100m³) when compared with the shallower sampling zone just behind the backline (30 larvae per 100m³). Preflexion larvae dominated the shallow nearshore. Mean larval fish body length was smallest in the deeper 15/16m depth zone (4.1mm) when compared with the shallower sampling zone just behind the backline (4.2mm). Four different flow patterns were observed within the shallow nearshore during the short term current surveys. These included a westward flow, an eastward flow, a northward/offshore flow and a mixed flow. A moored ADCP deployed for a one year period indicated two dominant flow patterns. These included an alternation between a westward flow pattern and a south eastward flow pattern. Current velocity decreased with depth. A mean current velocity of 10cm/s was recorded at a depth of 14m and a velocity of 29cm/s recorded at a depth of 4m. Critical speeds of *D. capensis* ranged from 2.7 to 35.1 cm/s and from 4.1 to 33.3 cm/s in *S. salpa*. Both species were able to exhibit a mean sustained swimming ability of 13hrs at current speeds of 18cm/s, with maximum sustained swimming at this speed exceeding 50 hrs for both species.

15h20-15h40: Peter Watt-Pringle (MSc student, third year) – Post-settlement movement behaviour of blacktail (*Diplodus sargus capensis*), zebra (*Diplodus cervinus hottentotus*) and white musselcracker (*Sparodon durbanensis*).

Supervisor: Dr P.D. Cowley (p.cowley@ru.ac.za)

Funder: Marine & Coastal Management Provincial Grant #61706, Rhodes University Joint Research Council

Blacktail, zebra and white musselcracker are important species in the South African marine recreational shore fishery. Movement behaviour of juveniles in rocky intertidal nursery areas, and adults in nearshore habitats was investigated in order to gain a clearer understanding of this aspect of their ecology for management purposes.

Movement of early juveniles was investigated by marking and resighting individuals in an intertidal gully. Resighting was made using snorkel gear in this and three adjacent gullies at the study site on bi-weekly sampling trips for a period of six months. The majority of juvenile zebra and white musselcracker displayed strong site-fidelity to the marking gully, with few movements to adjacent gullies. Juvenile blacktail, however, were only resighted regularly for the first two months. It is possible that the size of blacktail tagged marked the onset of an ontogenetic habitat shift to subtidal areas.

Movement of adults was investigated using data from the ORI/WWF National Tagging Programme (NTP) and a dedicated monitoring and tagging project in the Tsitsikamma National Park (TNP). Recaptured individuals of blacktail, zebra and juvenile and subadult white musselcracker tagged throughout their distributional range in the NTP displayed residency behaviour. Data from the TNP, with better spatial resolution, revealed that home ranges for these resident fish were small, with the majority of blacktail displacements (67%) being less than 100m and only 8% being greater than 500m. Zebra recaptures in the TNP were low (n=7) but most were made at their release site. Juvenile and subadult white musselcracker showed even stronger site fidelity, with 92% of recaptures made within 100m of their release site. Displacement distances of adult white musselcracker increased with age (size). Observed movements were generally eastwards of the tagging locality, with some considerable displacements (up to nearly 850 km) and were linked to the reproductive cycle. Adults aggregated in spring months and migrated eastwards to spawning areas, with fish from different regions migrating to different spawning localities. Based on inshore oceanographic conditions along the South African coastline it is suggested that the observed displacement patterns maximise transport of eggs and larvae to the southern and eastern Cape coasts.

The findings of this study highlight the role that Marine Protected Areas (MPAs) exempt of poaching activities provide in protecting populations of the two resident *Diplodus* species throughout ontogeny. White musselcracker are well protected by MPAs that incorporate areas of suitable habitat during the juvenile and subadult phases, but adults undertake movements in excess of the extent of most MPAs during the spawning season. The feasibility of potential management options such as closed areas or seasons for the protection of aggregating white musselcracker during the spawning season needs to be examined further.

Friday 6 October 2006

Mariculture (Chair: G. Paulet)

09h20-09h40: Alistair Green (MSc Student, second year) – The development of a high temperature maintenance diet for the South African abalone *Haliotis midae*.

Supervisors: Dr C.L.W. Jones (c.jones@ru.ac.za) and Prof. P.J. Britz (p.britz@ru.ac.za)

Funder: Marine & Coastal Management (DEAT Mariculture Frontier Programme),
Marifeed (Pty) Ltd., and Marine Growers (Pty) Ltd.

The culture of abalone (*Haliotis midae*) is currently the fastest growing sector of the mariculture industry in South Africa. A large portion of the industry's success can be attributed to the development of formulated feeds. The majority of feeds that are currently available were developed within the optimal temperature range of 18-20 °C and have been found to be unsuitable at elevated temperatures. Thus farmers often feed reduced volumes or no formulated-feed at elevated temperatures to avoid the usually fatal condition "bloat", where undigested feed ferments in the intestine. As a result cultured abalone often lose condition at elevated temperatures. With the development of new farms on the warm east coast of South Africa and the occurrence of periods of elevated water temperatures along the south coast there is a need for a feed that can be fed to abalone during these periods in order to reduce production losses. The objectives of the project were to compare the growth and survival of abalone fed diets with varying protein:energy ratios cultured at 18, 22 & 24 °C.

Nine experimental diets were formulated with varying protein (18, 22 and 26%) and energy (16.4-11.1 MJ/kg) contents. Treatments were represented in quadruplet at each temperature. Diets were fed to abalone (50 mm) cultured under farm-like conditions in three temperature controlled partially recirculating systems.

