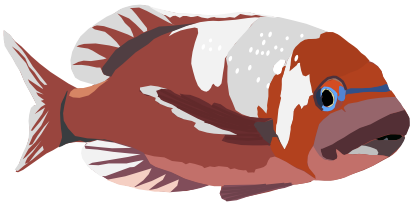
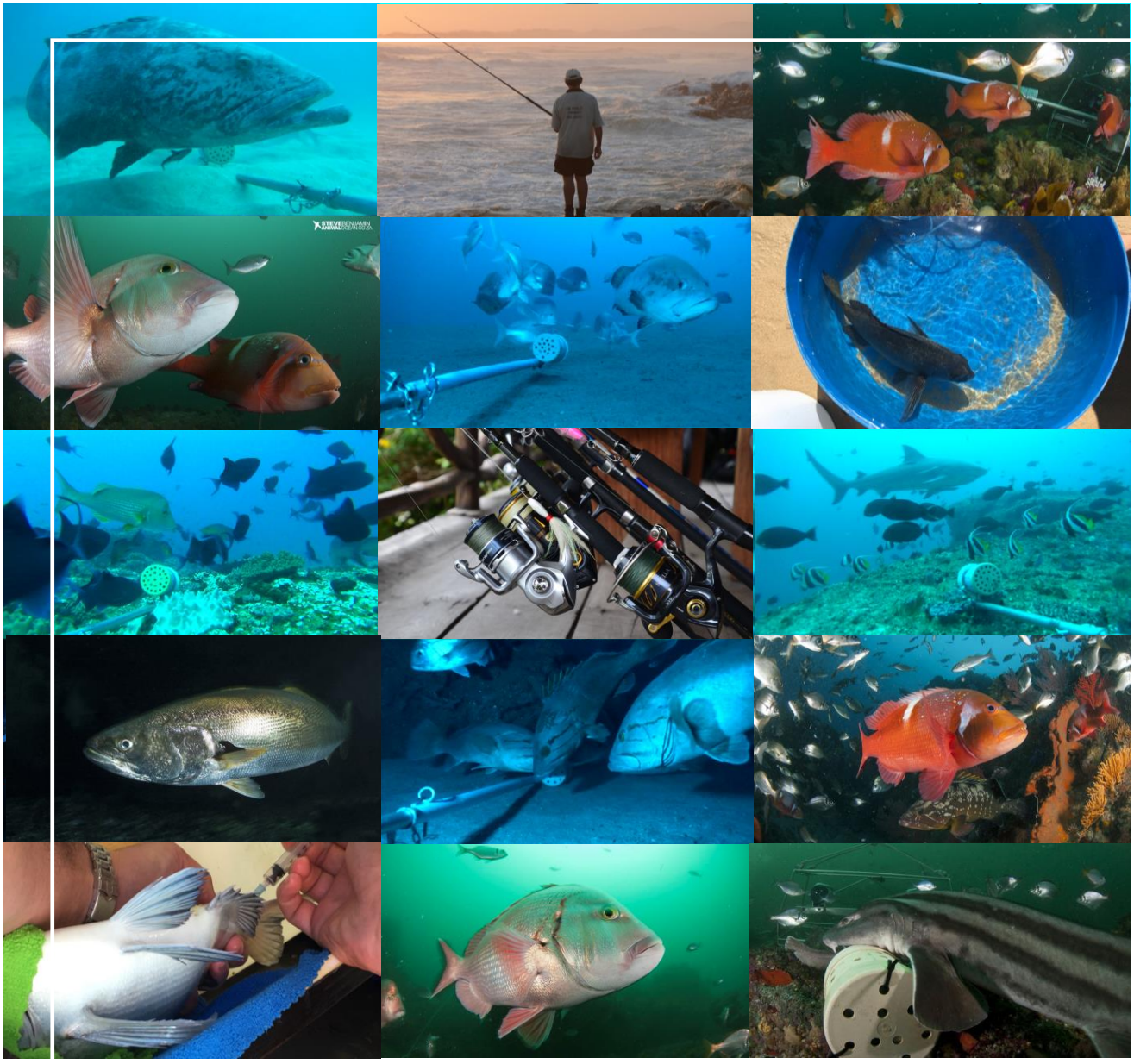
LINEFISH RESILIENCE IN THE ANTHROPOCENE:

The Proceedings of the 5th Southern African Marine Linefish Symposium



Taryn Murray, Murray Duncan, Alex Winkler, Amber-Robyn Childs, Bruce Mann, Warren Potts (Editors)



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Linefish Resilience in the Anthropocene

The Proceedings of the 5th Southern African Marine Linefish Symposium

Held at Mpekweni Beach Resort, Eastern Cape
8th to 11th July 2019

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Executive Summary

The Fifth Southern African Marine Linefish Symposium (5th SAMLS) held at Mpekweni Beach Resort along the Eastern Cape's sunshine coast, from the 9th – 11th July 2019 was attended by 99 delegates from a variety of academic, non-government organisation and government institutions, representing a 28% increase in delegate numbers from the last symposium held at Langebaan in 2012. This was largely attributed to the in-kind student funding provided by the NRF-SAIAB, financially supporting the attendance of five presenting students as well as 25 non-presenting undergraduate zoology students from the University of Fort Hare and Walter Sisulu University.

There were 43 scientific presentations, five poster presentations, three plenaries and one keynote address by Dr Stephen Brouwer from New Caledonia, South Pacific. Dr Brouwer is an internationally acclaimed fisheries scientist who started his career working on linefish in South Africa during the height of the linefish "state of emergency", which was declared in the year 2000. Dr Brouwer's experience working in fisheries management in the developed and developing world has provided him a great deal with insight on options for the management of Southern Africa's linefish populations. With the linefish "state of emergency" still in effect some 20 years later, Brouwer highlighted some of the positive steps as well as the failings and tribulations associated with linefish research and management in South Africa over the past 20 years and made several recommendations for the way forward.

Unfortunately, new challenges face our iconic, endemic and charismatic linefish species in Southern Africa brought upon by the Anthropocene, an epoch categorised by fossil fuel driven climate change, habitat loss, and relentless exploitation of our natural resources. All these factors influenced the session themes held at the 5th SAMLS, being broadly based around climate change, monitoring, fish biology and the response of society to these changes. Fortunately, technological advances have aided in many aspects of linefish research, with a strong representation of studies using electronic tagging, remotely operated camera systems, metabolism-measuring equipment and even the use of web-based applications to efficiently communicate scientific findings to the public. While the ecological knowledge of linefish has always been a strength in southern Africa, it is becoming increasingly apparent that the social systems of the linefishery are under researched. During this symposium, we attempted to promote the social components of linefish management, with dedicated sessions on science communication and socioecological systems. Despite this, our knowledge on the human dimension of our linefisheries is still underdeveloped.

Besides the development of this extended abstract document, the findings of this symposium have been disseminated in the form of two non-scientific public reports, which were compiled for the World Wildlife Fund and Fishing Industry News. Furthermore, selected studies have been submitted to the *African Journal of Marine Science* for a special issue that focusses on linefish research. Special thanks must go to the all attendees, and particularly the keynote speakers and presenting authors who graciously gave up their time to attend the conference and to the all of the sponsors for their financial support, without which, this symposium would not have been possible.

Foreword by Dr Judy Mann

Conservation Strategist and ex CEO
South Africa Association for Marine Biological Research (SAAMBR)

The Marine Linefish Research Group (MLRG), formerly recognised as a "Co-ordinating Group" under the South African National Committee for Oceanographic Research (the original name of SANCOR), has been a remarkable group of dedicated linefish researchers that has undoubtedly stood the test of time. Established in 1978, past chairmen of the MLRG have included Alan Heydorn, John Wallace, Rudy van der Elst, Colin Buxton, Bruce Mann, Paul Cowley, Colin Attwood and the current chairman, Warren Potts. Over this 41-year lifespan the MLRG has held five successful national linefish research symposia in East London (1989), Durban (1992), Arniston (1999), Langebaan (2012) and finally the 2019 symposium. The proceedings of all five of these symposia have been published and it is therefore a great privilege for me to be asked to write this foreword.

Professionally hosted by the Department of Ichthyology and Fisheries Science (DIFS), Rhodes University and the South African Institute for Aquatic Biodiversity (SAIAB), the 5th Southern African Marine Linefish Symposium (SAMLS) was held in July 2019 at the beautiful Mpekweni Beach Resort in the Eastern Cape Province. The symposium was attended by over 60 marine linefish researchers, students, managers and science communicators from around South Africa.

These proceedings highlight many of the almost 50 symposium presentations and provide a comprehensive summary of the state of marine linefish research and management in South Africa today. Reading through previous proceedings, it is clear that the topics addressed in these proceedings are far more diverse than in previous years, with the inclusion of aspects such as climate change, fish physiology and acoustic telemetry, as well as a stronger emphasis on the social and economic aspects of fisheries management. Notable are the many long-term monitoring studies which continue to provide extremely valuable information on changes in populations and systems that often cannot be revealed using short-term studies. The greater emphasis of research on fishermen reflects the growing understanding that fisheries management is as much about people and their behaviour, as it is about fish and their biology. It is encouraging to see that in addition to a greater diversity in topics, the diversity of the linefish community is also increasing, with attendance by staff and students from Rhodes University, Walter Sisulu University and the University of Fort Hare. The deliberate inclusion of more students will help to build the capacity of the next generation of linefish researchers and managers.

From these proceedings, it is evident that the scientists and managers involved in research and management of South Africa's linefish today, still exhibit the same passion for fish, fishing and fisheries management that has been evident since the 1970s. Since the early days, managers and scientists have worked together with fishermen to ensure that science was undertaken based on collaborative prioritisation, that management decisions were based on sound science and that management regulations were implemented. The foresight of the researchers who undertook the science and the managers who implemented the regulations is to be commended. Unfortunately, the current changes at multiple levels of government have the potential to decouple science from management. Furthermore, the loss of important management structures such as the South African Marine Linefish Management Association (SAMLMA) is cause for concern, particularly regarding management of recreational fisheries.

These proceedings are a testament to the work of the members of the MLRG for over 40 years. I hope that when you read them you will feel the same sense of pride that I feel in our colleagues and friends and in South Africa's marine linefish research and management community. Well done to Warren Potts and his team who put together an excellent symposium.

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NOTE: For extended abstracts, an asterisk (*) denotes the speaker and a dagger (†) denotes a student

Background to the theme: Linefish Resilience in the Anthropocene

Warren M. Potts
Professor
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The theme of the 5th Southern African Marine Linefish Symposium is centred on the idea of developing and fostering resilient linefisheries that can adapt to ecological, environmental and societal change and disturbance, while maintaining structure and function. We are in the midst of the Anthropocene Epoch where our linefish fish stocks are being subjected to unprecedented stressors associated with a rapidly changing climate and increasing levels of exploitation as a result of rapid human population growth. Maintaining resilience in the Anthropocene will not only require dedication by scientists, management and fishers, but the science serving the complex socio-ecological systems in fisheries will be dependent on interdisciplinary and even transdisciplinary research.

Fostering interdisciplinarity and transdisciplinarity is only possible through solid partnerships between research, management, the fishers themselves and other stakeholders. Up to now, marine linefish research has had a strong ecological orientation and there have been few successful attempts to combine ecological and human dimensions research. Although the ideals of interdisciplinarity are increasingly applied in the scientific community, many conferences are strictly discipline bound (e.g. ecology, economics). This linefish symposium attempted to bridge the gaps in ecological and human dimension research by bringing together researchers from a range of disciplines to a common venue to jointly discuss challenging issues, from interdisciplinary perspectives, with a goal of fostering resilience of our linefisheries in a rapidly changing world.

SESSION 1

Fisheries

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SESSION 1 | Fisheries

An introduction to the rich methodology to assess data-poor South African linefishes

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South African linefishers consistently target more than 50 species. Sustainable management of these species requires robust scientific advice, however choosing an appropriate manner in which to portray stock status advice is dependent on the availability of biological and fisheries data. Most of our linefishes are considered to be data-poor, as regular surveys are too costly, yet fishery-data are consistently available from commercial catch returns, supplemented with occasional port sampling. In addition, life history information is available for a large number of species and can be utilised, in conjunction with the available fisheries information, to assess stock status and estimate population trajectories. Here we introduce the linefish assessment toolbox that has been developed over the last eight years. The toolbox includes simple and advanced methodologies; and the application of each is defined by data availability.

For the purpose of assessment, stocks can be broadly grouped into three different tiers, data rich, data moderate and data poor. For data rich stocks a time series of total catch and an index of abundance are available, as well as annual catch at age data. These data enable fitting an integrated Age Structured Production Model, which is able to track the cohorts under exposure to fishing throughout the time series. Data moderate stocks typically lack consistent catch at age data due to the unavailability of dedicated annual surveys. These stocks are commonly assessed with surplus production models that do not require information on size and age composition. Data poor stocks are those that cannot be assessed within the frameworks above. For these, assessments are typically confined to time series analyses and tracking of some kind of index, such as catch- or encounter rates. If no time series information exists, catch curve analyses and “per-recruit” type models based on life history and size or age information remain the only option to provide snapshots of stock status under certain conditions.

South African linefishes fall into the data moderate and data poor tiers, which unfortunately belies the quality of data that are available. But for the absence of consistent annual catch-at-age information, the quality of data for many linefish species is on par with, or even exceeds, that of far more valuable national and international stocks. The South African National Marine Linefish System (NMLS) contains 4 million records of vessel specific, spatially referenced, daily catch data for over 200 species over a period of 35 years. Size frequency data from observer efforts and staff collections amounts to 0.5 million records - however recent size frequency records are few. The South African Marine Linefish Species Profiles contain detailed life history information for 139 species. Large shore angling datasets, such as the 2012–2013 Eastern Cape Small Scale Fishing Observer Programme which contains 115 000 length frequency records for more than 25 species caught by recreational and subsistence shore anglers, are also available.

Unlocking the available information for stock assessment has long been one of the main challenges of linefish research, and the standardisation of the Catch Per Unit Effort (CPUE) data time series into an index of abundance for the major commercial species was a major breakthrough. A particular improvement was the invention of the Direct Principal Component (DPC) method that used the proportion of species in the individual catches within a Principal Component Analysis (PCA) to account for differences in targeting. Including the eigenvalues of the PCA as covariates in the standardization model increased the relative deviance explained by up to 50% for some species as targeting accounted for most of the variation in the data.

The availability of a standardised CPUE index enabled the use of data moderate methods, such as surplus production models. This facilitated improvements to the basic Schaefer surplus production model, in the form of a bayesian state space modelling framework termed JABBA (Just Another Bayesian Biomass Assessment) and its extension, JABBA-Select (https://github.com/Henning-Winker). JABBA incorporates prior information on stock depletion at the beginning of the time series, uses what information is available from life-history studies and accommodates multiple abundance indices to estimate stock status. Changes in selectivity over the time-series are accounted for in the SELECT extension. Fast run-times facilitate quick turnaround to test alternative scenarios and the estimated relative spawning biomass can be directly compared with simpler steady-state spawning-biomass-per-recruit (SBR) and more complex ASPM models and visualised graphically in the form of familiar Kobe phase and projection plots for different catch scenarios. Since 2017 eleven linefish species were assessed with this framework, representing over 90% of the catch in the commercial linefishery. The JABBA framework has been endorsed by an independent international expert panel and accepted as a standard assessment tool by two major regional fisheries management organisations, ICCAT and IOTC, where ten species were assessed with JABBA thus far.

In cases were catches became so rare that landings became incidental, an index based on probability of encounter (PE) can be used instead of CPUE as it is less sensitive to bag and size limit changes when the information is only available in fish mass. It can be shown that across a wide range of scenarios that there is a linear relationship between CPUE and PE when catch rates have declined to less than 25%. The PE method enabled tracking the relative abundance of red steenbras and dageraad, which have shown worrying declines in the last decades despite stricter management regulations.

For linefish species that have life history information but no time series available, catch curve analyses and in particular SBR modelling remain the best options. There have been several improvements to previous SBR models which aim to better account for uncertainty in recruitment, natural mortality and total mortality estimates. SBR assessments for seven important shore angling species were finalised in 2016, revealing that spotted grunter, shad and dusky kob have collapsed ($SBR/SBRF_0 < 0.25$), with the latter being of serious concern ($SBR/SBRF_0 = 0.013$). An SBR assessment based on two snapshots, 1990 and 2010, before and after the linefish was declared to be in a state of emergency, revealed increases in spawner biomass for 17 of the 21 species that were assessed. The four species that showed a decrease in spawner biomass in this period were elf, white-edged-, catface- and yellowbelly rockcod.

Owing to the rapid developments within the last decade, the linefish assessment toolbox is on par with the best available practice in developed countries and is sufficient to provide detailed annual stock status for major stocks. Recent assessments confirm that there is a general positive trend across the linefishery and that most species, with a few concerning exceptions, are in a recovery phase. Secondary species assessments will always rely on 'snapshot' type methods SBR and trend analyses, but this methodology is also rapidly improving (e.g. Just Another Red List Assessment (JARA) https://github.com/Henning-Winker/JARA).

Regular updates of size frequency data and an in depth understanding of the species' biology remain crucial for all data limited assessment types. Data from BRUVs and other next-generation initiatives should be tested and integrated.

Existing and potential catches in South Africa's remaining coastal stonewall fish traps

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Background

Stonewall fish traps or "visvywers" were perhaps first built by aboriginal peoples but no links have been found between midden and visvywer catch composition nor is there any evidence for construction of these traps by them. Peak "industrial-scale" construction occurred in colonial times with most visvywers constructed after 1880 and permits held by farmers adjacent to the shore. Then, as in the present day, the traps were characterised by infrequent very large and lucrative catches. Inter-sector conflict (and lack of mounted police monitors) saw the banning of all visvywers in 1890 that lasted 12 years. Thereafter, visvywers were constructed on all available rocky-platform, boulder beach and mixed shore on the Cape south coast. Demand soon exceeded available area and trap construction spread to sandy beaches. These latter traps constructed of other material; railway tracks, steel cable and concrete, have all but disappeared. The most productive traps were fished to the early 1980s, the Still Bay ones legally to 1999 and, with Arniston, informally to the present day.

About 70 sets of these traps existed on the Cape south coast, limited by the extent of rocky platforms and boulder beach habitat. Only two of these sets are currently maintained and fished, albeit illicitly, but there have been numerous requests for access to fish traps throughout their historical extent including False Bay, Still Bay, Arniston and Skipskop to Koppie Alleen in the De Hoop MPA. The Still Bay visvywers are recognized as a heritage site of cultural significance and an integral part of the Still Bay MPA. Consequently, one set of visvywers of 24 traps is being maintained within the Still Bay MPA and catches recorded (& released) with a view to assessing the possible impact of this fishery on the resource. Also being assessed, is the feasibility of visvywer harvesting being offered as one of the cultural experiences available to visitors in the Still Bay MPA. Catch monitoring will help inform decisions with respect to applications for access to visvywers elsewhere on the Cape south coast.

Results

Historically, all fishing was on dark-moon spring tides from late autumn to early spring where falling tides commence during dark thus entrapping more fish, and dawn harvesting times are at a maximum. Thirteen dark-moon springs during 2017-18 saw 14 000 fish of 30 species caught in the traps. Numerically, catches were dominated by harder *Chelon richardsonii* (56%), strepie *Sarpa salpa* (24%), blacktail *Diplodus capensis* (6%) and elf *Pomatomus saltatrix* (2%). Harder (58%), elf (12%) and strepie (12%)

dominated by mass with blacktail (6%) and white musselcracker *Sparodon durbanensis* (5%) also being important. The fishery is characterised by low catches punctuated by 1-in-50 catch events. Conditions during these periodic high-catch events were low wave-height and relatively warm water inshore. Very low catches coincided with high seas.