Total mortality remained similar among all treatments including 24°C (1.3–1.7 abalone/basket) provided energy did not drop below ca. 15.5 MJ/kg, but increased (14.5–17.8 abalone/basket) at all temperatures if dietary energy and protein dropped to ca. 13.4 MJ/kg and 18%. Abalone grew fastest at 18°C, followed by 22 and 24°C (ANOVA; $F=3.15$ $p=0.0186$). At 18°C abalone (29.0 ± 0.16 g) gained between 4.2 and 5.4 g/month, which remained similar at all protein levels (18-26%) provided energy was not reduced to ca. 13.4 MJ/kg. At 24°C they lost weight at low energy and protein levels, but grew at 1.3 ± 0.13 g/month if protein was not dropped below 22% and energy was maintained at ca. 15.5 MJ/kg. It is recommended that at temperatures in excess of 22°C protein could be reduced to 18% provided energy is kept at ca. 15.5 MJ/kg to maintain body condition and to reduce the chance of bloat.

09h40-10h00: Caryn McNamara (PhD student, second year) – Haematology of the South African abalone, *Haliotis midae*.

Supervisors: Prof. H. Kaiser (h.kaiser@ru.ac.za) and Prof. P.J. Britz (p.britz@ru.ac.za)
Funders: Marine & Coastal Management (DEAT Mariculture Frontier Programme), National Research Foundation, HIK Abalone Farm (Pty) Ltd. and Roman Bay Sea Farm (Pty) Ltd., Ernst & Ethel Eriksen Trust.

The immune and stress responses of most molluscs are largely unknown. The South African abalone (*Haliotis midae*) is a species of large economic importance in South Africa and similarly, immune and stress responses for this species are unknown especially with regard to exposure to environmental on-farm conditions. The main aim of this study is to identify whether any easy-to-identify characteristics exist within the abalone (such as blood biochemistry of the haemolymph or whole tissue level studies) that could aid the on-farm health management of this species.

Characterisation of the abalone haemolymph involves studies including differential cell counts using light microscopy and electron microscopy, haematocrit studies, and heat shock protein analyses. Haemolymph can be obtained from this species by withdrawal from the pedal sinus. Lymphocytes can be concentrated by centrifugation through a modified Ficoll-Hypaque technique layer and isolated for study by removal of the pellet fraction at the gradient interface. Stressors currently being evaluated are long term and short term temperature stress. Changes in these values are being investigated with regards to long term and short term temperature stress to identify whether any of these values can become suitable markers of a stress and immune responses in abalone for on-farm health management.

This study also aims to identify the site of haematopoiesis in this species based on monoclonal antibody recognition of haemocytes. This involves selected organ dissection and monoclonal antibody probing to identify receptors on lymphocyte and other haemocyte cell types.

Abalone were kindly donated by HIK Abalone Farm in Hermanus.

10h00-10h20: Rowan Yearsley (MSc student, second year) – Water quality and growth on a South African abalone *Haliotis midae* farm and the potential for integrated mariculture.

Supervisors: Dr C.L.W. Jones (c.jones@ru.ac.za) and Prof. P.J. Britz (p.britz@ru.ac.za)

Funder: Marine & Coastal Management (DEAT Mariculture Frontier Programme) and National Research Foundation, HIK Abalone Farm (Pty) Ltd. and Roman Bay Sea Farm (Pty) Ltd.

South Africa's high-energy coastline requires abalone *Haliotis midae* farms to be shore-based in spite of the cost of pumping seawater ashore. Anecdotal observations suggest that abalone growth on these farms changes seasonally. If true, this may be caused by seasonal changes in water quality. Other researchers have shown that temperature, pH and concentrations of oxygen, free ammonia and nitrite all affect growth of abalone species. As yet there is little understanding of water quality and growth dynamics on South African abalone farms. Therefore, abalone growth and diurnal and seasonal changes in water quality were monitored at an abalone farm for one year.

Growth of different cohorts of juvenile abalone, measured as a percentage of the mean monthly specific growth rate, showed monthly variation. Growth declined from 100 % of the monthly mean in June to 94 % in October, after which it increased to 106 % in February. Growth in different months is compared to changes in the measured water quality. Oxygen concentration of the farm influent was dependent upon influent temperature by the relationship $O(\text{mg/l}) = 11.244 - 2.08T$ ($r^2 = 0.74$). The pH, total ammonia concentration and suspended solids concentration of influent exhibited monthly variation (Kruskal-Wallis ANOVA: $P < 0.05$). The pH and free ammonia concentration of farm influent and effluent water were lower in the morning than in the afternoon (t-test: $P < 0.05$). Annual mean (\pm standard error) free ammonia concentration of farm effluent was 0.98 ± 0.07 when measured at 09h00 and 1.32 ± 0.11 at 16h00. Oxygen consumption in abalone raceways followed a diurnal pattern of greater consumption at night. Oxygen concentration of farm effluent was related to flow rate ($\text{l s}^{-1} \text{ ton}^{-1} H. \text{ midae}$) and effluent temperature by the equation: $O_e (\text{mg/l}) = 9.47 + 0.14F - 0.223T$ ($r^2 = 0.71$). Total ammonia concentration at the outflow of abalone raceways A_o ($\mu\text{g NH}_{3-4}\text{-N l}^{-1}$) was related to temperature T , flow-rate F ($\text{l s}^{-1} \text{ kg}^{-1} H. \text{ midae}$), body weight W (g) and length of time since raceways were last cleaned U (d) by the equation: $A_o = 10.11T - 6093.6F + 2484.2[0.22W^{-0.57}] + 0.68U - 144.8$ ($r^2 = 0.90$). Total ammonia production in abalone raceways A_p ($\mu\text{g NH}_{3-4}\text{-N s}^{-1} \text{ kg}^{-1}$) was related to temperature, body weight and days that the raceways remained un-cleaned by the formula: $A_p = 0.08008T + 15.207[0.22W^{-0.57}] + 0.00296U - 1.535$ ($r^2 = 0.84$). When growth and water quality were recorded within abalone raceways in a gradient between the inflow and outflow, growth was found to be positively correlated to pH and oxygen concentration and negatively correlated with free-ammonia concentration.

In an assessment of the suitability of abalone effluent as a culture medium for other species the growth, mortality and nutritional indices of silver kob *Argyrosomus inodorus* and bloodworm *Arenicola loveni loveni* were assessed in unused seawater and abalone effluent. Specific growth rate (0.48 % BW d⁻¹), mortality (1.8%), feed conversion ratio (3.2) and protein efficiency ratio (0.9) of silver kob kept in either abalone effluent or unused seawater for 120 days did not differ significantly (t-test: $P > 0.05$). Bloodworm supplied with unused seawater lost weight at -0.19 % BW d⁻¹, while those given abalone effluent grew at 0.39 % BW d⁻¹. Mortality was 6% in effluent and 11% in seawater. Abalone effluent was found to be a suitable culture medium for bloodworm. While the quality of the effluent did not effect growth of silver kob, growth may be too slow at typical effluent temperatures to be commercially viable.

10h20-10h40: Andrea Bernatzeder (MSc student, second year) – Salinity induced physiological responses of dusky kob, *Argyrosomus japonicus* (Family: Sciaenidae).

Supervisors: Dr P.D. Cowley (p.cowley@ru.ac.za) and Prof. T. Hecht (t.hecht@ru.ac.za)
Funders: National Research Foundation, Deutscher Akademischer Austausch Dienst (DAAD), Espadon Marine Hatchery and Joint Research Council

Fisheries management regulations for dusky kob *Argyrosomus japonicus*, an important commercial and recreational fisheries species, have failed to ensure the sustainability of the species and the stock is considered collapsed (SB/R \approx 2%). Research is needed to gain more insight into the life history, biology and distribution of the species to assist with its management. Griffiths (1995) found that early juvenile dusky kob recruit into estuaries and appear to remain in the upper reaches of estuaries at low salinities until they grow to about 150 mm TL. Larger juveniles are found in the middle and lower reaches of the estuary and surf zone. Despite a lack of empirical evidence it has been suggested that early juveniles remain confined to the upper reaches of estuaries due to food availability and predator avoidance. To date research has not incorporated the physiological responses of dusky kob to various biological and environmental variables, which is especially important in dynamic estuarine environments that are exposed to significant daily changes in abiotic conditions such as temperature, salinity and turbidity as well as unpredictable freshwater intrusions following periods of high rainfall. This study aims to investigate the role of physiological responses and adaptations to salinity on the distribution, abundance and habitat utilization of early juvenile dusky kob. The objectives of the study are to investigate: (i) the effect of salinity on growth, food conversion ratio and condition factor (ii) the direct effect of ambient salinities on blood physiology and (iii) the histological and plasma osmolality changes as a result of long-term exposures to different salinity and adaptations with age. A preliminary study was undertaken to determine whether the use of 2-phenoxyethanol had an affect on plasma osmolality. There was no significant difference in the duration of exposure (2, 4, 6, 8 and 10min) to 2-phenoxyethanol (Friedman test: $p=0.976$), and between the anaesthetized and control fish (t-test: $p=0.96$), which were not anaesthetized and pithed prior to blood extraction. Plasma osmolality and histological samples (gills, urinary bladder and kidney) were taken every two weeks in the first experimental trial that exposed juvenile kob to 5, 12 (isosmotic to blood) and 35psu for 6 weeks. The histological samples have yet to be analysed. Throughout the durations of the experimental trial the plasma osmolality of juvenile kob at 5psu was significantly different from those at 35psu ($p<0.05$). Preliminary results from the growth data suggest that kob grow best at 12psu, however the significance of this will be tested in the second experimental trial, currently still running, which is testing differences in growth, food conversion ration and condition factor specifically. Juvenile dusky kob in the Great Fish Estuary occur at salinities below 5psu, hence, the hypothesis was that they would grow best at 5psu. A subsequent review of the literature has however shown that the high conductivity in the Great Fish Estuary, where the juveniles occur, is equivalent to 12psu and that juvenile dusky kob in Australian estuaries are found in salinities closer to 12psu. The relevance of the high conductivity in the upper reaches of the Great Fish Estuary and its effect on the distribution of the fish in the estuary will be investigated further. The results of this study will also have important implications for aquaculture of dusky kob.

10h40-11h05 Tea break

Mariculture (Chair: C. McNamara)

11h10-11h30: Maryke Musson (MSc student, first year) – Prediction of larval viability based on various egg and larval quality characteristics in dusky kob, *Argyrosomus japonicus*.

Supervisors: Dr N.G. Vine (n.vine@ru.ac.za) and Prof. H. Kaiser (h.kaiser@ru.ac.za)

Funder: Marine & Coastal Management (DEAT Mariculture Frontier Programme) and National Research Foundation, HIK Abalone Farm (Pty) Ltd. and Roman Bay Sea Farm (Pty) Ltd. Fish sponsored by Espadon Marine (Pty) Ltd and the Mariculture section of Irvin & Johnson (Pty) Ltd.