Still Bay monitored traps (2017–2018) yielded about 5.1 t caught per annum. This suggests that the 68 trap sets between Cape Point and Mossel Bay could potentially catch 340 t per annum. On the other hand, reported Still Bay commercial trap catches (1983–1999) were 12.6 t per annum. Extrapolated from Cape Point to Mossel Bay; 68 trap-sets could potentially catch 856 t per annum. In all, trap fishing and participation in maintenance could be a cultural, archaeological feature of the Still Bay MPA, but a potential 40–60% linefish bycatch of > 500 t suggests against re-establishing the fishery on the Cape south coast.

Striking disconnect between the economics, policy and management of SA's marine recreational fisheries

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Background
Global participation in the recreational sector outnumbers that of most other fishery sectors and the biomass captured in recreational fisheries often exceeds commercial harvest in many parts of the world (Arlinghaus et al. 2019). Despite this, recent studies have concluded that the importance and impacts of recreational fisheries have been largely ignored and the sector is generally poorly governed (Potts et al. 2019). South Africa's marine recreational fishery has huge participation rates and is capable of outcompeting many of the other coastal fisheries, which support the livelihoods of poor communities living along the coastline. The aim of this presentation is to contextualise the current status, economic impact and current state of governance of the South African marine recreational fishery in order to make recommendations for improvements to the status quo.

Methods
To do this, we summarise some of the recent research on South Africa's marine recreational fisheries, including estimates of the number of anglers and their catch, an economic impact assessment, information on the importance of fish as food to recreational anglers, information on the compliance of marine recreational fishers, and a review of the efficacy of the governance of marine recreational fisheries.

Results
A recent study on the economic impact of recreational fishing on the South African economy (Saayman et al. 2017) estimated the number of marine recreational anglers using a range of techniques. The most reliable estimate was based on information on the number of marine licences and the proportion of anglers that were licensed. The estimated number of marine recreational anglers derived from this method was 728 627. Of these, the majority were marine shore-based anglers (394 286), light tackle boat anglers (150 639), estuarine shore-based anglers (79 667), deep sea anglers (67 603) and spearfishers (33 616). The participation rate in marine recreational angling nationally was 2.3%, which is slightly below the global average (where information is available). Although the participation rate was relatively low, recreational anglers in South Africa are quite avid, with an average of 20 days spent fishing each year. This is high, when compared with other countries around the world (Australia 6 dpy – Henry and Lyle (2003), Europe 12 dpy – Hyder et al. (2017)) and has a large impact on the recreational fishery harvest. When the estimated number of angling days was combined with the catch per unit effort (from existing studies) for each sector, the total estimated catch for the South African marine recreational fishery was 8355 tonnes. This is larger than the harvest of the commercial linefishery (~ 8000 tonnes each year).

Despite its biological impact, the marine recreational fishery is very important economically. Saayman et al. (2017) estimated that marine recreational anglers spend R14.6 billion per year on their angling activities. This creates a large number of jobs (94 070), particularly in the trade, accommodation and catering sector (44 138 jobs). It also supports an informal sector of bait collectors, guides and fish cleaners (R227.5 million direct expenditure per

annum). One quarter of recreational fishers earned less than R140 000 per year and the majority of these used the fish they captured to supplement their food security needs.

Bova (2018) conducted a study on the compliance of marine shore-based recreational anglers. Using specifically designed techniques (ballot box method) to obtain truthful responses from anglers, Bova found that non-compliance to the recreational angling regulations is very high. A total of 48.3% of recreational anglers are non-compliant to at least one regulation. Non-compliance was most prevalent for size limits (24.6%), licence possession (19.3%) and prohibited tackle (11.1%) regulations but was very low for marine protected area violations (2.2%). These levels of non-compliance are higher than those recorded anywhere else in the world.

A recent review on the state of global recreational fisheries governance (Potts et al. 2019) used experts to gauge the efficacy of recreational fishery governance in over 27 countries, including South Africa. Although the governance of recreational fisheries was considered to be poor on a global scale, South Africa's recreational fishery governance ranked poorly when compared with both developed and developing countries. In terms of efficacy, the general content of policies and acts were rated to be 50%, the procedures incorporated and referred to in Policies/Acts was rated to be 42% and the efficacy of implementation of the policies was only 38%.

Conclusion

Based on these findings, we argue that participation in marine recreational fisheries in South Africa is considerable and the sector has a large biological impact on marine coastal resources and is economically valuable, supporting a large number of formal and informal jobs. However, there appears to be a striking disconnect between the importance of this fishery and the efficacy of its governance. To remedy this, we recommend a policy shift to recognise the recreational fishery as a separate sector; the promotion of inclusive stakeholder engagement; the implementation of biological monitoring programs; the initiation of human dimensions monitoring programs; and a broader (instrumental and normative) approach to address non-compliance to improve the benefits and resilience of this important fishery.

SESSION 2

Monitoring & MPAs

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SESSION 2 | Monitoring and MPAs

Habitat and associated fishes examined by a Remotely Operated Vehicle across the continental shelf in existing Marine Protected Areas and their offshore expansions in the Amathole area

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Background

Despite increasing anthropogenic pressure through seabed mining and fishing, fish assemblages in the temperate mesophotic zone (typically between 30 and 150 m deep) remain poorly understood. Sampling the mesophotic remains challenging in terms of accessibility and cost. Understanding mesophotic marine systems is a priority as they could provide refuge to exploited fishes and reseed shallower zones. Expanding pressures are being exerted on the mesophotic. In South Africa, efforts are underway to utilise the ocean to stimulate economic growth, which will result in further pressures on marine systems. To mitigate these pressures a network of Marine Protected Areas (MPAs) throughout South Africa's Exclusive Economic Zone (EEZ) has been created. Two existing MPAs, the Kei and Gxulu MPA on the continental shelf off the Amathole have been extended offshore, thus extending protection to the mesophotic zone. The Amathole shelf is an endemism hotspot and a transitional zone between the subtropical east coast and the warm temperate south coast. The region is largely unexplored due to its treacherous sea conditions, with strong currents reaching speeds of four knots. The strong currents and the narrow shelf, which is fortunately off the demersal trawl footprint, has protected the area from intensive fishing. To survey the Amathole regions' mesophotic fish and habitat for the first time we used a remotely operated vehicle (ROV) to fly video transects in two areas offshore of the Kei and the Gxulu Rivers. The locations of transects were chosen to include known recreational fishing spots and areas of high relief identified using multibeam sonar. From the video transects, we quantified mesophotic fish species diversity and relative abundance in relation to depth, distance to shore and benthic habitat type. We also determined which environmental variables best explain patterns of fish distribution, abundance, and community composition.

Methods

The ROV flew approximately a meter above the seafloor with its camera orientated forward. Video transect dives were approximately 90 minutes duration. For the analysis, transect paths were overlaid with a grid (each cell was a quarter of a nautical mile squared) in GIS. Within each cell, for every species observed we determined the maximum number of individuals of that species per frame per cell (MaxN). At five evenly spaced time intervals in each cell, depth and habitat substrate, biota, and relief was also determined. We clustered cells with similar habitat biota, substrate, and relief respectively using hierarchical clustering. We excluded cells that were explored for less than 3 minutes. To evaluate the impact of area on fish species abundance and composition, we used Non-metric Multidimensional Scaling (nMDS) to compare fish assemblages between the Kei and Gxulu area. A random forest algorithm was performed to determine which habitat clusters and environmental variables were important for predicting

fish species abundance. The four most influential variables were included in a Multivariate Regression Tree (MRT), which aimed to objectively group grid cells of high species similarity. The distribution of the resultant fish communities was mapped. Generalised Additive Models (GAMs) were used to model species richness. Explanatory variables included habitat clusters and depth or distance to shore, respectively, because of co-linearity among the latter two variables. For all GAMs distance to shore or depth was always retained in final models. Other variables were dropped using backward elimination until only significant variables remained or the variable with the lowest p-value was retained. Explanatory variables retained in the final models were isolated and their influence on their response variables explored. The impact of explanatory variables for a reference set of standard conditions was predicted for each response variable. The reference set was chosen by fixing categorical explanatory variables to their most common value and the continuous variables to their mode.

Results

Despite strong currents, the ROV video sampling was successful. From 62 ROV transects, 54 hours of footage was collected. These transects resulted in 117 valid cells. It took about 250 hours to extract the fish and habitat data from the footage. Total summed MaxN of fish individuals observed was 1829 and 98% were identified to species level. The footage provided quantitative information on fish and habitat diversity in the mesophotic depths of the Kei and Gxulu area of the Amathole shelf. Rare observations of large, overexploited and endangered or critically endangered endemic seabreams were made including red steenbras *Petrus rupestris*, seventy-four *Polysteganus undulosus*, red stumpnose *Chrysoblephus gibbiceps* and dageraad *Chrysoblephus cristiceps*. We witnessed the typically solitary species wreckfish *Polyprion americanus* schooling for the first time, on the shelf edge above deep-water corals. A living speckled guitarfish *Rhinobatos ocellatus* was videoed for the first time. Both these are IUCN Red List data deficient species. A potentially new *Liopropoma* species was observed. Habitat types sampled, included rhodolith beds, sponges, and delicate deep-water corals. Habitat formed the following clusters for Substrate: sand, coral rubble, rhodoliths and rock; Biota: no biota; algae; coral and sponges and fan coral; Relief: flat and low. Fish communities differed between the two regions where MPAs were recently expanded, despite having species in common. Fish community diversity was highest inshore and on the continental shelf edge. Maximum fish diversity corresponded with consolidated substrate types and the mid-continental shelf.

Conclusion

In conclusion, the ROV was effective for sampling fish and habitats in the strong currents of the Amathole shelf's mesophotic. The study provides support for the area's protection. It confirmed that the Amathole shelf is a diversity hotspot containing endangered and critically endangered species and fragile habitats. The shelf edge is a potential spawning ground for *P. americanus*, as their observed schooling suggests possible spawning aggregations. Fish communities differed between Kei and Gxulu region, likely because the region is a transition zone between the subtropical east coast and the warm temperate south coast. The different communities in the Kei and Gxulu regions provides support for MPAs in each region. High species diversity observed on the shelf edge and the peak in species richness on the mid-shelf supports the offshore extension of the MPAs. Going forward we are working on applying machine learning algorithms to reduce manual video data extraction time, such that underwater video can be more efficiently used by researchers and managers to monitor fish diversity and relative abundance.

Is depth a natural refuge for reef-associated linefish species occurring along the east and south coast of South Africa?

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Background

Historically, deep, isolated reefs were thought to be natural refuges from fishing and other anthropogenic disturbances that have collapsed resource populations and ecosystems in shallow habitats. The depth refuge hypothesis assumes that deep reefs are protected from disturbances that affect shallow reefs, as they are harder to access. The ecological significance of the refuge is based on the fact that numerous reef-associated fish species are depth generalist and that the subpopulations occurring on the deeper reefs should then act as reseeding populations for the more heavily exploited shallow ecosystems. This is the case in South Africa, where many of the important reef-associated linefish appear to be depth generalists. However, within a species considered to be a depth generalist, there is often structuring over the depth gradient linked to ontogeny. For example, juvenile dageraad *Chrysoblephus cristiceps*, red steenbras *Petrus rupestris* and seventy-four *Polysteganus praeorbitalis* are restricted to the shallows, while adults occupy much broader depth ranges. The fact that adults of important linefish species inhabit deeper reefs suggests that, if depth is a natural refuge, then it could be playing an important role in reseeding of the shallow habitats in South Africa.

However, there is a large body of research which suggests that fisheries have moved deeper, and that the unique assemblages of fish found on deep mesophotic ecosystems are as vulnerable to disturbance as their shallow neighbours. Line-fishing activity, targeting reef fish on the continental shelf of South Africa, is predominantly from the commercial and recreational sectors. These sectors both have access to new fishing technologies that allow them to access deeper habitats, suggesting that depth may be less of a refuge in our waters than in countries where reef fisheries are less technologically advanced. Alternatively, the strong Agulhas Current, together with adverse weather, typical to the south and east coast of South Africa, limits the number of fishing opportunities and this may still create an environment

where depth acts as a refuge. To test if the depth refuge hypothesis holds for reef-associated linefish in South Africa, we compared the total abundance, biomass, and assemblage structure of linefish between deep (45–75m) and shallow (5–30 m) reefs, inside and outside of four no-take marine protected areas.

Methods

To separate the effect of natural, depth-related variability in linefish assemblages from fisheries effects, this research took the form of a crossed-design field experiment (depth zone [shallow vs. deep] × management [protected vs. exploited]), replicated at four locations (Tsitsikamma, Bird Island, Amathole and Pondoland). Relative abundance (MaxN) and size (fork length) data were collected with baited (1 kg crushed *Sardinops sagax*) remote underwater stereo-video systems, using one-hour deployments. Total abundance was estimated by summing the relative abundance for each linefish species, per sample. Total biomass data were obtained by converting the length data to biomass, using published length-weight relationships, and summing the data for each sample. Generalised additive mixed effects models, with location as a random effect, were then used to determine the main effects of management and depth zone and if the effect of depth zone was consistent between protected and exploited areas. To determine which species and life stages were driving the observed patterns, permutational multivariate analysis of variance (PERMANOVA) of age-structured (where fish were either defined as mature or immature when they were greater than or less than the size at 50% maturity respectively) species assemblages, together with canonical analysis of principal coordinates (CAP) were conducted.

Results

For total abundance, linefish were significantly more abundant inside MPAs ($p = 0.008$), and there was no effect of depth zone ($p = 0.072$). However, the effect of depth zone on total abundance was inconsistent between the levels of management ($p = 0.040$), with greater abundances of linefish in the deep, compared to the shallow, zones in the MPAs, and the opposite in the exploited areas. Similar results were obtained for the total biomass, being greater in the protected areas ($p < 0.001$), and the effect of depth zone was inconsistent ($p = 0.043$) with a significant increase in biomass, from shallow to deep, in the protected areas, and no relationship with depth in the exploited areas.

The PERMANOVA indicated that the age-structured assemblages differed significantly according to management status and depth zone, and the effect of depth zone was inconsistent between the protected and exploited areas ($p = 0.001$, in all cases). The CAP analysis showed clear grouping and separation of the samples collected within the different management and depth zones, with correlation vectors ($r > 0.3$) indicating that deep reefs should be characterised by adults of numerous linefish species, but that exploited reefs are characterised by immature individuals from only a limited number of linefish species.

Conclusion

Our results clearly demonstrate that, in a South African context, depth is the opposite of a refuge for fish species targeted by line-fisheries. For many of South Africa's reef-associated linefish species, ontogenetic shifts in habitat preference result in larger individuals inhabiting deeper reefs, and this is clearly reflected in the data collected from inside the MPAs. However, the deep reefs in exploited areas were characterised by immature individuals, suggesting that fishing has disrupted the natural pattern and that the functional structure of deep reef fish assemblages is highly vulnerable to line-fisheries. Numerous factors contribute towards anglers targeting larger fishes (e.g. regulations, markets and ego), and when considered alongside the historic overexploitation of shallow reefs, targeting deeper reefs makes sense. In addition, advances in fishing technology (braided lines, high-resolution echo-sounders and GPS's) have made it easier for anglers to effectively fish in the deep. Our results further highlight that MPAs can play a critical role in protecting these vulnerable assemblages of fish species.

Zonation and reef size significantly influence fish population structure in an established marine protected area, iSimangaliso Wetland Park, South Africa

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Background
To demonstrate conservation effects resulting from marine protected areas, many studies rely on spatial comparisons between areas afforded different levels of protection. These spatial comparisons can be confounded if the habitat and reef size are dissimilar and not accounted for in the statistical analysis.

Methods
Taking into account reef size (obtained from sidescan sonar data) and benthic habitat structure, this research tested the effect of management zonation, namely the No-take Sanctuary Zone (NTSZ) and the Controlled Pelagic Zone (CPZ) on the population structure (relative abundance and average biomass) of six fish species in the iSimangaliso Wetland Park, South Africa. The NTSZ prohibited fishing, while the CPZ only allowed pelagic gamefishing (i.e. no bottom-fishing). Furthermore, this study tested the effect of ignoring reef size in the spatial comparisons.

Results
Our results showed that reef size had a significant positive effect on the relative abundance and average biomass of most, but not all species. When reef size was included in the models, the results showed that twinspot snapper *Lutjanus bohar* and yellow-edged lyretail *Variola louti* presented no effect of management zone; green jobfish *Aprion virescens* and bluefin trevally *Caranx melampygus* appeared to be directly affected by the permitted (past and present) fishing activity in the CPZ; and the lastly potato bass *Epinephelus tukula* and yellowtail emperor *Lethrinus crocineus* appeared to be affected by the disturbance caused by the diving and/or boating activity in the CPZ. Excluding reef size from the analysis consistently resulted in the predicted relative abundance and average biomass decreasing in the CPZ and increasing in the NTSZ. This effect was most marked in the average biomass data, as the management zone effect changed from negligible to significant for five of the six species.

Conclusion

Our results reiterate those of previous studies: covariates describing the nature of habitats, in particular reef size, need to be considered when measuring the effects of management strategies in marine systems as their omission may lead to spurious conclusions. This is especially true when arguing the case for Marine Protected Areas (MPAs) and fisheries closures. Increasingly, human needs must be accommodated (e.g. resource harvesting or recreation) within MPAs. In our example, the CPZ of the iSimangaliso Wetland Park MPA permitted fishing for pelagic species, scuba diving and the associated boating activity. Only two of the six reef-associated species examined here showed no effect of management zone. Two of the remaining four appeared to be directly affected by the permitted (past and present) fishing activity, whereas the remaining two species might have been affected by disturbances due to diving and/or boating activity. Our results highlight the importance of no-take sanctuary zones for the conservation of targeted species and illustrate some potential impacts of the trade-off required to accommodate human needs within protected spaces.

The Goukamma Marine Protected Area catch-per-unit-effort monitoring programme – 6 years down the line

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Background

The Goukamma Marine Protected Area (MPA) was declared in 1990 for the purpose of conserving and managing biodiversity in the marine environment. Angling from a boat was excluded from permitted activities but shore angling and bait collecting were still allowed. In 2012, the process to rezone and realign the boundaries of the MPA was initiated by CapeNature. The aim of the rezonation/realignment was to increase the protection of available habitats that host over-exploited fish species and to limit all extractive use along parts of the shoreline of the MPA. However, in order to determine whether such no-take areas are effective, it is necessary to collect baseline data on fish abundance pre- and post-rezonation/realignment. The Goukamma MPA controlled shore-angling programme was developed and implemented to assess whether fish stocks do recover with enhanced protection.

The Goukamma MPA is located in the Southern Cape, South Africa. The MPA has a terrestrial reserve adjacent to its boundary which is managed by CapeNature. Parts of the Goukamma Estuary falls within the boundaries of the Goukamma Nature Reserve. The rezonation of the MPA uses the estuary mouth as the transition area from "take" to "no-take" areas. The study site falls within the current MPA boundary and the control site falls outside, to the west, of the MPA boundary. Currently, the MPA is still open to shore based angling and is a popular fishing spot along the Garden Route. From this, one would assume that the fishing pressure at both sites is equal. Previous studies that have assessed shore angling in Goukamma have shown that a large proportion of undersized fish of over-exploited species were not released by anglers and that the extractive use of fish is high. The primary aim of the monitoring project was to determine if the closure of the MPA to shore angling would improve the state of over-exploited linefish species.