The variable quality of eggs available for larval rearing is a major constraint in large scale hatchery production. Rapid egg quality assessment is thus an important tool for fish hatchery management whereby egg and larval quality can be determined by assessing various physical and chemical egg and larval characteristics. The aim of this project was to determine whether egg and larval characteristics, such as morphology, size, fertilization and hatching rate, together with larval performance in stress tests, could be indicative of larval quality and viability. Fertilized eggs and newly hatched larvae from 10 different spawning cohorts were evaluated. An egg quality ranking index (RI) was formulated incorporating egg size, shape, colour, development and oil globule number and size. Newly hatched larvae were evaluated on hatching rate, size and morphology. Replicated samples of newly hatched larvae were then exposed to four different stress tests (formalin, temperature, salinity and exposure to air), which were optimized for dusky kob. From each cohort, a minimum of five larvae were measured daily for 30 days. After 200 degree days, larvae from cohorts with higher egg quality RI's and with better stress test survival, showed better survival and growth than those from cohorts with lower RI's and poorer stress test survival. It is thus possible to predict long-term larval viability for dusky kob using egg and larval characteristics combined with appropriate stress tests. The ontogenetic development of the digestive tract of fish larvae may also be indicative of larval quality. Successful development of the digestive tract is crucial for the survival and growth of fish. Larval samples from 4 different cohorts are being processed and prepared for gut development assessment. A more detailed understanding of the development of the digestive tract will contribute to optimizing larval quality and rearing techniques.

11h30-11h50: Lindsey Woolley (MSc Student, first year) – The development of an artificial feed for the South African finfish industry by adapting local technologies developed for the abalone industry, using dusky kob as a model species.

Supervisors: Prof. P.J. Britz (p.britz@ru.ac.za) and Dr C.L.W. Jones (c.jones@ru.ac.za)
Funder: THRIP (TP2005102700010), Marifeed Pty (Ltd) and Aquafarm Pty (Ltd)

Argyrosomus spp. is in the early stages of commercial development in South Africa. Dusky kob has been identified as a good candidate for aquaculture purposes based on its generalist feeding and growth rates, reaching a marketable size in 14-15 months. At present there is no locally produced pellet feed specifically for kob or other marine finfish species. Local industries rely on expensive imported feeds and locally produced trout feeds which have been poorly accepted due to poor water stability and poor food conversion ratios (FCR). Recirculating aquaculture systems are greatly dependent on the water quality so an overall decrease in pollutant wastes from the diet is crucial to maintain suitable water quality conditions for kob. Experiments aimed to improve water stability of pellets by including additional binding agents. The overall aim of this project was to develop a marine finfish diet, specifically suited to dusky kob, by adapting the existing technologies used in the local abalone industry. The objectives were to improve pellet water stability and to increase the rate of ingestion, growth, condition and FCR of kob.

Captive bred kob with an overall average (\pm standard error) starting weight and length of 15.8 ± 1.2 g and 107.2 ± 0.7 mm were fed a diet with no additional binder (i.e. control) and a second treatment with an additional binding agent. Both treatments were presented in hard (10% moisture) and soft (30% moisture) pellet forms. These test treatments were also compared to two commercial diets (i.e. reference diets): a locally produced trout pellet (*viz.* Indian Ocean Aquatics); and an imported finfish diet (*viz.* Biomar). The test treatments were represented in quadruplet (i.e. four tanks per treatment) and the reference diets were represented in duplicate. Population densities were maintained at $10 \text{ kg} \cdot \text{m}^{-3}$ and fish were fed to satiation three times a day.

After 29 days there was no difference in weight gain between the hard or soft treatments (Kruskal-Wallis Test: $H_{(5, n=20)} = 6.4, p=0.27$), with mean weight gains of 19.9g (137%) and 20.5g (127%) for fish fed the hard pellets and 20.1g (126%) and 19.3g (155%) for fish fed the soft pellet. The mean weight gains for the treatment containing the additional binder were 20.5 ± 2.2 g compared to 19.3 ± 3.3 g for the treatment without the additional binder, with no difference amongst the treatments (Kruskal-Wallis Test: $p > 0.05$). There was also no difference amongst the test diets and the commercial diets, with an overall mean weight gain of 128% (FCR 0.92) for the test treatments, while the Biomar feed realized a gain of 108% (FCR 0.98) and the Indian Ocean trout feed realized a growth gain of 96% (FCR 1.13). This experiment is still on-going, if a trend exists between the treatments it is likely to be revealed with time. Solid leaching trials are being conducted on the test treatments as well as the commercial diets to determine water stability and leach-out rates.

11h50-12h10: Paul Collett (MSc student, second year) – Early rearing technology of juvenile dusky kob, *Argyrosomus japonicus*.

Supervisors: Dr N.G. Vine (n.vine@ru.ac.za) and Prof. H. Kaiser (h.kaiser@ru.ac.za)

Funders: Marine & Coastal Management (DEAT Mariculture Frontier Programme), Deutscher Akademischer Austausch Dienst (DAAD) and the Ernst & Ethel Eriksen Trust. Fish sponsored by Espadon Marine (Pty) Ltd and the Mariculture section of Irvin & Johnson (Pty) Ltd.

The South African mariculture industry is developing the rearing technology of indigenous fish species. Dusky kob (*Argyrosomus japonicus*) has high-quality flesh and a good market demand. Research is needed to determine the environmental requirements under which growth of dusky kob is optimised. This study assessed the effect of temperature, light intensity, feeding frequency and stocking density, respectively, on growth, feed conversion ratio (FCR) and survival of juvenile dusky kob in a series of four 42-day growth trials.

The effect of temperature on growth and FCR was assessed at 14 temperatures from 17 to 28°C. The temperature for best growth was estimated to be 25.3 °C, while 21.4 °C was the temperature at which the best FCR was achieved. A growth trial testing the effect of light intensity on growth showed that light intensity did not affect growth in the range of 23 – 315 lx. Fish fed a restricted ration of 3.6% body weight per day had a better FCR than fish fed to satiation. A trial to assess the effect of feeding frequency on growth and FCR showed that fish fed both two or three times daily grew better than those fed once daily. FCR was best in fish were fed once or twice daily. Preliminary analysis of the results from a stocking density trial showed that stocking density in the range of 10 – 50 kg m⁻³ did not affect growth of juvenile dusky kob.

It is thus recommended that juvenile dusky kob are cultured at a temperature between 25.3 and 21.4 °C, and at stocking densities up to 50 kg m⁻³ to maximise growth. However, a study is needed to determine the environmental conditions needed to maximise profit under commercial conditions. The results provide the South African mariculture industry with the opportunity to assess the culture potential of this species. In addition, the results will help develop protocols that can be used in other candidate aquaculture species such as silver kob, yellowtail, white-stumpnose and sole.

12h10-12h30: Guy Paulet (PhD student, second year) – Towards the development of a suitable pelleted diet for the East Coast rock lobster, *Panulirus homarus rubellus*.

Supervisors: Prof. P. Britz (p.britz@ru.ac.za) and Dr A. Cockcroft
Funder: Marine & Coastal Management; National Research Foundation

The objective of this research is to develop a pelleted diet for the on-growing of juvenile lobsters caught by subsistence fisherman in order to add value to the resource. Reducing the dependence on feeding mussels to lobsters is the initial focus area and preliminary diets will determine a starting point for more detailed formulations. Analysis of the composition of lobsters and various dietary components were conducted in order to determine initial diet formulations. Iso-energetic diets comprising 44% protein and 10% lipid were extruded containing 0%, 3% or 4% gelatin binder. Leaching trials determined that a 4% inclusion of gelatin gave optimal water stability after 12 hours of soaking. Protein sources were primarily fishmeal with serial replacement with either mussel or squid meal at 0%, 5%, 10% or 15%. Frozen mussels were used as the reference diet and lobsters readily accepted all diets. Growth trials were conducted using groups of five VIFE tagged lobsters per tank followed by trials in which lobsters were kept individually in a recirculating system. Water quality and other environmental conditions were monitored and kept constant. Preliminary results indicated that none of the initial formulations performed as well as the reference diet but it is hypothesized that manipulation of specific dietary fatty acid composition and ratios will yield better results in future trials.

12h30-12h50: Ernst Thompson (PhD student, third year) – Characterization of alkaline digestive enzymes in fish larvae – implications for nutritional studies of larval finfish

Supervisor: Prof. T. Hecht (t.hecht@ru.ac.za)

Funder: National Research Foundation and Deutscher Akademischer Austausch Dienst (DAAD)

The value of enzymatic studies as a tool to understand basic physiological processes is well recognised. This is also true for studies on fish, especially those concerned with larval nutrition. Methods to determine enzyme activity throughout larval development are well established, and are used as a tool to predict, for example, the correct time of weaning and feed formulation. Despite the importance of enzymes, there are very few enzymological studies dealing with enzyme characterization, i.e. the effect of physiological and environmental parameters such as temperature, gut pH, etc. on enzyme activity in fish. Not all enzymes operate under the same physiological conditions, and there are as yet, no universally accepted standards, or sets of conditions for temperature, pH and ionic strength, for the collection of such data. The objective of this study was to investigate the effect of pH on enzyme kinetics in digestion. The main alkaline enzymes involved with digestion in fish larvae, namely trypsin, chymotrypsin, lipase, amylase and phosphatase were considered. Larvae of *Sarpa salpa*, *Diplodus sargus capensis* and *Argyrosomus japonicus* were used in this study. Three independent samples were used for each species as replicates. Enzyme activity, using existing assays, was tested over a wide pH range (pH 2 – 12) for each enzyme. Normal, skewed normal and gamma plots were fitted to enzyme activity levels at the different pH's and the AIC stat was used to determine the best fit for each enzyme. A likelihood ratio test was used to determine if there is a significant difference in the optimal pH between species and replicates. The results show that there is no significant difference in the optimal pH for each enzyme among species (Trypsin: 7.67; Chymotrypsin: 7.67; Amylase: 7.68; Lipase: 8.04; Phosphatase: 9.78). It was concluded that the optimal pH for enzyme activity is the same for different warm-temperate marine finfish species. The next step will be to use the conservative nature of enzymes to develop a general model for enzymatic digestion in marine fish larvae.

Marine fisheries continued (Chair: C. McNamara)

12h50-13h10: Serge Raemaekers (PhD student, fourth year) – Fisheries Governance of two high value resources in the Eastern Cape, South Africa.

Supervisors: Prof. P. Britz (p.britz@ru.ac.za) and Dr G. Calvo-Ugarteburu (gugucalvo@yahoo.com)

Funder: Marine & Coastal Management, ECRAM (P011), Belgische Stichting Roeping

Fisheries are in a state of crisis throughout the world. While there have been some successes, truly effective fisheries management still seems beyond our grasp. This is particularly true for abalone and east coast rock lobster, two high value resources harvested in the Eastern Cape Province of South Africa.

Aimed at establishing a knowledge base to manage the abalone and east coast rock lobster fisheries in the Eastern Cape, this study sought answers to the question: “What do we need to know to manage these fisheries?” Using an interdisciplinary approach, and while employing a wide range of data gathering methods, fishing effort and dynamics were determined for both fisheries, as well as the socio-economic characteristics of the fishers, and their behaviour in these seemingly open access – free for all – fisheries.

Results show that, despite Marine & Coastal Management’s (MCM) strengthened law enforcement capacity, their quasi no-management approach in the Eastern Cape has allowed the illegal abalone harvesting to develop into a full scale, highly organized industry run by several syndicates, mainly centred near the urban area of Port Elizabeth.