Methods

The study area comprised of one site within the MPA (Oysterbeds) and a similar site outside the MPA (Gona's), approximately 17 km west. Both study sites were 2 km long, with a mixture of sandy beach and aeolianite rock platforms, with subtidal reefs interspersed by sandy patches leaving a mosaic of reef in the surf-zone. Eight sampling trips were undertaken annually, over a period of six years, and all trips took place over a weekend. Eight experienced volunteer anglers partook in each trip where four anglers fished from sunrise to sunset at Oysterbed's and the other four at Gona's. On the second day of the weekend, the anglers swapped fishing locations. Anglers used standardised rock and surf fishing gear and were only allowed to use the bait provided to them or specified alternatives. Priority species (list provided by Oceanographic Research Institute) greater than 30 cm total length were tagged with plastic dart tags provided by ORI. Galjoen greater than 25 cm total length were tagged. All fish caught were measured, recorded and released.

Results

A total of 602 angler days (one angler fishing for one day equals one angler day), which equates to 6 013 angler fishing hours, were undertaken. Angling effort was highest in autumn (246 days) and lowest in

winter (99 days). A total of 1 696 fish from 41 species were caught. Of these species, 14 were sharks, six were rays and 21 were bony fish, which included nine species from the family Sparidae. The three most abundant species were blacktail *Diplodus capensis* (34.3%), galjoen *Dichistius capensis* (17.9%) and lesser guitarfish *Acroteriobatus annulatus* (17.2%). The remaining 38 species made up 30% of the total catch. Of the ORI priority species, 12 were caught during the project of which the most abundant were galjoen *D. capensis* (17.9%), white steenbras *Lithognathus lithognathus* (3.8%), elf *Pomatomus saltatrix* (2.5%) and dusky kob *Argyrosomus japonicus* (2.1%). The catch-per-unit-effort (CPUE) for all species was relatively low at both sites with a few species showing some variation between catches. The CPUE for *Dichistius capensis*, *A. japonicus* and *L. lithognathus* was noticeably higher inside the MPA than outside. However, the CPUE was so low that making meaningful deductions from this these results was difficult.

Recapture rates of tagged fish was also very low, of the 213 *Dichistius capensis* tagged, only seven (3.3%) recaptures were recorded and only one *L. Lithognathus* (5.5%) had been recaptured out of 18 tagged fish. The movement of *Dichistus capensis* ranged from 0 km (time at liberty = 226 days) to 994 km (time at liberty = 1431 days). Four of the seven recaptured *Dichistius capensis* showed a degree of residency, remaining within 30 km of their initial capture site. The one *L. lithognathus* recaptured was tagged at 436 mm and was recaptured 342 days later measuring 620 mm and only travelled 11 km. This fish was a juvenile and was expected to stay within the capture area until it reached sexual maturity and undertook spawning migration. In terms of population structure, the majority of *Dichistius capensis*, *L. lithognathus* and *A. japonicus* were immature and fell below the legal size limit which raises concerns about the lack of mature individuals. In contrast, the majority of catches of white musselcracker *Sparodon durbanensis*, *P. saltarix*, belman *Umbrina robinsoni* and *Dichistius capensis* were above the legal size limit and were mostly mature.

Conclusion

The overall catch rates for both inside and outside the MPA were low. While the fishing intensity of this project was not excessively high, it did raise concerns regarding the number of fish currently supported within the Goukamma MPA. Some species showed higher catch rates inside the MPA but because catch rates were so low overall, very little could be deduced from these figures. One would assume that the current catches via shore angling would be similar inside and outside the MPA because the same regulations apply to both areas. What this data have provided is a six-year baseline of fish catches prior to rezonation. Once the rezonation is approved, the potential recovery of fish stocks can be measured against this baseline dataset. By doing so, conservation agencies will have evidence and justification for the MPA closure.

SESSION 3

Fisheries

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SESSION 3 | Fisheries

Third aerial survey of the KwaZulu-Natal marine shore fishery

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Background

Two previous aerial surveys to assess shore fishing effort were conducted along the KwaZulu-Natal (KZN) coast i.e. from 1994-95 and 2007-08. These pivotal studies provided a comprehensive assessment of total effort in the KZN shore fishery and also provided information on other fishery sectors. The results of these two surveys have been used to make estimates of total catch, to investigate spatial and temporal changes in the distribution of shore fishing effort and to inform conservation planning for the KZN coast. Ten years have passed since the last aerial survey was completed and, bearing in mind the recent changes that have taken place with regard to the management of the KZN linefishery, it was considered essential that the aerial survey be repeated. The primary aim of this study was therefore to conduct randomised monthly flights to count shore anglers in an "instantaneous manner" along the entire KZN coast to determine the spatial and temporal distribution of shore fishing effort and to make a reliable estimate of total shore fishing effort. The flights also provided the opportunity have "eyes in the sky" for surveillance purposes.

Methods

Bi-monthly aerial surveys to count shore anglers were conducted along the entire KZN coast over a period of one year. Within the logistical constraints of flying light aircraft under visual flight rules (VFR), an attempt was made to randomise flights according to flight direction, time of day, day type (i.e. weekday, weekend-day), tide and angling conditions (weather and sea-state). Two weekday and two weekend day flights were undertaken each month when logistically possible. The survey aircraft was flown along the coastline above the surf-zone at an altitude of 200–500ft and a speed of 70–90 knots. A single trained observer (BQM) conducted all counts of shore anglers using a manual tally-counter and a digital camera (the latter was used when large groups of anglers were encountered). Separate flights were conducted along the north coast (Virginia to Kosi Bay, 385 km) and the south coast (Virginia to Umtamvuna River, 175 km) due to the length of the KZN coast (560 km) and the position of the centrally situated Virginia Airport. Cumulative counts were undertaken according to known landmarks along the coast that were between one and 14 km apart. Counts were also done according to EKZNW shore patrol zones to enable comparison of aerial count data with previous aerial surveys. Ground-truthing of counts was undertaken along short, easily recognisable sections of coast by simultaneously patrolling the beach and counting the number of anglers immediately after the aircraft had passed overhead. Interview data collected during previous angler surveys along the KZN coast was used to determine angler turnover rate in a 24-hour period. The total annual angling effort along the KZN coast was then calculated from the instantaneous counts of shore anglers using the method described by Pollock et al. (1994). Data analysis was conducted using MS-Access queries and MS-Excel data analysis tools. A single factor ANOVA was used to test between data sets.

Results

A total of 44 flights were conducted along the KZN coast during 2018 with 21 and 23 flights conducted along the north and south coasts respectively. Ground-truthing revealed that aerial counts of shore anglers were 89% accurate. Angler effort was significantly higher on weekends and during good weather days. Seasonality of shore angling effort showed that greatest effort occurred during the winter months (June to September) coinciding with the increased abundance of migratory fish species such as karanteen/strepie *Sarpa salpa*, shad/elf *Pomatomus saltatrix* and garrick/leervis *Lichia amia*. More developed stretches of the KZN coast with higher population densities and easier angler access (e.g. Durban Metro and the upper KZN south coast) had the highest angling effort. Total annual angler effort was calculated at 785 538 angler $d.yr^{-1}$ which represents a 22.9% decline from the estimate made in 1994-95 and a 6.9% decline from the estimate made in 2007-08. The ongoing decline in shore angling effort has been ascribed to a variety of reasons including security concerns, poor catch rates, increasing costs and the beach vehicle ban implemented in 2002. This has also resulted in a change in the pattern of shore fishing, which is now more concentrated at beach access points rather than being more evenly distributed along the coast. Current monitoring of the KZN shore fishery by means of patrols conducted by EKZNW ceased in August 2016 except within the iSimangaliso Wetland Park. As a result, an increase in illegal activities such as beach driving and estuarine gillnetting were observed during flights.

Conclusion

The results of this project are extremely pertinent for the ongoing management of the KZN shore fishery. Aerial surveys are arguably one of the best methods to determine shore angling effort in fisheries where effort is dispersed over a large area. They are efficient and cost-effective as they cover large geographic areas using minimal personnel, and they allow total enumeration on spatial scales that other survey methods cannot match. Aerial surveys such as this only produce angler-independent estimates of effort and they must be combined with other types of survey methods such as roving-creel surveys to produce estimates of catch per unit effort and total catch. However, they do enable the identification of popular fishing locations and times of year, which can help management authorities to maximise resource allocation and streamline daily law enforcement operations. Considering the fact that no catch and effort monitoring has taken place along the KZN coast since August 2016, it is essential that the current study be followed up with an independent roving creel survey, similar to those conducted during 1994-96 and 2009-10. Such surveys enable accurate calculation of catch per unit effort and estimation of total catch using the total annual effort obtained from the aerial survey. This at least provides fishery scientists and managers with reliable information on which to base sound management decisions. With the increase in poaching and illegal activities observed along the KZN coast, better law enforcement and angler compliance urgently needs to be addressed. This can be achieved by increasing the number of well-trained and well-equipped fishery control officers (FCOs) stationed along the KZN coast, as well as by improving angler awareness through well-coordinated campaigns.

The South African Large Pelagic Fishery

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It is unclear when tunas were first targeted commercially off the South African coast, but in 1948 a book titled '*The South African Tunas – A preliminary study of the economic potentialities*' was published by CJ Molteno. Longlining for tunas off South Africa began in the 1950s by Japanese and Taiwanese fishing fleets; however, this fishery only became commercially viable in the 1980s. The South African tuna and swordfish longline fishery was formally established in 2005 with 50 long-term rights being allocated. The tuna pole-line fishery sector was also formalised in 2005, prior to which it was managed under the bracket of commercial linefishing. Tuna-directed recreational fishing has been carried out since the middle of the 20th century, mainly off the Cape of Good Hope. The Large Pelagic fishery was created in 2011 by combining the tuna and swordfish longline sector and later the pelagic shark longline sector into a single fishery sector. This sector, together with the Tuna Pole and Line sector, represents the current structure of the South African Large Pelagic fishery.

In 2018, the fishery landed 2 710t of albacore (longfin tuna), 735t of yellowfin tuna, 613t of shortfin mako shark, 592t of blue shark, 501t of bigeye tuna, 314t of swordfish and 208t of southern bluefin tuna. Longline fishing effort across the South African EEZ can be disaggregated into three areas of high importance: offshore of Durban/Richards Bay, offshore of Port Elizabeth and the Agulhas Bank shelf edge offshore of Cape Agulhas. In contrast, the distribution of fishing effort in the tuna pole-line sector is spatially limited, and the majority of boats fish offshore between Cape Point and Hondeklip Bay on the West Coast.

Due to the migratory nature of large pelagic species, stocks are managed by tuna-directed Regional Fisheries Management Organisations (RFMOs) of which South Africa is a member of three, namely: International Commission for the Conservation of Atlantic Tunas (ICCAT), Indian Ocean Tuna Commission (IOTC), and Commission for the Conservation of Southern Bluefin Tuna (CCSBT). RFMOs are tasked with collecting fisheries statistics, assessing resources, making management decisions and monitoring activities. They also facilitate intergovernmental cooperation in fisheries management and global research collaborations that promote the ecosystem approach to fisheries (EAF). South African submits over 50 reports on data and implementation of RFMO conservation measures to the three RFMOs on an annual basis and attends numerous scientific and management meetings. South Africa has made significant contributions at RFMO scientific meetings, including stock assessments of shortfin mako and bigeye tuna in the Atlantic Ocean and black marlin and striped marlin in the Indian Ocean, to name a few.

Current species-specific Total Allowable Catch (TAC) allocations by the RFMOs include albacore (4 400t), swordfish (941t) and bigeye tuna (3 000t) in the Atlantic Ocean and a southern bluefin tuna allocation of 450t. A self-imposed Precautionary Upper Catch Limit (PUCL) of 2 000t for has been set for pelagic sharks, which comprise mainly of blue shark and shortfin mako shark. South Africa currently has

a limit of 70 longline vessels (no more than 50 of these vessels may be greater than 24 metres in length in the IOTC region) and 165 tuna pole-line vessels.

South Africa collaborates in several RFMO research programmes that aim to advance understanding in global fisheries. One such programme, the Atlantic Ocean Tuna Tagging Programme (AOTTP: https://www.iccat.int/aottp/en/index.html) aims to '*contribute to food security and economic growth of the Atlantic coastal states by ensuring sustainable management of tropical tuna resources in the Atlantic Ocean'*. This objective will be realized by improving the estimation of key parameters for stock assessment such as growth, natural mortality, migrations and stock-structure. These will be derived from tag-recapture data. To date, the AOTTP has tagged and released over 50 000 tunas – although South Africa has only contributed 177 tags. However, we focussed on electronic tagging and deployed 13 externally fixed electronic (pop-up) tags and 20 internal (archival) tags of which three were recaptured (15% recapture rate). These electronic tags provided vital information on the movement and preferred habitat of yellowfin tuna in the Atlantic Ocean.

The ecosystem approach to fisheries (EAF) requires the ecosystem to be considered in fisheries management and RFMOs are mandated to minimise the ecological impact of fishing. Incidental capture of seabirds in fisheries, particularly in industrial pelagic longline fleets, has long been identified as a significant source of mortality and a conservation concern for a number of threatened seabird species. South Africa is an active participant in research regarding the application of mitigation measures to reduce seabird bycatch. A recent collaborative study collated observer data from the southern Atlantic and Indian Ocean areas – the dataset comprised 15,779 individual longline sets representing 36.4 million hooks. The study results indicate that night setting is an effective seabird bycatch mitigation measure under all conditions, and it was recommended as mandatory for all longline vessels. Alternative measures, such as bird scaring (tori) lines were only found to be effective when applied correctly. Results indicated significant improvement in overall bird bycatch and individual bird groups (petrels and albatrosses) from period one (2002–2009) to period three (2012-2016), coinciding with the implementation of the mitigation measures in the two relevant tuna RFMOs: ICCAT and IOTC. This study justifies the RFMO implemented mitigations measures and highlights the importance of Regional Observer Programmes in monitoring fishing activities.

The Large Pelagic fishery remains underutilised. The 2018 landings for albacore only amounted to 56% of the species-specific TAC allocated to South Africa, swordfish landings were only 20% and southern bluefin tuna landings only 46%. Furthermore, recent studies mapping the global distribution of tuna fishing effort using AIS and VMS have shown that high seas tuna fleets aggregate on the border of the South African Economic Exclusive Zone (EEZ) where they target high value tunas, particularly bigeye and southern bluefin tuna. The Large Pelagic fishery arguably has the largest potential for sustainable growth of all South African commercial fisheries. Accessing the high value tuna stocks such as southern bluefin and bigeye must be prioritised to unlock the economic potential of this fishery.

Sustainable livelihood and fishing effort assessment of Namibian marine subsistence shore fishers

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Background

The overall aim of this study was to assess the contribution of fisheries to the livelihood, as well as to assess the catch and effort of Namibian marine subsistence fishers. The subsistence shore fishers focused on in this study fish for a living from the beach using fishing rods. They are not recognized by law and therefore, they either use the recreational fishing permit or register to fish under the Hanganeni Artisanal Fishing Association (HAFA), a government established association in Henties Bay. Little research has focused on these fishers resulting in a lack of available knowledge concerning their livelihood, socio-economic status and fishing effort. The objectives of this study were: 1) to assess the livelihood assets of the fishers in Henties Bay; 2) to assess the dependency level on a fishing-based income; and 3) to assess the vulnerability perspective of these fishers.

Methods

This study adopts the mixed-method data collection approach following the facts that livelihood research combines qualitative and quantitative methods drawn from a range of disciplines. Since only 6.5% of the Namibian population resides in the coastal area, of which less than 200 marine subsistence fishers were reported in 2003, a total of approximately 50 fishers per town (Henties Bay and Swakopmund) were targeted in this study. Structured questionnaires (consisting of both closed and open-ended questions) were used to collect data through personal interviews. The questionnaire was formulated based on the Sustainable Livelihood Framework developed by the Department for International Development (DFID) with five major sections: 1) Livelihood assets, 2) Vulnerability context, 3) Transforming structures and process, 4) Livelihood strategies and 5) Livelihood outcomes. For the current preliminary results, 23 marine subsistence fishers were interviewed near Henties Bay from April to May 2019.

Results

None of the fishers interviewed had registered to fish under HAFA. Among the species caught, galjoen *Dichistius capensis* and silver kob *Argyrosomus inodorus* were in highest demand. Other retained species included west coast steenbras *Lithognathus aureti*, blacktail *Diplodus capensis* and barbel (*Galeichthys* spp.). More than 90% of the fishers interviewed had attended school until either primary, secondary or even tertiary level. Most fishers were aged between 31–60 years old, while 5 others were aged between 21 and 30 of which some were scholars. The results indicated that more than 70% of these fishers were living either in permanent build houses or temporally structured houses, build on serviced land well equipped with potable water and sanitary facilities. Others were living in temporary structures built on un-serviced land, using community water and sanitary facilities. The majority of them came from large (5–10 people) family sizes and had other additional dependants. Most fishers earn between N$ 1 000 to 3 000 per month from fishing, while those with other sources of income (mostly involved in the business) earn between N$ 3 000 to 5 000 per month. Even though some fishers have other sources of income to supplement the income derived from fishing, most of them still considered fishing as their main sources of income. The results also showed that there was no relationship between the fishers' dependency level on fishing and their monthly income from fishing, their number of dependants and their age groups. While 13 of the 23 fishers interviewed indicated that they have no immediate challenges, others highlighted issues such as low catches, need for employment, and competition for resources with recreational fishers as major challenges. Less than half of the fishers interviewed had knowledge of climate change, while

others related it to changes in temperatures, wind, freshwater (availability and quality), droughts and floods. Only one respondent referred to changes in sea conditions and fish depletion. Fishers with five or more years of fishing experience more indicated that all their target fish species had decreased both, in number and size.

Conclusion

All in all, fishing plays an important role in the livelihood of subsistence fishers in the Henties Bay community, both in terms of food security and income. Even though some fishers are completely dependent on fishing for their livelihoods, this was not influenced by their age, income or number of dependants. The fishers appeared to have limited knowledge regarding climate change and the impact this could have on their livelihood. For this reason, there is a need to educate fishers about various issues such as climate changes, sustainable utilization of resources, as well as how to diversify their livelihoods in case something goes wrong with the fishery that they rely on for a living.

Accounting for linefish dependency on small pelagic fishes in management of the South African small pelagic fishery

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Background

Implementing an ecosystem approach to fisheries (EAF) requires that ecosystems need to be considered in management procedures. For the South African small pelagic fishery that targets primarily sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus*, both of which are important prey for a variety of fish, marine mammal and seabird predators, this means that the forage needs of small pelagic fish-dependent predators should be considered and accounted for. Ecosystem considerations in the South African small pelagic fishery have to date focused on the African penguin *Spheniscus demersus* because of its dietary dependency on sardine in particular, its endangered status, and a wealth of available data on this species. The present operational management procedure (OMP) for the small pelagic fishery incorporates a functional relationship between the annual mortality of adult penguins on Robben Island and the annual biomass of the western sardine stock which is distributed to the west of Cape Agulhas, with penguin mortality increasing sharply below a threshold sardine biomass level. Western sardine stock biomass projections from sardine stock assessment models are incorporated into a population dynamics model of Robben Island penguins via adult survival to predict penguin population trends under different fishing scenarios. A suite of penguin performance statistics (including the rate of increase of the Robben Island penguin population, as well as the number of times the western sardine stock biomass falls below the threshold level) are then compared among scenarios with varying levels of catch and a no-catch scenario, in order to assess fishery impacts on the Robben Island penguin population. Here we investigate possible additional ecosystem indicators derived from other small pelagic fish-dependent predators to broaden ecosystem representation in management processes for the small pelagic fishery. Key to developing such indicators is the establishment of a functional relationship between some index of abundance of a predator species and the abundance of one or more of the species targeted by the small pelagic fishery. This analysis seeks to develop such functional relationships by comparing abundance time-series of three small pelagic fish species with time-series of catch-per-unit-effort (CPUE) for four exploited linefish species, all of which are predators of small pelagic fishes.