In the rural communities of the Eastern Cape, along the former Transkei coastline, east coast rock lobster has been traditionally harvested for subsistence since centuries. However, MCM is currently seeking to regulate this fishery as a small-scale commercial sector. This process, allowed to be solely driven by market forces, has caused a ‘lobster boom’, with export companies lobbying subsistence fishers for exclusive supply, and thus threatening the broader national goals of poverty alleviation through livelihood development and tourism opportunities.

It is concluded that although statements have been made to combat abalone poaching, and to manage subsistence fisheries using a co-management approach, greater political will, government commitment and a multi-institutional tactic, are required if long-term sustainability of these high value resources is to be achieved.

Non-presenting students

Rhett Bennett (MSc student, third year) – Optimisation of a sampling protocol for long-term monitoring of temperate reef fishes.

Supervisors: Prof. W.H.H. Sauer (w.sauer@ru.ac.za) and Dr P.D. Cowley (p.cowley@ru.ac.za)

Funder: ORCA (Ocean Research Conservation Africa) Foundation

Marine Protected Areas (MPAs), the Ecosystem Approach to Fisheries management and Integrated Coastal Management have been identified as possible alternatives to traditional linefish management measures, which have largely failed. Monitoring and assessment of fish communities on a long-term basis is necessary, and will provide a means to evaluate the effectiveness of such management measures. Therefore, standardised protocols and optimal sampling methods for long-term monitoring (LTM) and assessment of coastal fish communities are essential. This study aimed to identify suitable methods and develop such a standardised protocol for assessment of inshore reef fish communities. A suitable location for evaluation of proposed methods was identified in the warm temperate biogeographical region of South Africa, encompassing the well-established Tsitsikamma Coastal National Park MPA and an adjacent exploited area (Plettenberg Bay). *Chrysoblephus laticeps* (roman) was identified as an indicator species for the study, as it has been well-studied and is well represented in the area. Underwater visual census (UVC) and controlled fishing were identified as suitable methods. UVC strip transects were compared to point counts, and were found to be superior, in terms of sampling efficiency, variability, bias and required sample size. A range of fishing efforts, from one to ten angler hours, was tested to determine the optimal effort to exert at each fishing station. An effort of two angler hours per station provided low catch variability and a representative catch, without excessive cost or required time. The methods were incorporated in a proposed sampling protocol, and evaluated in the field. Significantly higher catches (dominated by large predatory species) were taken in the protected area ($p=0.001$), while significantly higher UVC counts were obtained in the exploited area ($p<0.001$), explained by dominance of small opportunistic species. Generalised linear model (GLM) analysis showed significantly higher catches ($p=0.003$) and fork lengths ($p<0.001$) of roman in the protected area. Stock density ratios provided results consistent with the GLM analyses. Multivariate analysis (MVA) was able to detect differences between areas, and is recommended for detecting relative differences between areas, or long-term change (natural or anthropogenic) within an area. However, community-level analysis provided no insight into the status of the communities, or causal relationships between exploitation and observed differences between areas. Diversity and species richness were not significantly different between areas. Therefore, it is recommended that LTM within a protected area (for detection of natural change) be focused on community-level indicators, such as MVA, while LTM in an exploited area (aimed at assessing community status and detection of anthropogenic change) be focused on species-level indicators, such as catch-per-unit-effort, mean densities, mean lengths and stock density ratios of selected indicator species (such as linefish target species and smaller opportunistic and prey species). The protocol (with standardised methods) will allow for comparisons across a network of LTM sites and provide the opportunity for a broad-scale assessment of the effects of environmental variables on reef fish stocks. The protocol is suitable for assessing the effectiveness of new or well-established marine reserves, comparing reserves of different sizes and for evaluating changes in management regime or fishing activities. The protocol developed in this study has application in other biogeographical regions in South Africa, and other parts of the world. Shift in the focus of much marine research, in South Africa and elsewhere, to LTM, highlights the relevance and timeous nature of this study.

Naomi Richardson (MSc student, third year) – A preliminary investigation into the use of biomarkers and a fish community index to assess estuarine health in selected Eastern Cape estuaries.

Supervisors: Dr A.K. Whitfield (a.whitfield@ru.ac.za) and Dr W.J. Muller

The aims of this study were to determine the potential use of biomarkers at multiple levels of biological organisation together with a fish community bioindicator to assess the estuarine health status of three temporarily open/closed estuaries. The estuaries investigated were the East Kleinemonde (EK), Old Woman's (OW) and Mtana (MTN), all of which are situated in the Eastern Cape Province. Three biomarkers, the acetylcholinesterase (AChE) assay, lipid peroxidation (LPx) assay, liver histopathology, and a condition factor were used to determine sub-organism health and one bioindicator, the Estuarine Fish Community Index (EFCI) was used as a bioindicator of community health. The estuarine-dependent marine species *Rhabdosargus holubi* was selected as an indicator species for the sub-organism level analyses.

The results from the community analyses indicated that the EK and OW estuaries were in 'good' condition, while the MTN was found to be in 'moderate' condition. Histological analyses revealed that *R. holubi* from all three estuaries showed signs of pathological changes to the liver, with the fish from the MTN eliciting the highest occurrence of these changes. The LPx assay found that *R. holubi* from both the OW and MTN showed signs of oxidative damage in the liver tissue, but those from the EK did not appear to be affected. The AChE assay showed that only the fish from the OW had been affected by anticholinesterase compounds.

A laboratory study was undertaken using *R. holubi* as a positive control for the AChE and LPx assay. The fish were exposed to 3 µg/L chlorpyrifos, a known cholinesterase inhibitor, for six hours and their tissues were examined for changes to LPx levels and AChE activities. AChE activity was significantly inhibited (Mann Whitney U test, $z = 3.65$, $n = 38$, $P < 0.001$) by the exposure, but LPx levels were not significantly affected.

A composite index incorporating the biomarkers at different biological levels of organisation was developed. The index was designed to assist managers and scientists to determine whether the ichthyofauna of a system was being affected by environmental stressors and what management interventions could be undertaken to ameliorate the water quality in an estuary. The index was applied to the three estuaries investigated during the present study and both the OW and MTN were assessed to be in need of immediate management intervention.

The fish in the OW were found to be stressed at all the sub-organism levels measured and the reason for this was hypothesised to be as a result of golf course activities in this adjacent estuary. A number of management actions are proposed to reduce the sub-organism stress observed in the fish from the OW. The livers of fish from the MTN were shown to be under stress; however the causative agent of this stress was unknown because there is no formal development in the MTN catchment. However, a possible contaminant source is proposed and management interventions to alleviate the stress on the biota of the MTN are suggested. The EK does not require immediate management intervention, however, continuous routine monitoring is recommended to ensure that conditions do not deteriorate. Shortcomings of the index were outlined and a number of suggestions were made in terms of other measures of biological health which could be incorporated into the index.

Albert Esterhuizen (PhD student, second year) – The development of an artificial weaning diet for the South African abalone, *Haliotis midae*.

Supervisors: Prof. P.J. Britz (p.britz@ru.ac.za) and Dr C.L.W. Jones (c.jones@ru.ac.za)

Funders: THRIP, Marifeed (Pty) Ltd, Aquafarm Development (Pty) Ltd, HIK Abalone Farm and Joint Research Council, Rhodes University.

Juvenile abalone growth and survival are unpredictable when weaned onto an artificial diet. Currently, farms in the Western Cape in South African culturing *Haliotis midae* use standard ground Abfeed® as a weaning diet. This feed was originally formulated for grow out purposes and not a weaning diet and thus might not fulfil the nutritional requirements of the juvenile abalone. This may explain the low survival rates and sometimes poor growth during weaning. Knowledge of the physiological changes during the first few weeks of weaning will provide a better understanding of the juvenile abalone's digestive capabilities and its dietary requirements. Therefore, the overall aims of this study are 1) to gain a better understanding of the physiological changes during weaning and 2) to improve on the artificial diet currently used for weaning.

Juvenile abalone (mean length 2.605 mm ± 0.55) were fed (1) diatoms, (2) kelp, (3) Abfeed® fed in natural photoperiod and (4) Abfeed® fed in 24 h darkness. They were stocked into 90L bins connected in a flow through system. Each treatment was triplicated. Growth was monitored over 21 days and abalone were sampled every three days for analyses of digestive enzymes (including lipase, trypsin, chymotrypsin, pepsin, phosphatase and amylase), radula development and histological analyses of the gut. Abalone fed diatoms and Abfeed®-in-the-dark had similar growth rates (3.92 ± 0.76 and 3.99 ± 0.8 respectively; Kruskal Wallis, $p \leq 0.05$) that were significantly faster than the other treatments. Of particular interest was the little to no trypsin and chymotrypsin activity in all treatments. These enzymes are responsible for breaking down complex proteins, yet there was evidence of rather high levels of phosphatase activity in all treatments. This finding suggests that phosphatase might play an important role in the digestion and assimilation of smaller, less complex amino acid chains. This further suggests that juvenile abalone might require a degraded form of protein. Of great interest was the unexpected high level of lipase observed in all treatments. Lipase activity was significantly higher in abalone fed Abfeed® in total darkness (1.59 ± 0.42 mg p-nitrophenyl/min/mg protein) compared to abalone fed diatoms (0.57 ± 0.15) and kelp (0.51 ± 0.73) (ANOVA; $p \leq 0.05$). This finding contradicted past research which concluded that lipase does not serve as an important energy source for abalone and hence necessitated an investigation into the effect of lipid level and lipid source inclusion in the artificial diet for juvenile abalone.

A second study was conducted where juvenile abalone (mean starting length 2.79 mm ± 0.63) were fed diets containing bergafat, old fat, bloodworm and spirulina as lipid sources, which were fed to abalone for a period of 40 days. Ground Abfeed® was used as a reference diet. No significant differences were observed between treatments (Kruskal Wallis; $p \geq 0.05$). Similarly, diets containing lipid levels of 7, 10, 13 and 16% Bergafat did not yield any significant differences (Kruskal Wallis; $p \geq 0.05$). This study, however, revealed that protein:energy ratio could be lowered. Abalone were sampled every three days and pepsin, lipase and amylase were assayed. These results still require further analyses and will be presented at a later stage.

In conclusion, the focus of the present research study will be orientated towards the investigation into the effect of different protein:energy ratios on growth and survival of juvenile abalone as well as the effect of degraded proteins. Also, this project needs to investigate the role that phosphatase plays in protein digestion in juvenile abalone.

Michael Markovina (MSc, third year) Flatfish sperm physiology.

Report not available.

Justin Kemp (MSc student, second year) – The effect of temperature on the growth and survival of juvenile wild-harvested *Panulirus homarus rubellus* in a partial-recirculating system.