Methods

Annual biomass (total, west of Cape Agulhas [WoCA] and east of Cape Agulhas [EoCA]) time-series of sardine, anchovy and west coast round herring *Etrumeus whiteheadi* derived from acoustic surveys were compared to time-series of standardized CPUE (total and by area: west [W], southwest [SW], south [S] and southeast [SE]) of geelbek *Atractoscion aequidens*, silver kob *Argyrosomus inodorus*, snoek *Thyrsites atun*, and yellowtail *Seriola lalandi*, for the period 1987–2017. Time-series were initially compared using a Granger causality test to assess whether small pelagic fish biomass had significant effects on linefish CPUE, and/or *vice versa*, over lags of 1 to 5 years. For small pelagic fish/linefish pairs where all five lags were significant ($p < 0.05$) or three of the five lags were highly significant ($p < 0.01$), a Sequential T-test Analysis of Regime Shifts (STARS) analysis was conducted to identify regimes and assess temporal matching of such regimes for that small pelagic fish/linefish pair. Species pairs that showed similar temporal correspondence in regimes and regime shifts were then subjected to cross-correlation analysis (also known as convergent cross mapping), a technique that seeks to detect whether

causality exists (in either direction) between a pair of time-series that exhibit non-linearity (such as typically observed in ecological systems), again at lags of 1 to 5 years.

Results

Granger tests showed significant or highly significant effects of small pelagic fish biomass on linefish CPUE for: (i) anchovy total biomass on kob overall CPUE; (ii) anchovy EoCA biomass on kob SW CPUE; (iii) anchovy EoCA biomass on yellowtail W CPUE; (iv) sardine total biomass on geelbek overall CPUE; and (v) sardine EoCA biomass on geelbek SW CPUE. Significant or highly significant effects of linefish CPUE on small pelagic fish biomass were observed for: (i) snoek SW CPUE on anchovy EoCA biomass; (ii) snoek SW CPUE on sardine EoCA biomass; and (iii) geelbek E CPUE on sardine WoCA biomass. No significant effects of round herring abundance on CPUE of any linefish species, or *vice versa*, were observed. STARS analyses for sardine EoCA biomass and geelbek SW CPUE showed three distinct regimes and a close (1 year) temporal match in regime shifts, and two regimes and a relatively close (4 years) temporal match in regime shifts for anchovy EoCA biomass and yellowtail W CPUE. Cross-correlation analysis of the EoCA sardine/geelbek SW CPUE time-series showed the strongest effect (indicating a high degree of causality) of sardine EoCA biomass on geelbek SW CPUE at a lag of -1 year. A similarly strong effect of geelbek SW CPUE on sardine EoCA biomass at a lag of -2 years was evident, which is indicative of predator-prey dynamics.

Conclusion

The analyses described above have demonstrated highly significant causal links between sardine EoCA biomass and geelbek SW CPUE, and *vice versa*, indicating that sardine EoCA biomass has a subsequent effect on geelbek SW CPUE and that geelbek SW CPUE also has a subsequent effect on sardine EoCA biomass. Assuming CPUE is proportional to abundance, these results provide a strong starting point for developing a functional relationship between these two species for possible inclusion into the OMP for the small pelagic fishery. The strong result for the sardine/geelbek species pair compared to other cases is unsurprising, given that geelbek is reported to be a “specialist” sardine predator whereas the other linefish species are reported to prey on both sardine and anchovy. Similarly, the lack of effects of round herring on linefish CPUE, and *vice versa*, suggests that this small pelagic fish is not an important prey species for the linefish analysed here.

SESSION 4

Genetics

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SESSION 4 | Genetics

DNA barcoding of South-African linefishes

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Background
South African linefishes represent an important natural resource for the country, but overexploitation is posing a threat to both the stocks and the communities relying on them. To ensure the sustainable use of this natural resource, management decisions need to be implemented. Good knowledge of species biodiversity is a prerequisite to any management actions, but traditional taxonomy alone has shown some limitations. The use of DNA barcoding can help addressing the issue of rapid and reliable species identification, but it is critical to rely on a reference database built using the national collection. This may be accomplished following an integrated approach generating high-quality molecular data for a collection of voucher specimens identified by taxonomic experts.

Methods
Using both the BOLD database and the sequencing of new specimens, we assembled such a reference database for 139 of the most common South African linefish species.

Results
We increased the number of reference DNA barcodes and identified the targets for future barcoding projects. From the new database, we could recognize possible misidentifications and cryptic species and highlight areas for improvement regarding sequence quality.

Conclusion
The present work offers new perspectives on the study of linefish biodiversity around South Africa and has implications for the management of this resource.

A temporal comparison of genetic diversity in the slinger *Chrysoblephus puniceus* over a period of six years along the east coast of South Africa

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Background

The slinger, *Chrysoblephus puniceus*, is endemic to the south-eastern coast of Africa, and is distributed from southern Mozambique to Algoa Bay in the Eastern Cape. This seabream is highly resident but tagging studies have indicated a northward migration of a few adults. A previous study, using microsatellites, indicated a panmictic stock for *C. puniceus* with high connectivity from southern Mozambique to the southern Transkei. The aim of the present study was to do a temporal comparison of *C. puniceus* between two sampling events (2012 and 2018) and considering two sites, Richards Bay and Shelly Beach, along the KwaZulu-Natal coast. The study examined and compared estimates of genetic diversity, variation and structure across the two sites and two sampling events. Differences in allele frequencies between the two sites and sampling events were expected, based on the complex history of this species, a protogynous hermaphrodite (changing sex from female to male), reaching sexual maturity at the age of three years and changing sex at the age of five years. Temporal differences in allele frequency could reflect the sweepstake nature of spawning and the random contributions to the various cohorts of larvae recruiting into the population, and to the successive spawning generations. This information on the slinger could be vital, since this would be six years of exploitation of this species since the last genetic study and this species is the main target of the commercial linefish sector in KwaZulu-Natal. This information provided on temporal structure could be essential for fisheries management.

Methods

Fin clips from the 2012 study were sourced from the National Fish Collection, South African Institute for Aquatic Biodiversity, and recent (2018) fin clips were collected as part of the multidisciplinary project, CAPTOR – Connectivity And disPersal beTween prOtected aReas. Genomic DNA was extracted from fin clips following 'the salting out' method. For the microsatellite genotyping, eight microsatellite loci (SL1, SL7, SL26, SL29, SL29, SL33, SL34, SL35) were selected, and amplified in two multiplex PCR reactions. Fragments were analysed, and individuals were genotyped using GeneMapper. Standard diversity indices such as number of alleles, observed heterozygosity, expected heterozygosity, and fixation index were calculated using GenAlEx version 6.503. Allelic richness was calculated using Genepop version 4.2. Pairwise comparisons were conducted to test for genetic differentiation among two sampling events, as well as sites, using GenAlEx, and, in addition, a principal coordinate analysis (PCoA) was done in GenAlEx to examine the variation among sampling years using Nei's unbiased genetic distance. Hierarchical Analyses of Molecular Variance (AMOVA) were carried out, testing for temporal variation (between two sampling events, 2012 and 2018) and for spatial structure (between sites) in ARLEQUIN version 3.5. Bayesian clustering in STRUCTURE version 2.3.2 was used to estimate the optimal number of homogenous genetic clusters present in the data set, regardless of sampling event or locality.

Results

Levels of genetic diversity were consistent between the two years. Slightly greater diversity was recorded at Shelly Beach compared to other sites. Pairwise comparisons indicated F_{st} values significant differentiation between the two sampling events and all sites ($p < 0.05$) (0.011–0.019). This was supported by the PCoA analysis, indicating that all sampling sites are distinct populations. The hierarchical AMOVAs revealed that most genetic variance was distributed among samples ($F_{it} = 0.15$; $p = 0.02$) rather than between the sampling years or sites for the temporal and geographical tests, respectively. Results from STRUCTURE showed the samples to be an admixture of three distinct genetic populations, but without any clear temporal or geographic structure.

Conclusion

Pairwise comparisons indicated genetic differentiation at all sites and years. The diversity estimates were consistent across the two years and sites. AMOVAs showed that most variation was between individuals. Three distinct genetic populations were detected using microsatellites; however, these are not defined geographically or temporally, and will need further investigation using high resolution markers. This study indicated that there was no measurable impact on genetic diversity as a result of fishing pressure over the past six years. This study represented a first assessment of temporal genetic variability using only microsatellites data. Single Nucleotide Polymorphisms (SNPs) should be better markers to interpret temporal and spatial patterns. SNPs are markers of high number and low cost compared to traditional approaches, such as microsatellites. For further investigation, population genetic data in the form of multi-locus SNPs genotypes will be generated, using a recent Restriction Associated DNA sequencing method, quaddRAD. This should aid in the interpretation of patterns over space and time in the slinger.

Genetic diversity and species recovery of *Polysteganus undulosus* after stock collapse

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Background
It is estimated that 75% of our global fish stocks are either overexploited or have reached maximum exploitation levels. Information about species recovery after stock collapse is scarce. Here we have the opportunity to compare the level of genetic variation before and after such a stock collapse event in the seventy-four *Polysteganus undulosus*. This species is a south-east African endemic that used to be found along the coast from Maputo Bay to False Bay. Following the stock collapse in the 1960s, the distribution of the species has decreased with no reports of fish caught north of Leven Point in the St Lucia Marine Reserve and south of Cape Agulhas. Seventy-four made up more than 50% of the total commercial line-fish catch along the KwaZulu-Natal coast between the early 1900s and the 1960s before the stock collapsed. By 1996 it was estimated that seventy-four was at less than 5% of pristine spawner biomass per recruit. The first management regulations to protect this species were only implemented in 1984 (i.e. bag limits, size limits and a closed season). This was followed by a total closure (recreationally and commercially) of the fishery in 1998 in accordance with the South African Marine Living Resources Act (No. 18 of 1998).

In this study we compare the genetic diversity of samples collected from 1962/63 (before the collapse of the stock) with samples collected during 2005/06 using polymorphic microsatellite markers. We assessed the effect of missing genotypic data on the estimation of the effective population size and investigated the projection power.

Methods
Three species specific and three heterologous polymorphic microsatellite loci were used to genotype samples collected from 1962/63 and during 2005/06. We used the rarefaction method for estimating the average number of alleles expected, with a hypothetical increase in the number of individuals analysed, based on the observed allele diversity for the 1962/63 and 2005/06 samples. Using IMa we estimated the effective population size for both samples. We also tested the effects of different levels of missing genotypic data on the estimated effective population sizes by using a simulated data set with the same characteristics as the empirical data.

Results
A dramatic decrease in the allele diversity was observed between the 1962/63 and 2005/06 samples. The most dramatic difference was for locus PU065 where 23 individuals analysed for the 1962/63 sample displayed 16 alleles. Only three alleles were detected using 87 individuals from the 2005/06 sample. We showed that for the 2005/06 sample a total number of 25 individuals will reveal most of the alleles present whereas no plateau is reached with more than 30 individuals from the 1962/63 sample. In cases where

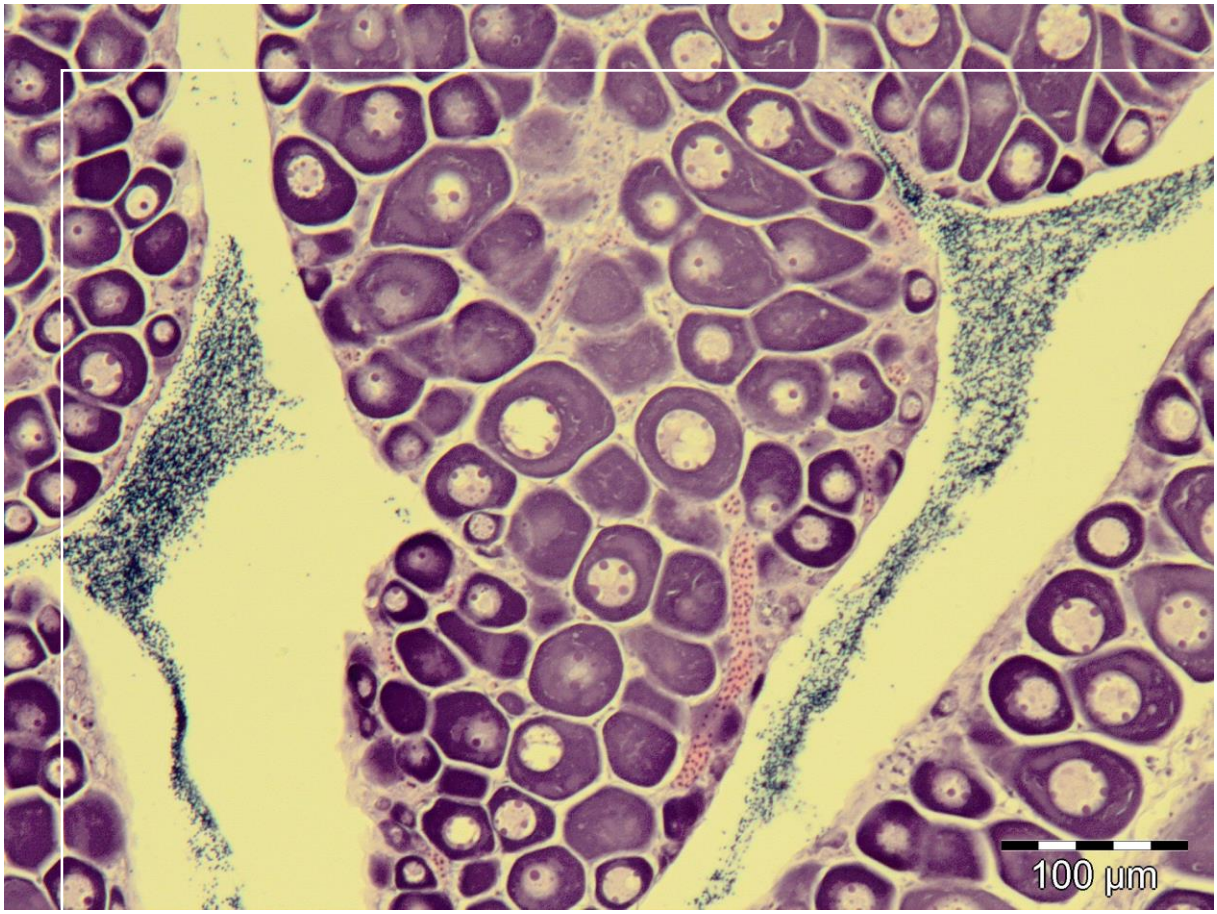
the abundance of a species changed significantly over time, it is expected to significantly affect the genetic diversity. This will then be observed in the estimates of the effective population size. The effective population size decreased by a factor of 9 due to the decrease in the abundance of the species between 1962/63 and 2005/06. The effect of missing data was relatively low for missing data between 5% up to 60%.

Conclusion

Our results clearly illustrated that there has been an extensive reduction in the level of genetic diversity, more than what would have been expected, due to a decrease in the overall number or abundance of the species. The effect of missing data on estimating the effective population size was surprisingly low, with missing data exceeding 60% only marginally starting to influence effective population size estimates. The results obtained from this study will be integrated and form part of conservation and management strategies.

SESSION 5

Life history



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SESSION 5 | Life history

Life-history trade-offs among four sympatric seabreams

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Background
Seabreams have the most varied sexual strategies of any vertebrate family. South Africa has the largest number of seabream species of any country. Its waters exhibit a greater degree of environmental variation than almost any other coastline of equivalent length. Fish life-history is affected by environmental and ecological factors but is also constrained by phylogenetic influences on morphology and physiology. True life-history trade-offs can be exposed in a comparison of closely related species which are subject to identical environmental conditions, and which have similar diets. We compare the life histories of four closely related and similar-sized, sympatric, omnivorous seabreams which share the same physical habitat, namely steentjie *Spondyliosoma emarginatum*, hottentot *Pachymetopon blochii*, white stumpnose *Rhabdosargus globiceps* and fransmadam *Boopsoidea inornata*. The aim of the work is to quantify the extent of co-variation among life-history parameters, including qualitative parameters such spawning mode, behaviour and migration. The work should have a bearing on fishery management strategies for fisheries which catch a variety of species.

Methods
Samples of each species were obtained in every season from the south-western Cape, South Africa, to obtain measures of sex ratio, total length, mass, gonadosomatic index (GSI) and condition. Sample sizes were 649, 308, 1145 and 804, respectively.

Results
Spondyliosoma emarginatum is a nest-guarding, short-lived, protogynous hermaphrodite. The others are rudimentary hermaphrodites. *Pachymetopon blochii* is a resident, group-spawner, engaging in sperm competition with a sex ratio of 1.5:1 (female to male). *Rhabdosargus globiceps* is a moderately long-lived migrant and group-spawner, with a sex ratio of 1.4:1. *Boopsoidea inornata* is a polygamous (sex ratio is 4:1), long-lived resident with low annual fecundity, but has a protracted spawning season. It is also the longest lived of the four species, but it achieves the lowest GSI both in aggregate during peak spawning (3%) and among ripe females (3.7%). *Boopsoidea inornata* male GSI is approximately half that of the female. A sex difference is also evident in *S. emarginatum*, for which average female fecundity in season (7%) and among ripe females (11%), is four times that of the male. The other two species have GSI maxima mid-way between these extremes, and their males and females have very similar GSI maxima. The pattern in the timing and length of the spawning season varied markedly too. *Pachymetopon blochii* has a broad nine-month spawning season centred over winter. *Boopsoidea inornata* has a similar protracted spawning season centred over summer. At the other extreme, *S. emarginatum* has a short, two-month winter spawning season, and *R. globiceps* a three-month spring spawning season. Condition varies and was predictable among the seasons for females of each species, with a build-up in the season prior to peak spawning and a depletion immediately after. The male condition in *P. blochii* and *R. globiceps* vary to a similar degree and with similar timing to that of the females. The other two species however display a telling mismatch in the phases of male and female condition cycles. In *S. emarginatum*, the male cycle lags that of the female by one season. In *B. inornata*, the female cycle lags the male cycle.

Conclusion

Substantial differences exist among the four life-histories, despite the sympatry, recent common ancestry and common habitat and diet. Our comparison reveals a wide range of options available to seabreams and shows how disparate life-histories can be equally adaptive under virtually identical conditions. Life-history trade-offs are evident between annual fecundity and longevity, migration and spawning season length, hermaphroditism and bet-hedging and hermaphroditism and migration. Three of the four species are periodic (bet-hedging) strategists, following the classification outlined by Winemiller. The outlier, *S. emarginatum,* not only has a short life-span, but protogyny has further halved its egg-laying lifespan to a mere three years, in contrast to the 30 years of the rudimentary hermaphrodite *B. inornata*. The latter has a female-skewed sex ratio and displays signs of polygamy, including small testes and a pre-spawning dip in male condition. Were it to switch to protogyny, *B. inornata* individuals would lose the advantage associated with spawning over three decades. The pelagic spawners are at the mercy of one of the most variable habitats on earth, which explains their adoption of a periodic strategy. It is no coincidence that the species which abandoned this strategy, glues its eggs in a male-guarded nest.