Supervisors: Prof P. Britz (P.Britz@ru.ac.za) and Dr. A. Cockcroft (cockcrof@deat.gov.za)

Funder: Marine & Coastal Management (MCM2006071700012)

The east coast rock lobster *Panulirus homarus rubellus* is a high value indigenous species collected by subsistence fisherman along the former Transkei coastline in the Eastern Cape, South Africa. However, non-compliance with the minimum size limit and inefficient local enforcement results in the regular removal of sub legal sized animals (<65 mm cl). These under-sized lobsters are generally sold directly to tourists, often for a reduced price, or used for personal consumption. Initial indications suggest that this harvest is sustainable as no boat-based commercial fishery exists and the majority of the population occurs at a depth that is inaccessible to subsistence fishers. The potential to create a win/win scenario arises if these under-sized lobsters could be on-grown under permit from the national regulating body, Marine & Coastal Management (MCM). Not only would this relieve pressure on the strained enforcement network but an increased market price for live lobster would add value to the resource and result in a suite of cascading social economic benefits.

It is well established that temperature is a key factor influencing somatic growth in aquatic crustaceans, hence this experiment aims to establish the effect of temperature on the growth and survival of *P.h. rubellus*. Juveniles (40.4±9mm CL; 63.64±12.05g) were grown in a partial-recirculating system at temperatures spanning 18.9°C to 28.6°C for 223 days on a diet of fresh mussel. There was no significant difference between moult increment in terms of both weight increase (ANOVA, p=0.56) and carapace length increase (ANOVA, p=0.54) across all temperature treatments. However, in terms of intermoult period (days), there was distinct grouping between the 19.2 ±0.3°C and 21.1±0.5°C treatments and the 24±0.4°C, 26.3±0.2°C and 28.3±0.2°C treatments, with the lower temperature group displaying a longer intermoult period and inherent slower growth rate. Furthermore, dry food consumption as a percentage of total body weight showed a strong positive correlation with temperature ($y = 0.36x - 3.67$; $r^2 = 0.95$). Mean food conversion ratio (FCR) calculated at each temperate suggest an optimal growth temperature in this trial of 24 °C (FCR = 5). Further research is aimed at determining the effect of a suite of intrinsic and extrinsic factors on ammonia production and oxygen consumption of *P.h. rubellus* with the aim of enhancing post capture, transport and culture conditions.

Index: funder, supervisor and author

A

Aquafarmiii, 11, 40, 47

B

Belgische Stichting Roeping iii, 44
BENEFIT iii, 4, 8
Bennett45
Bernatzeder38
Bills21
Booth1, 3, 4, 19, 20, 23
Britz 1, 6, 11, 17, 34, 35, 36, 40, 42, 44, 47, 50

C

Calvo-Ugarteburu44
Chalmers 24, 30
Cockcroft42, 50
Collett41
Cowley10, 28, 30, 33, 38, 45

D

DAADiii, 30, 38, 41, 43
DEAT iii, 13, 15, 34, 35, 36, 39, 41
Department of Biochemistry iii, 27
Deutscher Akademischer Austausch Dienst iii, 30, 38
Donovan 25

E

East Cape Parks Board iii
Eastern Cape Development Corporation iii
ECRAM iii, 44
Ellender18
EnviroFish Africa iii, 4
Ernst & Ethel Eriksen Trust iii, 35, 41
Escobar-Porras28
Espadon Marine iii, 13, 15, 38, 39, 41
Esterhuizen 11, 47

F

Filmalter 8
Forget10
Freestate Nature Conservation iii
Fresh Tuna Exporters Association iii, 8, 27
Frontier Programme iii, 13, 15, 34, 35, 36, 39, 41

G

Green34

H

Halley13
Hecht25, 38, 43
HIK Abalone Farm iii, 11, 35, 36, 39, 47

I

Irvin & Johnson iii, 13, 15, 39, 41

J

Johnson11
Joint Research Council iii, 11, 12, 16, 21, 33, 38, 47
Jones i, 11, 34, 36, 40, 47

K

Kaiser 12, 13, 15, 16, 35, 39, 41
Kemp50

M

Magellan16
Marifeed iii, 11, 34, 40, 47
Marine & Coastal Managementiii, 6, 13, 15, 25, 27, 28, 32,
33, 34, 35, 36, 39, 41, 42, 44, 50
Marine Growers iii, 34
Marine Living Resources Fund iii, 32
Markovina49
McNamara 35, 39, 44
Mollatt6
Montoya-Maya31
Mthombeni21
Muller46
Musson39

N

National Research Foundationiii, 18, 19, 20, 23, 25, 28, 29,
30, 31, 32, 35, 36, 38, 39, 42, 43
Naylor12
Newcombe27
Nicolle15
Northrop23

O

O'Connell	30
Ocean Research Conservation Africa	iii, 45
ORCA	iii, 45

P

Patrick	i, 32
Paulet.....	34, 42
Petersen	17

R

Radloff.....	23
Raemaekers	6, 44
Rhodes University	iii, 11, 16, 21, 27, 33, 47
Richardson.....	1, 4, 46
Roman Bay Sea Farm	iii, 35, 36, 39

S

SANCOR.....	25
SASMIA	iii, 29
Sauer	8, 24, 27, 28, 29, 45
Shaw	29
South African Environmental Observation Network	iii, 24
South African Institute for Aquatic Biodiversity	iii, 21, 32
South African National Parks	iv, 18, 20, 24
Stonier	29
Strydom	31, 32

T

Teske.....	10
Thompson	12, 18, 43
Thornycroft	3
THRIP	iv, 11, 40, 47
Timmer	16
Traas	20

V

Vine	13, 15, 39, 41
------------	----------------

W

Water Research Commission	iv, 21
Watt-Pringle.....	33
Western Indian Ocean Marine Science Association	iv, 24
Weyl.....	i, 1, 3, 4, 8, 11, 18, 19, 20, 21, 25, 27
Whitfield.....	46
Winker	19, 23
Wooldridge	31
Woolley.....	40
World Wildlife Fund	iv, 24

Y

Yearsley	36
----------------	----