Sequential hermaphroditism is associated with hyper-allometric growth in seabreams, whereas separate sexes are usually iso- or hypo-allometric. The former need to fight, so get stocky with age. We speculate that sequential hermaphroditism is more commonly associated with social structures that are facilitated by philopatry. Migrants are typically separate sexes, which suggests that the advantages of these two strategies are traded-off. The heavy reliance on algae for food by *P. blochii*, may account for its predominantly autumn and winter spawning, as algal production is high in summer when gonads need developing. Nevertheless, it has a protracted spawning season, covering more than half the year. Having a protracted spawning season is not an option for spawning migrants such as *R. globiceps*, as they cannot leave the feeding grounds for extended periods. The expected trade-offs between annual fecundity and longevity is evident. The short-lived highly fecund *S. emarginatum* contrasts against low GSI and extreme longevity of *B. inornata*. The other two species occupy intermediate positions along this spectrum. The GSI and the length of the spawning season are also traded off, but the short spawning season of the migrant *R. globiceps* presents an outlier. The several costs of migration must be viewed as a contribution to reproductive success, which explains its lower-than-expected annual fecundity. She needs less eggs, if she takes care to place them correctly. Finally, the sex-ratio differences are negatively correlated with the female:male GSI ratio in a manner that seems counter-intuitive. The less males present, the less sperm is needed. This trade-off speaks of the alternative modes of male competition – physical aggression vs sperm competition. No explanation for the divergence in life-histories among the four sympatric seabreams can be offered and we are not convinced that an explanation is needed, but competition among the young is a candidate.

Contemporary growth patterns and batch fecundity of *Sparodon durbanensis* (white musselcracker), with implications for its assessment and management

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Background
White musselcracker *Sparodon durbanensis* is a large (maximum length of 1 029 mm fork length, FL), late maturing (5.4 years), slow growing, and long lived (maximum recorded age of 31 years) species belonging to the Family Sparidae. It is an important target species in the South African marine recreational fishery. The most recent life history information of *S. durbanensis* was collected 30 years ago and there is a paucity of contemporary information. This study aimed to compare the relative growth rate of *S. durbanensis* over time using historical and contemporary data and to use batch fecundity data to determine a possible maximum size limit which can be used in the development of a slot limit regulation for the species.

Methods
A collection of 30 otoliths from the largest *S. durbanensis* specimens collected during the mid-to-late 1980s (1984–1988) between Knysna and East London on the South east coast of South Africa by Buxton and Clark (1991) formed the historical collection used in this study. Sampling for the contemporary collection of otoliths and fecundity data were carried out in and around Port Elizabeth (34°01'45.1"S 25°42'04.3"E) on the South East coast of South Africa from the beginning of March to the end of June 2017. The otoliths were sectioned at a width of approximately 0.4 mm along the dorsal ventral axis, perpendicular to the sulcus and through the focus using a double blade diamond edge isomath saw. The end of each hyaline zone was marked along a transect through the dorsal side of the sulcus acusticus. The date of capture was known for the historical and contemporary collection and this allowed for growth zones to be assigned a calendar growth year (CGY) which was applied working from the outermost (most recent years) to the innermost (earliest years of the fish) growth zones. In order to minimize errors only otoliths with clearly defined growth bands were considered. Methods proposed by Thresher et al. (2007) were used to compare the growth rate from the historical (1960-1976) to the contemporary (1999-2011) growth years. The mean growth rate during the first five years (juvenile years) for each individual was calculated by independently standardising the widths. Dendrochronological techniques were used to develop a master growth biochronology of *S. durbanensis* and investigate the influence of sea surface temperatures from Algoa Bay on growth rates.

All gonads were weighed, staged and sectioned to determine the batch fecundity. Batch fecundity was estimated based on the methods proposed by Hunter et al. (1985). The smaller ovary of the two from each female was sectioned longitudinally using a scalpel to cut through the membrane. Sub-samples of oocytes, each weighing 0.01 g were removed from the proximal, middle and distal end of the ovary. The oocytes were loosened and separated from one another using glycerine. The slides were photographed, oocytes were categorised into size classes and the number of oocytes that fell into the largest size class were enumerated. The counts were then extrapolated to account for the entire area of each sample and an exponential regression line was fitted to describe the batch fecundity. The cumulative batch fecundity

was determined using the exponential batch fecundity equation and length structure provided by Buxton and Clark (1991). A polynomial 4th order regression was fitted to the cumulative batch fecundity and the fork length (FL) at which 50% cumulative batch fecundity occurred was selected as the maximum limit for application in a slot limit regulation.

Results

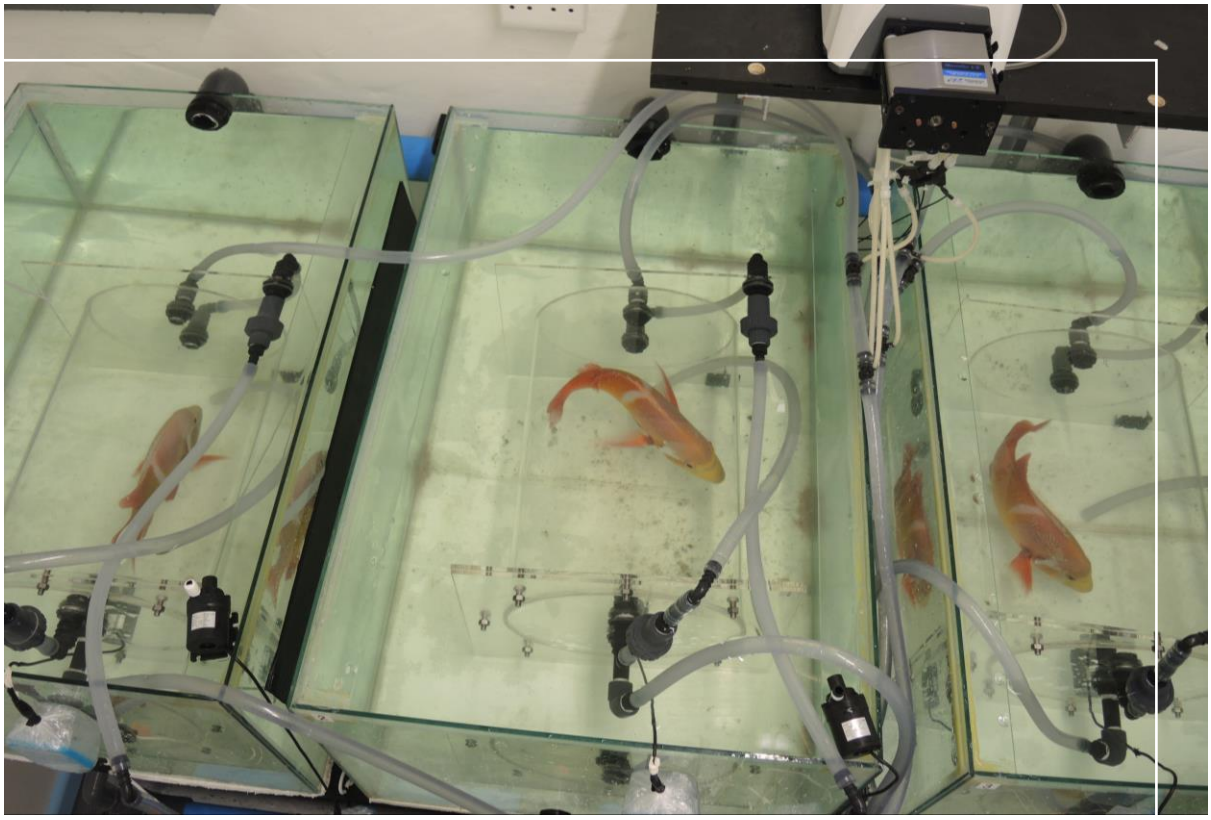
The mean age of the readable otoliths was older for the historical collection (14.6 y) compared to the contemporary collection (10.7 y). The standardised growth rate of white musselcracker remained constant (m = 0.005) from the 1963 (earliest birth date in the historical collection) through to 2011 (latest birth date in contemporary collection). No statistically significant ($p>0.05$) difference was found in the standardised growth rate over the 48-yr period. The highest peak in growth observed in the annuli width index from the historical collection occurred in 1970 (1.14), followed by additional, less substantial peaks which occurred in 1975, 1978, and 1980. There was a very weak negative and non-significant correlation between the otolith chronology and the mean SST, mean winter SST and mean summer SST. Out of the 30 specimens collected between 01 April 2017 and 19 August 2017, 21 were identified as males and nine as females. The gonads of all the females were found to be ripe with a range in the mass of ovaries from 25.44 g for a fish of 570 mm FL to 149.31 g for a fish which measured 820 mm FL. A positive relationship was found between the length of fish and the mass of ovaries in females as well the length of the fish and the number of oocytes. There was an exponential relationship between FL and batch fecundity, with the smallest batch observed in the smallest female (570 mm FL) and the largest batch in the specimen of 820 mm FL. The length-at-50% population batch fecundity was 771 mm FL.

Conclusion

The constant growth rate from 1963–2010, suggests that *S. durbanensis* may be resilient to environmental variability and that the historical growth parameters remain applicable for contemporary stock assessment. The exponential relationship between length and batch fecundity of white musselcracker advocates the need to protect older and larger individuals. The length-at-50% cumulative population batch fecundity was 771 mm FL (863 mm total length, TL) and therefore an appropriate slot limit for the species would be between 600–850 mm TL.

SESSION 6

Climate change



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SESSION 6 | Climate change

Linking physiology to movement behaviour of coastal fishery species to understand adaptation in the Anthropocene

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Background
Human-induced impacts of climate change and overharvesting are threatening coastal ecosystems and the maintenance and diversity of our marine, coastal and estuarine fish resources. Since coastal fisheries are important socially, politically, economically and ecologically, their sustainability directly impacts the livelihoods and well-being of coastal communities. In South Africa, it is expected that increased sea temperatures and the intensification of upwelling events will have a significant impact on our already overexploited coastal linefish stocks. Climate change has been shown to alter biodiversity through changes in the phenology, distributions, life history and behaviour of many organisms. Therefore, understanding the ecological processes of organisms in the Anthropocene is critical to understand their ability to adapt. For ectothermic fish, behavioural adjustments represent the first response to changes in environmental conditions. Advances in technologies such as biotelemetry have allowed scientists to track fish in their natural habitat, providing important information on the movement and behavioural ecology of fishes and how they respond to changes in environmental conditions. While these studies have provided much-needed insight into improved management, conservation and the predicted effects of climate change, they are largely pattern-based and lack the mechanistic processes driving the behavioural response, preventing robust adaptive strategies. For example, it has been suggested, through tracking fish in their natural habitat that behavioural diversity within a population is driven by the interaction between an individual's physiology and its environment, and is an adaptive evolutionary strategy to promote population persistence and regulation, and offset environmental variability. Up to now, the underpinning mechanism (physiological or molecular) explaining this behavioural complexity and hence evolutionary significance of the adapted behaviour remains largely unexplored. Since for example, changing temperatures can affect the physiology of fish through increased metabolic demands and changes in species performance and fitness, studies focusing on fundamental and applied science to examine physiological phenotypes and interrogate the link between physiology and behaviour of coastal fishery species are essential to improve our understanding of the plasticity of fish in the Anthropocene. This research investigates a new paradigm of fish movement ecology - linking fish physiology and behaviour, and interrogating the largely-ignored individual variation responsible for behavioural diversity within populations, to fully understand linefish resilience in the Anthropocene.

Methods
This study will adopt a laboratory and field-based approach, incorporating aspects of fish physiology and movement behaviour. Ecophysiology experiments will be used to describe the thermal tolerance and metabolic rates of estuarine-associated coastal fishery species caught in the estuarine and marine environment. Intermittent flow respirometry will be used to determine the oxygen consumption rate of the different species at selected temperatures and environmental conditions that fish have been exposed to in the wild, including temperatures that mimic coastal upwelling and extreme maximum riverine temperatures, and at various salinity concentrations. In some instances, fish will also be equipped with heart rate loggers while determining metabolic rates as

measurement of heart rates of fishes have been shown to be useful estimates of energy expenditure, biological and behavioural fitness. The laboratory-based behavioural experiments will be conducted to link fish behavioural syndromes (personalities) with physiological phenotypes. Individuals will be marked, and physiological experiments will be conducted on individuals to determine their metabolic phenotypes. Once fish have been categorised into either high or low performance metabolic phenotypes, personality types will be examined using laboratory assays such as open-field, novel-object and mirror tests to test behavioural strategies such as general activity, boldness – tendency to explore new habitats and aggressiveness. The behavioural traits of each fish will then be linked to their metabolic phenotype to investigate behavioural plasticity under changing environmental conditions. Fish will be captured using simulated fishing trials and each will be tagged with coded acoustic transmitters. Since it has been hypothesised that fishing removes bolder, fitter individuals of a population, each fish will also be categorized according to their susceptibility of being caught. Fish will then be released into the estuarine and coastal environment and will be continuously monitored for a year using a series of automated stationary receivers and environmental loggers (temperature, dissolved oxygen). Telemetry field data will be analysed for behavioural diversity (e.g. migratory versus resident individuals) and responses to environmental conditions.

Conclusion

In conclusion, this project will use a theoretical behavioural framework and testable laboratory-based hypotheses to explain the physiological mechanisms ('processes') responsible for fish behavioural 'patterns', and their responses to environmental changes (e.g. extreme temperatures, upwelling events and dissolved oxygen), observed in the wild. It is envisaged that this research will improve our understanding of the adaptive capacity and hence resilience of important coastal fishery species to the ever-increasing impacts of human-induced global change; and ultimately determine the evolutionary consequences of these human-induced pressures on our coastal fish stocks.

Considering "Ocean Weather" will improve predicting the effects of climate change on marine biodiversity

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Background

Anthropogenic induced climate change is affecting patterns and processes of biodiversity at rates previously not endured and will be one of the dominant drivers of species persistence in the future. Predicting how species will respond to climate change has thus become a prerequisite for sustainable management, particularly in the marine environment, where sea temperatures drive biological rates of many ectotherms. To predict species responses, scientists have generally used lab and modelling experiments to quantify thermal niches and extrapolated results onto future climate scenarios. Almost all this research has investigated species responses to long-term (up to 2100) changes in mean environmental variables (e.g. 2 ˚C increases) but emerging theory suggests that an increase in acute (day to day) environmental variability, termed "ocean weather", associated within long-term mean changes, may have a more pervasive effect on biodiversity. To test how ocean weather can affect the performance of marine fish, this study used a multi-method approach to first quantify energetically limiting thermal fluctuations in the lab and then ascertain if exposure to these conditions in the wild compromised growth performance.

Methods

We used a seabream, red roman *Chrysoblephus laticeps*, endemic to the South African south coast as a model species for this experiment. We measured standard and maximum metabolic rates and absolute aerobic scope of *C. laticeps* across a range of ecologically relevant acute thermal fluctuations using intermittent flow respirometry. After identifying energetically limiting thermal fluctuations, we developed a long-term (1973–2013) annual time-series of the cumulative intensity of these events from *in situ* sea temperature data and used this index to explore the growth response of *C. laticeps*. Otolith increment width was used as a proxy for annual somatic growth and historical otolith collections combined with contemporary otoliths to develop a long-term times series of annual growth for *C. laticeps*. A mixed modelling framework was used to partition growth variation within and among individuals and attribute it to intrinsic (e.g. age) and a host of temporally resolved extrinsic environmental processes.

Results

We found that *C. laticeps* can maintain absolute aerobic scope (> 2.5 $O_2.min^{-1}.kg^{-1}$) across a wide range of temperature fluctuations except when extreme upwellings (16 to 8 ˚C) were simulated and absolute aerobic was compromised (< 2 $O_2.min^{-1}.kg^{-1}$). Furthermore, the natural logarithm of standard metabolic rate scaled linearly against the inverse of temperature (kT) except during extreme upwelling, indicating physiological stress during such events. An index of the cumulative intensity (IC) of such extreme upwelling events showed inter-annual variability ranging from 143 – 20 between the years 1973 – 2013. The best base growth model included a random age slope for both a random individual intercept and year intercept and included age as the only fixed intrinsic effect. Including IC as a fixed extrinsic effect

improved the base model more than any other longer-term environmental variable (ΔAIC > 2), suggesting that extreme upwelling events are the overarching environmental driver on the somatic growth of *C. laticeps* through compromising available energy.

Conclusion

The results of this study highlight the importance of acute environmental variability in moderating the physiological performance of *C. laticeps* and show how this influences demographic parameters such as growth rates. As more evidence accumulates that organisms have the capacity to acclimatize and adapt to novel environmental conditions over time, tolerance to short term environmental fluctuations may be a more important indicator of climate resilience. Indeed, this theory is gaining momentum among ecologists and recent research, such as the research presented here, are corroborating this paradigm shift. Furthermore, the intensity of ocean weather at a local scale is often governed by global weather patterns such as the El Niño-Southern Oscillation which is predicted to remain the dominant driver of global climate and increase in frequency and intensity with time. Predicting how marine organism's respond to climate change must therefore consider the effects of "ocean weather" to improve forecasting accuracy.

Tipping point of tolerance to CO_2-induced ocean acidification for larval dusky kob *Argyrosomus japonicus* (Pisces: Sciaenidae)

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Background
Increased CO_2 production and the consequent ocean acidification (OA) have been identified as one of the greatest threats to both calcifying and non-calcifying marine organisms. Traditionally, marine fishes, as non-calcifying organisms, were considered to have a higher tolerance to near-future OA conditions owing to their well-developed ion regulatory mechanisms. However, recent studies provide evidence to suggest that they may not be as resilient to near-future OA conditions as previously thought. In addition, earlier life stages of marine fishes are thought to be less tolerant than juveniles and adults of the same species as they lack well-developed ion regulatory mechanisms for maintaining homeostasis. This study followed up on previous studies examining the effects of near-future OA on larval dusky kob *Argyrosomus japonicus,* an estuarine-dependent marine fish species, in order to identify the tipping point of tolerance for the larvae of this species.

Methods
Larval *A. japonicus* in the present study were reared from egg up to 22 days after hatching (DAH) under three treatments. The three treatments, (pCO_2 353 µatm; pH 8.03), (pCO_2 451 µatm; pH 7.93) and (pCO_2 602 µatm; pH 7.83) corresponded to levels predicted to occur in year 2050, 2068 and 2090 respectively under the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (IPCC RCP) 8.5 model. Size-at-hatch, growth, development and metabolic responses (standard and active metabolic rates and metabolic scope) were assessed and compared between the three treatments throughout the rearing period.

Results
Five earlier larval life stages (hatchling – flexion/post-flexion) were identified by the end of the experiment. There were no significant differences in size-at-hatch ($p > 0.05$), development or the active metabolic ($p > 0.05$) or metabolic scope ($p > 0.05$) of fish in the three treatments throughout the study. However, the standard metabolic rate was significantly higher in the year 2068 treatment but only at the flexion/post-flexion stage which could be attributed to differences in developmental rates (including the development of the gills) between the 2068 and the other two treatments. Overall, the metabolic scope was narrowest in the 2090 treatment, but varied according to life stage. Although not significantly different, metabolic scope in the 2090 treatment was noticeably lower at the flexion stage compared to the other two treatments, and the development appeared slower, suggesting that this could be the stage most prone to OA.

Conclusion
The study concluded that, in isolation, OA levels predicted to occur between 2050 and 2090 will not negatively affect size-at-hatch, growth, development, and metabolic responses of larval *A. japonicus* up to 22 DAH (flexion/post-flexion stage). Taken together with the previous studies of the same species, the tipping point of tolerance (where negative impacts will begin) in larvae of the species appears to be between the years 2090 and 2100.

Exploring the effects of exploitation and temperature on the energy use of *Chrysoblephus laticeps* using acoustic accelerometer tags

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Background
Southern African linefish populations are exposed to the effect of climate change and anthropogenic stressors and it is imperative that we understand their interactions in order to efficiently manage these stocks. Energy, acquired through consumption and expended on metabolic activities, is the key currency by which we can measure an individual's response to the aforementioned stressors. Recent advances in acoustic telemetry has allowed scientists to use acceleration, a proxy of energy expenditure, to measure field metabolic rate (FMR) through the use of acoustic accelerometer transmitters. This study aimed to compare the FMR of red roman *Chrysoblephus laticeps* from the exploited Port Elizabeth (PE) and protected Tsitsikamma National Park (TNP) populations in response to *in situ* temperature variability.

Methods
VEMCO V13AP tags were surgically implanted into fish that were subsequently swum in a custom-built swim tunnel at various speeds and temperatures during which oxygen consumption was measured. A linear mixed model, with fish ID as a random intercept and acceleration as a random slope, presented a significant relationship between oxygen consumption, acceleration, mass and temperature allowing us to estimate FMR from these components in the field.

After a range test, two fine-scale acoustic telemetry arrays were designed and deployed in PE and TNP between February and June 2019. The use of 13 VEMCO VR2W receivers, with two synchronization tags and one thermostring per site, gave a total of 90% detection coverage within an area of 176 400 m^2. Ten fish per site were later tagged with accelerometer transmitters and released in the centre of the array.

From the acceleration data captured by the receivers and the temperature data from the thermostring, FMR was estimated using the aforementioned model. Linear mixed models were used to identify key drivers of FMR and to analyse the second order polynomial relationship between FMR and temperature, including population (exploited/protected) as an interaction term. Linear breakpoint regression models were used to identify the temperature at which each fish drastically reduced their FMR.

Results
Temperature variability was prominent in both sites with numerous coinciding upwelling events. A total of 567 035 and 395 187 accelerometer detections were recorded by the PE and TNP array's, respectively. Significant drivers of FMR included temperature, diel period, population, acceleration and mass ($p < 0.05$). There was no significant influence of exploitation/protection (population) on day ($p = 0.145$) or night FMR ($p = 0.388$). There was, however, a significant interaction effect between population and temperature^2 on FMR, more so during the day ($p = 0.000$) than at night ($p = 0.005$). The exploited population's FMR was reduced at a greater intensity when temperatures deviated from an *in situ* mean of 15.52 °C towards thermal extremes. Ninety percent of the PE fish reduced their FMR greatly at colder temperatures whereas only 57% of the fish from TNP did.

Conclusion

This study is the first to assess the FMR of a resident reef fish in southern Africa using acoustic accelerometer transmitters. It is evident that fish from the exploited population have a reduced physiological capacity to expend energy at temperatures further from their environmental mean. This could be a direct result of fisheries-induced evolution whereby the fittest fish within the population have been removed. As a result of climate change causing upwelling triggering winds, temperature variability is likely to increase off South Africa's eastern coast. If exploitation continues to reduce the ability of red roman to expend energy at temperature extremes, then the combined effect of climate change and anthropogenic stressors may have accelerated implications on the fitness of our local line-fish stocks. This study thus provides further evidence of the benefits of protected areas.

The link between behavioural plasticity and aerobic scope phenotypes in predicting the survival of linefish *Chrysoblephus laticeps* under climate variability

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Background

Warming sea surface temperatures and ocean acidity, attributed to anthropogenic CO_2 emissions, have decreased aerobic performance in fish species with limited thermal tolerance or acid-base regulation ability. Behavioural plasticity is the primary mechanism allowing species to adapt to climate change by remaining within their thermal envelope. Fishing-induced mortality is thought to aggravate marine environmental stressors by reducing the genetic potential and selecting for particular phenotypes, such as a reduced aerobic scope or target bold fish deemed to have high fitness potential. Although the causal link between physiological phenotypes and behavioural phenotypes is not known, an understanding of climate variability and exploitation on the novel link between behavioural plasticity and aerobic scope phenotypes is critical to predict linefish survival. To assess the vulnerability of an important linefish species, red roman *Chrysoblephus laticeps*, this study will be the first to examine how hierarchical behavioural plasticity varies with aerobic scope under changing temperatures. We predict that bolder fish with a broad aerobic scope are likely to possess the energetic capacity for adaptive behavioural plasticity to changing temperatures.

Methods

To address the susceptibility of exploited species to temperature variability, we will use respirometry to quantify and compare changes in energy expenditure under temperatures mimicking variations experienced in the home range of the species. We will use intermittent-flow respirometry to determine the oxygen consumption rate of *C. laticeps* at control temperatures of 16 °C and experimental temperatures of 10 °C and 24 °C. For each test temperature, standard metabolic rate (SMR) measurements will be recorded for 24 hours, to increase confidence that estimates are close to minimum O_2 consumption rates by accounting for circadian rhythm changes in metabolic rate. For maximum metabolic measurements (MMR), we will transfer a fish to the 2100 L cylindrical tank where it will be chased for 10 minutes until exhausted (or unresponsive to touching of the caudal fin. This will be followed by 30 seconds of air exposure to ensure that the fish is maximally exhausted and likely to reach the maximum O_2 consumption rate during the recovery period. Absolute aerobic scope will be calculated by subtracting SMR measurements from MMR measurements. Once we have categorized high and low performance aerobic phenotypes, we will relate these to behavioural syndromes (bold vs timid) of individuals through a series of behavioural tests.

Behavioural assays will include Gopro recording of 10 minutes of exposure to a novel object to measure boldness, 10 minutes of exposure to a mirror to measure aggression, and lastly 20 minutes of routine activity. To determine different physiological responses amongst behaviour types, we will assess the plasticity of behavioural responses under temperature variability. Temperature will be adjusted by 1 °C per hour to reduce thermal stress and fish will be acclimated for 2–3 days at each temperature treatment (10 °C and 24 °C), at which behavioural assays will be repeated. Behavioural assays will be measured

as individual behaviour tests and then will be repeated in social groups of five fish (one male, four females) housed together.

Conclusion

This study will further our understanding of the likely impacts of climate change on linefish, by protecting the behaviourally and physiologically fittest individuals and allowing them to reproduce. This will ultimately add to the benefit of Marine Protected Areas as a climate change resilience tool.

Comparing activity levels of exploited & unexploited fish populations under stressful physiological conditions

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Background

The upper oceans are rapidly changing as a result of global climate change. As a result, fish populations in southern Africa are and will be subjected to physical changes, such as increasing frequency and intensity of upwelling events. Upwelling events can last several weeks and cause rapid and large decreases in water temperature.

Variation in water temperature impacts the metabolic rate of fishes, affecting their activity patterns. The metabolic scope of fishes is maximised at a specific temperature range to promote fitness related traits, such as growth and reproduction. When temperatures fall outside of this optimal temperature range, the capacity of fishes to perform aerobically declines. Thus, it is expected that increasing frequency and intensity of upwelling may place fish under significant physiological stress, impacting on their resilience to temperature change. Their resilience is largely dependent on their physiological attributes, such as metabolic rate. Theoretically, fish with broader metabolic scope will be more tolerant to the impacts of climate change as they have energy available for adaptation.

Recent research has found that populations of an important component of South African hook and line fisheries, *Chrysoblephus laticeps* (Roman seabream), have broader metabolic scope inside marine protected areas (MPAs), compared to outside of MPAs. Many other studies have also found that MPAs preserve greater abundances and diversity of fishes. Thus, it is possible that fish populations protected within well-established MPAs may be more resilient to the physiological stresses caused by upwelling.

However, one aspect that is not often included in these studies is behaviour. Thus, our objective is to quantify the impacts of temperature change on fish behaviour. Given this context, this project aims to assess the composition of fish communities (i.e. diversity, abundances, and sizes) and their behaviour inside and outside of MPAs. Our study will provide insights as to whether MPAs support fish populations that are more resilient to physiological stress and better able to cope with the effects of climate change.

Methods

Tsitsikamma MPA and Goukamma MPA have been chosen as study sites as they are both situated within upwelling cells, are well-established (having prohibited fishing for more than two decades) and are within close proximity to heavily exploited areas. Two sites in Noordhoek and Cape St. Francis have been identified to sample for exploited fish populations. These sites were chosen as they have similar environmental conditions and thermal regimes to our two MPAs. Our sampling design will allow us to obtain data covering a broad temperature range at depths of 15–25m.

We will be making use of baited remote underwater stereo-video systems (stereo-BRUVs), which are a non-extractive method for estimating the relative abundances, diversity and sizes of fishes. Using Stereo-BRUVs we can detect local changes in fish assemblage structure resulting from short-term changes in

water temperature. These changes typically manifest in reduced diversity, abundance and greater levels of lethargy in the fish that are seen.

To assess behaviour Behavioural Observation Research Interactive Software (BORIS) will be used. BORIS allows you to create ethograms as well as observe and analyse behaviour from videos. The focal species of behavioural analysis is *C. laticeps*.

A pilot study was conducted to guide and inform our sampling program, as well as to test the viability of using Stereo-BRUV footage for behavioural analysis of fish. The behaviours included in the study included feeding behaviours (such a feeding on bait, feeding in the water column or feeding off the benthos) and agnostic behaviours (this includes displays of aggression, such as chasing other fish and responding to displays of aggression). Additionally, the following covariates were taken into account: season, depth, temperature, size and the presence of other species, especially predators.

We were particularly interested in the seasonal effect of behaviour. This is due to concerns that the summertime spawning of roman would affect their behaviour in summer. Accordingly, our pilot study samples consisted of stereo-BRUV footage from Tsitsikamma MPA, taken in summer and winter between 15–25m in depth and 14–19 °C (what would be considered optimal temperature conditions).

Results

We found that at optimal temperatures there was no seasonal difference in the occurrences (how many times a particular behaviour was displayed by a *C. laticeps*) of feeding and agnostic behaviours ($p_{(perm)}$ = 0.638). We also did not find seasonal differences in the durations of behaviours (how long a particular behaviour was displayed for) of feeding and agnostic behaviours ($p_{(perm)}$ = 0.722).

Interestingly, juvenile and female *C. laticeps* (which are smaller in size compared to intersex and male roman) were found to only occur at a narrow temperature range, of warmer temperatures. In comparison intersex and male roman were found to occur throughout the temperature range.

Conclusion

Using stereo-BRUVs is both a viable and useful method for analysing fish behaviour. Our findings indicate that seasonality has no effect on behaviour, thus, allowing us to compare samples collected in winter to samples collected in summer. There is also potential to incorporate archived data into our analysis. Furthermore, in our main study, we will pay particular attention to the relationship between temperature and the occurrence of juvenile and female *C. laticeps*.

Combining the dynamic method, static respirometry and maximum heart rate experiments to understand the thermal physiology of the common recreational linefish *Diplodus capensis*

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Background
Knowledge of thermal performance of fishes is increasing in importance due to the effects of climate change. At the individual level of all life stages, rising ocean temperature has the potential to alter energy consuming activities, ultimately influencing their fitness and survival. As such, the aim was to use blacktail *Diplodus capensis* as a model species to determine the thermal tolerance and performance of a common coastal recreational linefish species using a range of different methods.

Methods
The critical thermal maximum (CT_{max}) and critical thermal minimum (CT_{min}) of both juvenile and adults was measured along with; the routine metabolic rate (RMR) and maximum metabolic rate (MMR) of juvenile *D. capensis*; and maximum heart rate (f_{Hmax}) of adult *D. capensis* under conditions of acute warming.

Results
The CT_{max} of adult *D. capensis* was significantly lower than juvenile blacktail. The CT_{min} for both adults and juveniles were similar and not significantly different. The RMR and MMR for juvenile *D. capensis* increased with acute warming but decreased slightly from a temperature of 28 °C. An aerobic scope curve, further indicated that the optimum temperature (T_{OPT}) was 25 °C and lower and upper T_{CRIT} temperature occurred at 2.5 °C and 47.6 °C. The average maximum heart rate (f_{Hmax}) for adult *D. capensis* was observed at 27.3 °C. The average T_{ARR} was at 28.3 °C and the average T_{AB} was observed at 20.8 °C.

Conclusion
The results from this study suggest that the effects of acute warming will differ between life stages of *D. capensis*. Furthermore, in terms of climate change, *D. capensis* juveniles will be more tolerant of increasing ocean temperatures compared to adults because they have a higher thermal tolerance (CT_{max}/T_{CRIT}) and a greater metabolic scope (T_{OPT}) at higher temperatures.

Examining the physiological responses of fishes to a climate change-induced hybridisation event – a case study on *Argyrosomus* species in Namibia

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Background

The northern Namibian coastal ocean has been identified as an ocean warming hotspot with temperatures rising at approximately ten times the global average which is suspected to have caused climate-driven changes on the endemic marine fauna. One change has been a general south-ward distributional shift of the Sciaenid, West Coast dusky kob, *Argyrosomus coronus* from Angola into northern Namibia. A further consequence of this distributional shift is that *A. coronus* has recently begun hybridising with the local Namibian silver kob, *Argyrosomus inodorus*, most likely because reproductively active adults are in the same habitat as a result of the distributional shift. These species have varying life history patterns which complicates the current management structures. For example, *A. coronus* matures between 80 and 90 cm, while *A. inodorus* reaches sexual maturity at approximately 40 cm. *Argyrysomus coronus* reaches much larger sizes (up to 77 kg) while *A. inodorus*, Namibia's most important linefish species, attains a size of 36 kg. Interestingly, these hybrids are successfully reproducing with the pure species (a phenomenon known as backcrossing), having consequences on the future genetic integrity of *Argyrosomus* spp. in the region. Hybridisation has often been regarded as negative due to the loss of genetic diversity or reduced fitness. However, it is possible that hybridisation may facilitate evolutionary adaptation to climate change as it can increase genetic variation to cope with rapidly changing conditions such as heatwaves and upwelling. Therefore, it is vital to identify which species are potential evolutionary winners and losers living near their physiological limits. Moreover, understanding the impacts of this hybridisation event will make an important contribution to our understanding of the potential impacts of climate change on fishes. The broad aim of this study is therefore to examine the impacts of ocean warming in Namibia and more specifically to examine the impact of hybridisation on the thermal physiology of *Argyrosomus* species.

Methods

The collection of specimens will be obtained via rod and line from the Namibian coast and transported to the University of Namibia's (UNAM) Sam Nujoma research station at Henties Bay. Fish will be acclimated at ambient sea temperature until feeding normally. Fish will be placed into custom-built intermittent flow-through respirometers to determine metabolic rate, oxygen consumption and aerobic scope at a range of temperatures; 12, 15, 18, 21 and 24 ˚C. Once experimentation has been completed a DNA sample will be removed and analysed using DNA barcoding to identify the pure species from the hybrids. This information will be used to determine the optimal thermal range for each species and their hybrids. Once this information is available, the future distribution patterns of the pure species and hybrids can be predicted for 2050 and 2100.

Potential conclusions and implications

The results from this study will provide valuable distributional data for these fish in the future, which can be used to develop sustainable management strategies for the affected areas. As *A. inodorus* is currently Namibia's most important linefish species, the shift of *A. coronus* into central Namibia may impact the catch composition of the fishery. This is likely, because *A. coronus* may outcompete the silver kob as it is more robust in nature and attains larger sizes. This, combined with the cold Luderitz upwelling cell, may also cause a concentration of fishes in central Namibia, which may increase the recreational fishing effort in the area placing strain on the already pressured fish stocks. Thus, management structures will have to be amended as the catch of *A. coronus* has increased substantially in the last 20 years from 10% to 60%. The current minimum size limit of 40 cm (based on *A. inodorus*) is no longer applicable to the general "kabeljou" caught in Namibia as *A. coronus* matures at approximately 85 cm and seems to be increasing in abundance.

There is also the potential that the hybridisation of these two species may negatively impact their resilience to climate change. Alternatively, it may increase their resilience and be a potential evolutionary adaptation to climate change.

SESSION 7

Socio-ecological

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SESSION 7 | Socio-ecological

Can foreign fishing tourism provide an alternative for artisanal fishers in West Africa? A case study of the fishery for *Polydactylus quadrifilis* in the Kwanza Estuary, Angola

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Background
Globally, recreational fisheries have been acknowledged as major economic contributors. However, very few publications have focused on the fishing tourism sector, which is expanding in the developing world and in Africa. It has further been suggested that this growing sector may have the ability to raise the value of landed catch, thus creating a potential for alternative livelihoods for local artisanal fishers, aiding in poverty alleviation and, because recreationally caught fish are often released, simultaneously conserving fish stocks. However, for fishing tourism to meet ecotourism standards and make meaningful change, sustainable, local economic benefit is imperative and economic leakage needs to be reduced. Therefore, this study aimed to assess the direct economic benefit of a model West African recreational fishery and evaluate the direct benefit gained by the local community.

Methods
The recreational fishery for giant African threadfin *Polydactylus quadrifilis* on the Kwanza Estuary was divided into two main sectors. These included the recreational fishery operating out of the Kwanza Tarpon Lodge (the 'lodge fishery') and the recreational fishery operating separately from the lodge (the 'non-lodge fishery') using private vessels and charters with artisanal fishermen. The lodge fishery was further divided into three separate sub-sectors. These included the 'domestic lodge fishery', the 'foreign lodge fishery' and 'lodge casuals', or hereon referred to as 'casuals', who are defined as domestic and foreign tourists who visit the lodge for purposes other than fishing.

Catch-per-unit-effort (CPUE) data was collected for the different fishery sectors during winter fishing seasons (1 June–30 September) in 2016 and 2017. Tourist spending (US $) was then recorded for each of the fishery sectors during the same period and was recorded on a local (15 km radius of the lodge), regional (within the province of Luanda), national (within Angola) and international scale (outside of Angola). Tourist spending was considered as total revenue (TR) while tourist spending in the local area was considered local total revenue (LTR). LTR was further analysed from spending by tourists to spending by recipients of local tourist spending to analyse for economic leakage. Leaked revenue (LR) was defined as LTR not accruing to a local person either through payment or profit. Retained revenue was the remainder of LTR following leakage. Catch estimates were made for each of the fishery sectors for all species and for *P. quadrifilis* and in terms of fish numbers and kgs of fish. Economic values were then estimated in terms of recreationally-caught fish and per kg of fish and were estimated in terms of TR, LTR and retained revenue (economic value divided by the catch). The values of recreationally-caught *P. quadrifilis* were then compared with the market value of *P. quadrifilis* in the artisanal fishery ($7.98) to attain a 'recreational-to-commercial ratio' (RCR).

Results

The lodge and non-lodge fishery generated a mean TR of $273 865 per four-month fishing season while $228 940 (83.6% of TR) was spent locally (LTR) and $40 099 (17.5% of LTR) was retained. Of this, the lodge fishery generated the largest proportion with a mean TR of $214 902 and an LTR of $189 422 (88.1% of TR). However, the lodge fishery exhibited high rates of economic leakage with LR averaging $175 973 (92.9% of LTR) per season while only $13 449 (7.1% of LTR) was retained. The high rates of leakage observed in the lodge fishery resulted from the sourcing or lodge supplies outside of the local economy. Additionally, lodge transport costs, the hiring of non-local staff, including foreigners who filled higher-paying positions, and the repatriation of lodge profit contributed to increased rates of economic leakage.

The non-lodge fishery generated an average TR of $58 963 and an LTR of $39 518 (67.0% of TR) per season. However, rates of leakage were lower than those in the lodge fishery with an average of $26 650 (67.4% of LTR) retained per season. The lower rates of economic leakage observed in the non-lodge fishery resulted from the direct chartering of fishing trips with local artisanal fishermen while leaked LTR largely resulted from the sourcing of fuel for private vessels and chartered trips from a non-locally owned business.

Prices per fish and per kg of fish were considerably higher in 2017 based on reduced catches in that year (i.e. a lower 'supply' of fish). In terms of TR generated, recreationally caught *P. quadrifilis* were valued at between $263 and $2 906 per fish and $273 (RCR = 34.2) and $27 (RCR = 3.4) per kg depending of the fishery sector and the fishing season. Values in terms of TR were higher in the lodge fishery (mean price of *P. quadrifilis* per kg per season = $173) than the non-lodge fishery (mean price of *P. quadrifilis* per kg per season = $35). However, in terms of retained revenue, the value of *P. quadrifilis* in the lodge fishery dropped significantly ($0.9 - $18.9 per kg) and largely fell below the price of artisanally caught fish (RCR < 1). In terms of retained revenue, the non-lodge fishery maintained values above the price of artisanally caught *P. quadrifilis* in both seasons ($12.4-$19.80, RCR: 3.4-5.4).

Conclusion

The recreational fishery for *P. quadrifilis* generated significant economic activity in an area that would otherwise likely receive little input from external sources. However, rates of economic leakage from the study area were found to be high and may inhibit the achievement of potential ecotourism goals. It was found that the main sources of economic leakage were via the sourcing of lodge supplies, services and staff outside of the local area and through the repatriation of profit by foreign business owners (at the lodge and the local fuel pump).

Capacity building within the local community is likely required in order to reduce leakages and to create 'linkages' between the local community and the recreational fishery. It is suggested that potential linkages could include the contractual sourcing of fresh produce within the local community following appropriate capacity building. Additionally, domestic fishing tourists could be channelled towards charters within the non-lodge fishery to reduce overall rates of leakage. Capacity building via the training of locals, including the opportunity to undertake English language lessons, may allow for the provision of local staff within the lodge fishery. Additionally, it may allow for local staff to occupy higher positions and could improve local's employability across other employment categories.

Greater community involvement within the fishery, including the provision of business shares and greater communication and control, is suggested in order to achieve sustainability and provide incentive for the protection of recreationally important fishery species and their associated ecosystems. A community-based approach which aims to simultaneously promote the quality of life of local people and the conservation of resources is recommended. This should be achieved by maintaining a higher level of

communication and cooperation between the recreational fishery and the local community in order to facilitate direct local benefits from the recreational sector. It is suggested that the devolution of authority by national government may allow the local community to manage the fishery through catch limits, with direct funding through access fees for domestic and foreign recreational anglers.

Social and ecological research and monitoring associated with community fishing in the Tsitsikamma Marine Protected Area

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Background

Changes to the regulations for the management of the Tsitsikamma Marine Protected Area (MPA) were gazetted in December 2016 enabling controlled access to three zones within the previously no-take MPA by local community members from a spatially defined area for fishing and bait collecting purposes. The regulations stipulate the three areas where fishing can occur (known as Tsitsikamma Coastal Control Zones – TCCZ's), the times when fishing may occur, the number of fishing days allowed per angler per month and the daily bag and size limits for fish and bait species harvested within the TCCZ's. In addition, all anglers need to be registered with South African National Parks. The decision was not without contention and concerns were raised by interested and affected parties around the sustainability of fishing and potential impacts on both fish and bait stocks. The Tsitsikamma MPA has a number of objectives including i) the protection of biodiversity and ecological processes, ii) protection of threatened species and ecosystems, iii) facilitate fishery management by protecting spawning stock and nursery areas and iv) to provide a reference environment for research and monitoring including the impact of limited recreational fishing in the TCCZ's. As the designated management authority, SANParks is responsible for monitoring possible positive and negative impacts of the new regulations and in assessing the effectiveness of the MPA in achieving its objectives.

Methods

Accepting MPAs as social-ecological systems, a multifaceted approach to undertaking this monitoring is being implemented. An angler database is being maintained of all anglers registered to fish; comprising limited socio-demographic information (place of residence, age and sex) whilst access point surveys monitor catch and effort at each of the TCCZ's. The following information is recorded from each angler: SANParks access number, time in, time out, time started and finished fishing, species and sizes of all fish caught (and released), numbers and species of bait used / harvested. Survey monitors are stationed at each of the TCCZ access control points seven days a week between 06:00 and 19:00 from October-March and between 06:00 and 18:00 from April-September.

Fishery independent techniques were used following using an 'inside-outside, before-after' experimental design to monitor changes in intertidal invertebrate and sub-tidal fish communities. Data on bait species is collected using a mixture of (1) fixed photo transects (for *inter alia* red bait and mussels) in conjunction with rapid survey counts (for more mobile species such as rock crabs) and (2) strip transects along gullies (for *inter alia* siffie, alikreukel and rock crabs). A mix of mono and stereo baited remote underwater video

surveys are used to monitor inshore sub-tidal fish communities. In addition, in depth interviews and questionnaires provide information on community perceptions, whilst information obtained during angler registration enabled key actors in the communities to be identified.

Results

Since 2016, a total of 313 anglers have registered to fish in the TCCZs from 16 different communities; with the highest number of registered anglers residing in Coldstream, Nompumelelo, Stormsriver and Thornham. Only two anglers have registered annually whilst 59% (186) of the anglers have only registered once indicating a high turnover in participants. Total recorded fishing effort for 2017 and 2018 was 1 289 fishing outings or 5 976 angler hours. Fishing effort was higher on weekends (52%) with an annual peak in effort occurring in April and May. Changes in the spatial distribution of fishing effort were recorded between years; with TCCZ 3 being consistently the most popular. A total of 2 680 fish (37 species) were caught during this period with an average catch-per-unit-effort of 0.43 fish.angler.hr^{-1}. Small bodied species dominated catches with strepie *Sarpa salpa* comprising 37% of total catch followed by blacktail *Diplodus capensis* (15%).

Both angler interviews and data from the independent intertidal monitoring currently indicate that bait harvesting effort within the TCCZ's is low. The most commonly harvested bait species are red bait, mussel worm and octopus (albeit in low numbers) in the TCCZ's. Signs of red bait harvesting was only recorded along one transect in TCCZ 3 (compared to 43 harvesting outings noted during checkpoint monitoring activities) and along two transects in TCCZ 2 (compared to 19 harvesting outings).

Network analysis undertaken on information flow within the communities reveals the presence of six major (interconnected) sub-communities within the region with 10 key mediators or linking actors. Interviews indicate an improvement in community relationship with SANParks.

Conclusion

Shore-based fishing occurring within the TCCZ's by local community members is still developing. Adopting a social-ecological framework to our monitoring has enabled a deeper understanding around the implications of the new regulations. For example, although total fishing effort is increasing, angler turnover is high with only a few anglers fishing consistently between years. Interactions with local community members highlighted the difficulty of the terrain and the older age groupings of local anglers as factors contributing to this turnover. Spatial and temporal patterns in fishing effort varied between years with the exception of increasing effort prior to Easter holidays whilst catches are dominated by small bodied species in part due to fishing practises, type of gear used and also anglers' knowledge of the area. Bait harvesting is generally low and to allow better prediction of changes in the intertidal community due to harvesting practices, changes to the intertidal monitoring programme are being investigated. The network analysis has highlighted the presence of key actors that SANParks should target with regards to information sharing amongst the identified sub-communities. Importantly, relationship building with local communities needs to be ongoing and proactive with an understanding that external forces make this relationship dynamic.

Modelling the socio-ecological implications of Dwesa-Cwebe MPA opening for harvesting

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Background
Society and government conflicts associated with the proclamation of the Dwesa-Cwebe Marine Protected Area (MPA) dates back to 1890. The recent re-opening of zoned sections of this MPA for public harvesting, after years of being a strictly no-take MPA and legal battles, is something unique which poses special challenges regarding efficient marine resource management, while catering for socioeconomic demands at the same time. The recent ruling by the South African Supreme Court of Appeals to grant traditional fishing rights to coastal communities near this MPA may have sparked a sense of community entitlement thus leading to overexploitation of the marine resources in this MPA. We, therefore, aimed to determine what fish species have been harvested and the origin of harvesters at Dwesa-Cwebe MPA since its opening for harvesting.

Methods
The resource use data sheets kept at the access gates, dating back to December 2015 when the MPA was opened for fishing, were collected. Network analysis was used to detect socio-ecological interactions between the fish and harvesting communities. Four models (i.e. ARIMA, ETS, Holt Winters and linear regression) were compared in forecasting harvested fish densities. Structured interviews were administered to profile the fishers in order to determine their socioeconomic conditions, their indigenous knowledge and their attitudes regarding the MPA and its resources.

Results
A total of 714 fish from 14 different species were recorded caught during the study period. Blacktail, barbel and bronze bream were the dominant species caught. Bronze bream was the largest, while Cape stumpnose was the smallest fish species caught. Network analysis detected 460 edges and 17 vectors. Source analysis detected that Ntubeni villagers had 267 edges, Mpume villagers had 151 and the visitors had 42 edges. Forecasting revealed AIC results revealed that Holt Winters was not a suitable model while ARIMA was the best model to use. Augmented Dickey-Fuller test detected that lag order = 7, p = 3, d = 0 and q = 2. Socioeconomic analysis detected that 75% of people fishing were below an age of 30 years, unmarried and unemployed. A total of 48% depended on fishing for food, 43% sold the fish they caught and the remaining 9% used the fish they caught as bait. Indigenous knowledge and attitude analysis revealed that 57% of the fishers knew that overfishing affected the fish populations, while 43% believed that the fish stocks replenish themselves whenever populations declined.

Conclusion
Fishing pressure associated with the opening of Dwesa-Cwebe MPA for fishing is skewed towards certain targeted fish species. Equitability in fishing benefits has not yet been attained as only a select few fishers catch the bulk of the fish harvested. Balancing the socioeconomic needs and marine resource protection in this area is the major challenge. Transparent dialogues, education and awareness campaigns are therefore needed to achieve a sustainable relationship between the community and the MPA.

SESSION 8

Movement studies

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SESSION 8 | Movement studies

Spatial dynamics of west coast dusky kob *Argyrosomus coronus* in southern Angola

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Background
West coast dusky kob *Argyrosomus coronus* Griffiths & Heemstra 1995 occurs primarily in northern Namibia and Angola. It is exploited by many fisheries (artisanal, recreational and commercial) during most of its life history stages and, although there is biological information available, knowledge of their spatial dynamics is limited. Conventional tagging information showed that juveniles (<600 mm TL) were more resident (57% recaptured at release site), while subadults and adults were more mobile (13% recaptured at release site). Conventional tagging and catch-per-unit-effort data from the recreational shore-based fishery suggested that adults undertake a seasonal migration, following the shifting Angola-Benguela Frontal Zone (ABFZ), which leads to intra-annual water temperature fluctuations of ~13 °C (15–28 °C observed during this study), into Angola in winter and into northern Namibia in spring. This study aimed to address the spatial dynamics knowledge gap and test the hypothesis of an annual return migration, by using acoustic telemetry techniques.

Methods
Thirty *A. coronus* were fitted with acoustic transmitters (juveniles: *n* = 7; sub-adults: *n* = 7; adults: *n* = 16) and monitored for a two-year period. The acoustic receiver array was deployed in three study sites, covering 160 km of coastline in southern Angola, between Flamingo where tagging occurred (30 km south of Namibe Harbour) and Baia dos Tigres (50 km north of the Namibian border). The array was designed to monitor local-scale area use and movements within study sites and to detect longshore movements to test the migration hypothesis.

Results
Monitored fish were largely resident to the site of tagging. No fish were ever detected in the southern-most portion of the receiver array (Baia dos Tigres) indicating that they did not undertake any longshore migration during the two-year monitoring period. Rather, tagged fish predominantly remained at the Flamingo site. A seasonal behaviour, exhibited in particular by monitored adults, explains the disappearance of *A. coronus* from the shore-based fishery previously noted. During austral summer, there was a tendency for adults to be located further offshore, while during winter an inshore distribution was noted. A Generalised Linear Model (GLM) predicted a reduction of ~ 80% in the daily number of tagged fish detected on the closest inshore (~400 m offshore) line of receivers during summer compared to winter. Detections of juveniles and subadults were low, likely due to very low levels of movement and due to their vulnerability to being captured in the fishery. Juveniles tended to occupy deeper waters offshore, when adults were located inshore.

Conclusion
We found no evidence to support the migration hypothesis that predicted a longshore movement of *A. coronus* associated with the seasonally shifting ABFZ. Rather, monitored individuals exhibited a high

degree of residency to a relatively short (~24 km) stretch of coastline. We noted seasonal shifts in area use, which aids in explaining the disappearance of the species from the shore-based fishery, likely linked to foraging behaviour. This study highlights the important contribution that acoustic telemetry can make towards understanding fishes' spatial dynamics, beyond that which we can infer from mark-recapture techniques and CPUE based approaches.

New insights into the migrations and vulnerability of leervis *Lichia amia* gained from long-term passive acoustic tracking

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Background

The leervis *Lichia amia* is a highly prized recreational fishery species in South Africa. Juveniles are targeted mostly by artificial lure enthusiasts in estuaries along the south-east coast while adults are targeted by multiple fishery sectors, including shore-based, ski-boat and spear fishers along the KwaZulu-Natal (KZN) east coast during their annual spawning migration. The collapsed status of the stock – estimated to be at 14% spawner-biomass per recruit – has resulted from at least three factors; (i) the predictability of the annual spawning migration, (ii) the readiness of this species to take a lure or live bait resulting in high catchability and overfishing, and (iii) ineffective management measures such as minimum size and daily bag limits in a fishery plagued by non-compliance.

Adult leervis undertake an annual migration to spawn in KZN coastal waters during austral winter. After spawning, eggs and larvae are transported southwards inshore of the Agulhas Current, where juveniles recruit into estuaries in the Eastern and Western Cape during summer. They remain in these nursery habitats for 1 to 3 years, before moving to the coastal marine environment to join the adult population. Knowledge on the movement behaviour of leervis in South Africa is limited to anecdotal observations and two conventional dart tagging studies, which provide limited data on individual movements. Acoustic telemetry can provide considerably better resolution information on individuals' movements, thus providing an opportunity for a more detailed assessment of the behaviour of this migratory species. Therefore, the aim of this study was to assess aspects of the movement behaviour and vulnerability of sub-adult and adult leervis along the South African coastline using acoustic telemetry.

Methods

Multiple-year telemetry data obtained from the nation-wide Acoustic Tracking Array Platform were extracted and analysed. In total, 77 fish, ranging in length from 439 to 1000 mm fork length (FL; average ± SD: 744 ± 89 mm FL), were fitted with acoustic transmitters throughout their South African distributional range (tagging range extended from the Berg River Estuary, Western Cape to Mapelane, northern KZN) between May 2011 and February 2018, and fish were monitored for up to six years.

Results

In total, 87% of the tagged fish were detected, with a total of 232 507 detections. Individual monitoring periods ranged from 1 to 376 days (mean: 59 ± 63 days). Approximately 80% of all detections were recorded within estuaries, which can be attributed to: (i) most individuals tagged (70%) were juveniles , with 56% of those fish having been tagged within estuaries, and, (ii) while in the marine environment,

tagged individuals presumably utilised surf-zone and backline habitats, inshore of the detection range of the closest deployed marine receivers, which were normally deployed at least 1 km offshore of the high-energy coastline to minimise risk of loss (and hence these fish were seldom detected).

The findings of this study revealed considerable plasticity in the behaviour of leervis. Tagged individuals utilised both estuarine and marine environments, with fish that were tagged within estuaries spending more time in this environment, before moving to sea, with most individuals returning to an estuary at some point. This behaviour is typical of juvenile leervis; however, in this study, 90% of sub-adult and adult fish displayed the same behaviour, with 68% of those fish being detected more on estuarine than marine receivers. Numerous tagged leervis undertook the "typical" annual migration, with fish tagged in the Western and Eastern Cape moving up to KZN waters in winter and returning to Cape waters during summer. Some fish were recorded undertaking this migration over multiple (n = 4) consecutive years. Adult leervis regularly move between the warm-temperate (WT) and sub-tropical (ST) biogeographic zones. Previously, no leervis had been recorded moving between the cool-temperate (CT) and WT biogeographic zones. However, one leervis tagged in the Berg Estuary (CT) was detected moving into the WT zone and was eventually recaptured in the ST zone at Blythedale (KZN), covering a distance of approximately 1 900 km, crossing two biogeographic boundaries. Despite the presence of a predictable seasonal migration, the telemetry data revealed evidence of some fish overwintering in Cape waters (i.e. did not migrate to KZN). There was also evidence of homing, where fish returned to the same site where they were tagged over multiple years. For example, a fish tagged in the Mzimvubu Estuary at Port St Johns in September 2013 returned to the estuary over the next three years at approximately the same time each year.

In addition to revealing behavioural plasticity, this study provided evidence of high fishing mortality. Of the 77 leervis tagged, 17 (22%) were recaptured and killed in the fishery (at the time of writing), which was confirmed by the return of all transmitters. Of those, five (29%) were recaptured in the Swartkops Estuary, Eastern Cape (all were tagged in this estuary), on average 101 ± 77 (range: 32 – 1 449) days after tagging. This mortality rate is similar to the rates recorded in the Kowie (33%) and Goukou (24%) estuaries. The remaining 12 (71%) recaptures were made along the KZN coastline, on average 462 ± 398 days after tagging, and between May and October which coincides with the spawning migration. This highlights the extreme vulnerability of this species to capture during the spawning migration.

Conclusion

These new insights into the behaviour of leervis can assist with the identification of alternative management options, such as spatio-temporal closures. The high mortality in KZN during the annual spawning migration suggests that implementing a closed season may be a useful management intervention. A closed season in KZN from 01 July to 31 August would afford protection during this vulnerable period. This would not coincide with existing closed seasons of other targeted species in the area, such as shad *Pomatomus saltatrix* (01 October to 30 November), thereby still providing anglers the opportunity to catch something other than leervis. The creation of voluntary control measures through education programmes would also be beneficial, such as getting anglers to practice catch-and-release only or get involved in research projects such as the Oceanographic Research Institute-Cooperative Fish Tagging Project.

Refuges and risks: Evaluating the benefits of an expanded MPA network for mobile apex predators

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Background
Concurrently assessing the effectiveness of marine protected areas (MPAs) and evaluating the degree of risk from humans to key species provides valuable information that can be integrated into conservation management planning. Tiger sharks *Galeocerdo cuvier* are a wide-ranging ecologically important species subject to various threats. The aim of this study was to identify "hotspots" of tiger shark habitat use in relation to refuge areas and potential risks.

Methods
Satellite tags were fitted to 26 tiger sharks. A subset of 19 sharks with an average period at liberty of 197 ± 110 days were analysed using hotspot analysis to identify areas of core habitat use. The spatial and temporal overlap of significant hotspots with current and planned MPAs as well as risks from fishing and culling were then calculated.

Results

There was a 5.97% spatial overlap between MPAs and tiger shark hotspots which would increase significantly ($p < 0.05$) to 24.36% with the expansion of planned protected area network in South Africa and could be as high as 41.43% if Mozambique similarly expanded neighbouring protected area boundaries. Tiger sharks remained largely coastal, but only showed a spatial overlap of 5.12% with the location of shark nets in South Africa. Only three sharks undertook open ocean migrations during which they were more likely to interact with longline fisheries in the region.

Conclusion

This study demonstrates how spatial information for highly mobile species can be used to design MPA networks that incorporate a significantly higher proportion of their core habitats and highlights how congruent transnational conservation management can improve the effectiveness of protected areas. Core habitat use of marine apex predators may also be indicative of productive habitats, and therefore, predators such as tiger sharks could act as surrogate species for identifying key habitats to prioritise for conservation planning.

SESSION 9

Science communication

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SESSION 9 | Science communication

An update of the ORI - Cooperative Fish Tagging Project, current developments and things to come

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Background

The tagging of animals is an ancient method used to develop a greater understanding of species growth, movement, behaviour and mortality rates. Fish tagging started as early as the mid 1800's where Atlantic salmon were tagged by means of fin clips, attaching pieces of wire to tails and jaws, and attaching unique labels to tails and opercles. Many tagging projects have been initiated in South Africa in the past but few yielded results, with much of the data being unpublished or not used. During the 1970s, ORI's Rudy van der Elst recognised the value of fish tagging information and involving the angling public in the collection of such data. He formally started the ORI Cooperative Fish Tagging Project (ORI-CFTP) in 1984 with the intention of enlisting active angler support in the tagging of specified marine fish species around the entire southern African coastline. This project has now become one of the longest standing and most successful citizen science projects of its kind in South Africa, involving conservation conscious anglers and the marine angling public. By allowing anglers to actively participate in collecting scientific data, the ORI-CFTP has helped develop and improve cooperation between fishermen, managers and scientists, and has helped increase our knowledge and management of many important linefish species.

The aim of this project is to provide information on the movement patterns, growth rates, stock identity and population dynamics of important linefish and elasmobranch species. The objectives are to develop, improve and maintain a nation-wide marine linefish tagging project with voluntary participation by recreational anglers, commercial fishermen, scientists and resource managers; ensure the latest tagging and fish handling techniques are used and demonstrated to members; manage the data resources in a professional and organised manner, so as to maximise the output of the data which can be used in important biological studies and stock assessments of marine linefish; and communicate effectively and professionally with our angling members and members of the public.

Methods

Anglers join the ORI-CFTP by applying online or via email with an application form motivating why they would like to join the tagging project. If they are accepted, they receive a tagging kit and an individual membership number. Tagging kits include an instructional DVD, tagging manual, the latest Tagging News, five tags and accompanying tag cards, a tag applicator, applicator cleaning swabs, tape measure, and a pencil. There are three types of tags that can be used by members based on their target species. The D-tag which is used for fish between 30–60 cm, the A-tag which is used for fish larger than 60 cm and for shark and ray species, and M-tags which are used for billfish or larger game fish species. Each tag has a unique tag ID, and the tagging data is stored and managed on a database run by ORI. Members are encouraged to tag species that are on a priority species list (n = 109 species), which is derived from species that can handle the tagging process and which require the most research. When a member tags a fish, they are required to fill out the necessary information onto a tag card and return the data to ORI via email, phone, or the interactive website. Any fish that has been recaptured can be reported via the website or by telephone or email using the phone number and email address listed on the tag.

Results

The ORI-CFTP has been successfully running for 34 years (1984 to 2018). By the end of 2018 there were a total of 5 938 members (~170 new members.yr^{-1}) that had joined, with an average of 482 active members/year (tagged at least one fish in a given year). The highest number of new members to join was in 1985 (*n* = 441), with the lowest in 2002 (*n* = 54). There was a constant decline in new members from 1992–2004 largely due to decreasing interest, poor marketing, and a stricter application process for members being implemented. From 2005 onwards new member numbers increased due to improved communication and active promoting of the project. A total of 331 320 fish have been tagged, up until the end of 2018, with an average of 9 466 fish tagged per year. The highest number of fish tagged was in 1992 (*n* = 12 777), with the lowest number tagged occurring in 2000 (*n* = 6 101). The total number of recaptures is 21 355 (6%) with an average of 610 recaptures per year. Recaptures have increased with the cumulative number of tag releases due to a higher number of tagged fish in the ocean, improved tags and tagging techniques leading to higher survival rates, commencement of various Marine Protected Area (MPA) tagging projects conducted by trained scientists (e.g. Pondoland MPA = 24% recapture rate), and improved communication to the angling public about the tagging project and how to report recaptures. There has been a total of 372 different species tagged, with an average of 166 species tagged per year. The top five species tagged include: galjoen *Dichistius capensis* (*n* = 66 239), dusky kob *Argyrosomus japonicus* (*n* = 21 069), garrick/leervis *Lichia amia* (*n* = 16 788), dusky shark *Carcharhinus obscurus* (*n* = 14 617), and spotted grunter *Pomadasys commersonnii* (*n* = 13 529). The high galjoen numbers are partly due to tagging efforts by scientists in the De Hoop MPA and the Cape Peninsula area. The Western Cape has the highest number of tag releases (*n* = 142 211) and 41% of all recaptures, followed by the Eastern Cape (*n* = 88 471) and 27% of all recaptures, and KwaZulu-Natal (*n* = 79 544) and 28% of all recaptures.

These results are communicated to members of the public via various means, such as: the annual Tagging Newsletter which provides an overview of the previous year's statistics, interesting angling articles, and tips to improve fishing and handling techniques; the ORI TAG Facebook page which posts exciting recaptures, interesting articles, news for anglers, and video tips for successful tagging; through to refereed scientific journal publications (*n* = 91), books and book chapters (*n* = 74), public talks and tagging demonstrations (*n* > 100), popular magazine articles (*n* = 81); and the interactive tagging website (www.oritag.org.za) which allows tagging members to access their personal tagging profile and allows members of the public to read various news articles, view statistics, and submit recaptures online.

Conclusion

The ORI-CFTP has grown annually and we plan to continue to improve the project going forward. This project has greatly improved angler awareness and knowledge about linefish resources and has played a major role in influencing policy and decision-making on the management of specific linefish species in South Africa. The project has been instrumental in guiding the competitive angling community towards catch and release by using published length/weight relationships to calculate the weight of their catch. The large number of members that have joined the ORI-CFTP have not only learnt about how to tag and release but also about the importance of correct fish capture and handling procedures to ensure their greatest chance of survival. Members have also gained a better understanding of the biology of many linefish species, the value of sustainable fishing and ultimately, they have contributed towards the improved conservation and management of many of South Africa's linefish species.

Working with not against recreational anglers: two case studies on changing competitive angler behaviour through engagement, education, rule changes and incentives

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Background
With over 500 000 active recreational anglers in South Africa, the economic benefits of this sector is hard to ignore. However, there is growing concern that the environmental footprint of these fisheries is unsustainable, particular those that target imperilled species. Given the participation size and the amount of money spent in this sector, it is not surprising that many large corporate companies sponsor angling competitions, attracting, in some cases hundreds of anglers with the chance of winning prizes. Unfortunately, on occasion these sponsors support competitions which practice unsustainable fishing practices, attracting in some instances unfavourable publicity to both the competition anglers and the associated sponsors. One of the easiest ways in which some competitions have become more environmentally benign is by the adoption of catch-and-release (C&R) angling within various competitive angling formats. While this pro-environmental move is highly commended, post C&R fish health and mortality problems have been linked to bad handling practises such as high air exposure times associated with scoring fish (measuring, photographing etc). Given the high levels of competitive C&R adoption within the South African recreational marine fishing sector, this study assessed the efficacy of a scientific intervention to improve fish handling practises at both shore and boat-based marine fishing competitions held along the South African coastline.

Methods
Over a period of five years, a group of fisheries scientists, volunteered to help at selected angling competitions introducing rule changes, educating anglers on how to handle fish correctly and asking survey questions to better understand angler knowledge. The initial intervention occurred at the Rock and Surf Super Pro League (RASSPL) annual national competitions where groups of students recorded various fish handling metrics such as air exposure and consequent fish health metrics. Each year different rule changes and incentives such as how fish are photographed, and best handling prizes were introduced respectively. The second intervention, which followed a similar intervention format but at a local ski-boat bottom fishing competition, focused on trying to educate and increase the use of barotrauma mitigating techniques by competing anglers during the C&R event.

Results
Significant achievements have been made in reducing fish air exposure times during the shore-based intervention through angler education and incentives. While still in its infancy (two years old), the boat-based intervention has yielded less obvious reductions in air exposure times following the changing of

competition rules and the introduction of incentives. The most likely cause for the discrepancy between the efficacy of the program between the two angling competition types relates to each competition scoring system. These findings suggest that when implementing interventions careful planning based around the competition's rules need to be fully considered to achieve a pro-environmental response.

Conclusions

These two case studies highlight the importance of working with, not against recreational anglers when trying to promote pro-environmental behaviour amongst recreational users that are not accustomed to it. Furthermore, the use of incentives and scoring system designs play an important part in achieving pro-environmental behavioural objectives such as reduced fish air exposure times and subsequently lower post capture mortality rates.

Communication with fishers in the Anthropocene – using research to do it better

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Background

In the past fisheries scientists worked on the assumption that by researching fish biology and ecosystem functioning and by accurately estimating biomass and harvest rates, they would be able to ensure the sustainable use of marine resources. Unfortunately, this approach has addressed only half of the fisheries equation. It is clear that without a better understanding of fishers, and how to communicate effectively with them, many challenges facing fisheries management will remain unresolved.

Recreational fishing is a very popular pastime in South Africa. The total number of active recreational anglers fishing along the coast is estimated to be about 730 000 (Saayman, et al. 2017). The large number and diversity of users, along with the diversity of species targeted in this fishery pose many challenges for effective monitoring and management (Brouwer et al. 1997; Dunlop and Mann 2012). South Africa has limited capacity to enforce marine fishing legislation and it is widely acknowledged that transgressions of fishery regulations are widespread. It is also recognized that while essential, law enforcement can only go so far in achieving the aims of effective fisheries management. The co-operation of the anglers themselves is critical. This co-operation can only be achieved through effective communication and through building the support of law-abiding anglers. For this to happen it is critical that the anglers are provided with information about the regulations, the rationale for the regulations; as well as information about responsible fishing practices (Kramer et al. 2017).

The declaration of the new Marine Protected Areas (MPA) in South Africa has provided greater impetus to the need to more effectively communicate with recreational anglers. These new MPAs have been declared with limited supporting communication with anglers. Without effective communication with these stakeholders, the new MPAs are likely to be little more than ineffective 'paper parks'.

Methods

Clear communication with recreational anglers is challenging, however, research and practical experience are resulting in much information that can help to improve our ability to effectively communicate with anglers. With the dawning realisation of the critical importance of communication in conservation, many international best practices in conservation communication are emerging. Selected theories and models of behaviour change in conservation in relation to angler behaviour include - community based social marketing (McKenzie-Mohr & Smith, 1999), social norms (Cialdini, 2003), diffusion of innovation (Rogers, 2003) and the knowledge behaviour and intention action gap (Kollmuss & Agyeman, 2002). To ensure communication efforts are designed to meet the needs of a South African audience, recent research undertaken in South Africa on environmental learning and behaviour change are also valuable (Mann, 2016; Mann, Ballantyne, & Packer, 2018). Using these theories and models a five-step process has been developed to improve communication with recreational anglers.

These steps include – 1) understanding the audience; 2) clarity on angler behaviours to be changed; 3) a deep understanding of current behaviour; 4) an understanding of the barriers to and benefits of the appropriate behaviour; and 5) how to support the new behaviour and finally how to evaluate the effectiveness of the communication. All these steps highlight the critical importance of social research.

Each of these steps are currently being considered as a part of the new Angler Aware campaign currently being undertaken by the South African Association for Marine Biological Research (SAAMBR) in Durban.

Conclusion

To integrate anglers more effectively into fisheries management requires a better understanding of anglers and how to communicate more effectively with them. Integrating social dimensions into fisheries management is no longer desirable – it is critical. This campaign and associated research will start to address this critical gap in South Africa's current approach to recreational fisheries management.

Communicating scientific monitoring data through a public user-friendly interface: R SHINY app

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De Hoop is one of several marine protected areas (MPA) on the South African coast where fishing is prohibited. Since its promulgation in 1985, fish populations have been completely undisturbed by fishing. One of the objectives of the MPA is to aid in the protection and recovery of species that have been severely impacted by fishing. To monitor the status of fish populations and the efficacy of the MPA, the Department of Environmental Affairs runs a research project at De Hoop, involving scientists from the University of Cape Town and volunteer anglers. The De Hoop monitoring programme occurs at two sites within the MPA: Koppie Alleen and Lekkerwater, where each site is sampled three times annually. Anglers catch, tag and release fish, recording vital information on their abundance, size and movement habits. The project began in 1984, one year before the MPA was established, and has continued ever since, making it the longest project of its kind. Fishers use standard angling techniques and each fish is identified and measured, and some of them are tagged with a plastic dart tag bearing a unique number and a return address.

Results from the De Hoop monitoring programme appear in several scientific peer-reviewed articles that have been cited worldwide in support of MPAs, fish movement and conservation. The importance of scientific publications is undeniable, but the broad communication of these scientific findings to all stakeholders remains challenging. Scientific jargon, restricted access journals and a tendency for scientists to follow traditional formats inhibit the natural flow of information to the general public. This problem is particularly troublesome for so called 'citizen science' programmes that rely on voluntary public participation and for programmes financed through public funds. Therefore, bridging the communication gap between science, public and policy makers is essential to provide evidence for programme efficacy, and hence provide support for participation and their continuity. Dissemination of information outside of the scientific community is now accepted as a vital part of the scientific process. Effective communication of results requires engaging and novel communication media, beyond scientific journals and conferences.

We developed a R SHINY app to provide a platform to communicate the De Hoop monitoring results to the general public. R SHINY is a package in the statistical freeware R that allows you to build user friendly web interfaces, essentially providing often complicated and in-depth data analysis to the public who have no prior knowledge of R (Chang et al., 2018). The app provides an overview of the De Hoop monitoring programme, along with the results of 30 years of fishery-independent data on the observed surf-zone fish and selected photographs, all packaged in a website-type interface that is easy to use, understandable and accessible to all to browse in their own time. The results are not exhaustive, but rather illustrate the basic scientific provisions of fish monitoring programmes: total catch, catch-per-unit-effort, size-structure data and fish movement. Species of interest can be selected in a drop-down menu and data can be disaggregated according to sampling area (Koppie Alleen and Lekkerwater) and year (1985–2018) using

interactive toggle switches and slide bars that are intuitive to users. This provides a custom experience to the user, whereby they are able to select parameters of interest from a prescribed set of options and the results appear instantaneously in an appropriate format. The raw data are not available to the user, nor is the user able to extract any information additional to the graphics and tables on display. The generated website can be housed on any local server and data updates are quick and simple.

Technological advances, such as the development of R SHINY, provide scientists with new and exciting means to share information with a wider audience. Defining our audience is key. As a wider audience will have a broad diversity of interests and ability to engage with statistical data, meaning the material provided will be more generally accessible and less specialised, which would ultimately reduce the app's overall impact. To identify the key target audiences, we must recognise the sole purpose and intention of the app. Firstly, this app intends to provide evidence supporting the continuity of this particular monitoring programme, and secondly, inform stakeholders on the benefits of the MPA. It is therefore envisaged that the primary audience will likely be policy makers, managers and fishers - representing a reasonable diversity of social backgrounds. Hence, packaging the platform in an easy-to-use and understandable format that directly targets these audiences, is challenging. Furthermore, passive approaches of stakeholder engagement are ineffective, and the spontaneous uptake of novel media and knowledge is desired but not anticipated. Consequently, marketing the app to the intended user is vital for its efficacy.

The plausibility of this concept has been demonstrated during the initial development of the De Hoop R SHINY app. Once live, we are positive that this form of communication will have the desired results. It is intended that the app will not remain static but will be continually developed to include data from similar projects such as acoustic telemetry of surf-zone species. Once established, the platform will be a useful tool to channel increasing amounts of information with relatively little effort.

SESSION 10:

Monitoring in estuaries

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SESSION 10 | Monitoring in estuaries

The demise of an iconic species: Does site fidelity and habitat dependence drive the vulnerability of adult dusky kob *Argyrosomus japonicus* in coastal fisheries?

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Background

The dusky kob *Argyrosomus japonicus* is arguably the most iconic recreational fishery species in South Africa. It is also one of the most imperilled due to its slow growth, late maturation and habitat preferences. The dusky kob stock was considered collapsed more than 20 years ago with no reports of recovery. Juveniles recruit into estuaries from 15-100 mm TL and remain in these nursery habitats for several years. During this period fishing mortality can be as high as 50%. Ontogenetic changes in habitat use are poorly understood but use of the marine environment is expected to increase with size. Detailed information on habitat use and movement habits of adults is particularly lacking. Historical movement models, based on seasonal catch data suggest annual migrations of adults from the Western Cape to the Eastern Cape and even up to the Kwa-Zulu Natal region for spawning. However reproductive data has suggested potential for regional stock separation along the coast. Large adults are critical for maintaining populations and crucial for stock recovery, and as such require improved conservation and management strategies that to enable the stock to rebuild.

Methods

By making use of acoustic telemetry, this study aimed to provide insights into the movement behaviour and habitat use patterns of adult dusky kob in the Breede Estuary and surrounding coastal environment, as well as assess connectivity between the nearby De Hoop Marine Protected Area (DHMPA). A total of 71 dusky kob were tagged with long-life (8 year expected battery life) acoustic transmitters between November 2015 and February 2019. Two size classes were tagged in the Breede Estuary; juveniles (66 – 75 cm TL, mean = 69 cm, *n* = 10) and adults (114 – 172 cm TL, mean = 131 cm, *n* = 37). In DHMPA larger juveniles and early adults (81 – 97 cm, mean = 87.5, *n* = 10) and adults (101.2 – 152.0 cm, mean = 115.8 cm, *n* = 14) were also tagged. Passive monitoring was conducted with an array of 15 acoustic receivers within the Breede Estuary and ten receivers in St. Sebastian Bay and the DHMPA. Passive monitoring began in 2015 and is ongoing. Larger movements along the coastline and visits to other estuaries were monitored via the Acoustic Tracking Array Platform's (ATAP) network of acoustic receivers. Information on catches of adult dusky kob from the Breede Estuary and surrounding marine environment was collected through key informants within the local fishing community.

Results

In excess of 2.8 million detections have been recorded on the array of acoustic receivers to date. Results for dusky kob tagged in the Breede Estuary indicate high levels of phylopatry to the estuary over multiple years and limited long-shore movements. All 47 dusky kob tagged in the Breede Estuary have been detected while 16 of the 24 dusky kob tagged in the DHMPA have been recorded to date. Preliminary analysis suggests that adults tagged in the Breede Estuary spend the majority of their time in the marine environment and briefly enter estuaries for periods spanning hours to days. Eastward movements were

limited to approximately 100 km (close to the Gouritz Estuary mouth) despite high levels of receiver coverage by the ATAP. Westward movements were recorded as far as the western boundary of the DHMPA (50 km) however, a lack of receivers beyond this point limits information on the true extent of these movements. Seasonal return rates for adult fish to the Breede Estuary were 81% and 80% in the second and third year after tagging. Confirmed recapture rate of tagged adults was 10.8%. Juveniles from the Breede remained entirely within the estuary, with the exception of one fish which moved to the neighbouring Duiwenhoks Estuary where it was recaptured shortly after it entered. Of these juveniles, 40% have been recaptured and removed by recreational fishers during the study. As data from fish tagged in the DHMPA is yet to mature, information on connectivity between the two sites remains limited, nonetheless 12.5% of fish from the DHMPA have been recorded in the Breede Estuary to date, all of which were adults.

Catch information revealed annual catches of adult dusky kob ranged between approximately 150 and 300 individuals from 2016–2018 in the Breede Estuary and surrounding marine environment (both shore and boat angling). This equated to a total recorded catch weight of over 15 000 kg in three years, with the average fish weighing 23 kg.

Conclusion

Coastal movement of both adult and juvenile dusky kob were found to be very limited, supporting the hypothesis of the existence of spatially distinct populations along the South African coastline. Adult range appears to be in the order of 200 km in this region, while maximum recorded movements of juveniles was less than 30 km. High levels of philopatry and predicable seasonal use of the Breede Estuary and surrounding marine environment by adult dusky kob tagged in this study highlight their vulnerability to capture. This study also demonstrates the extreme vulnerability of juveniles within estuarine environments which results directly from their extreme residency over multiple years. Although data on connectivity between the Breede Estuary and the DHMPA are only preliminary, the DHMPA appears to play an important role in protecting both adults and the marine component of the juvenile dusky kob population in this region. Information on catches revealed that large numbers of adults are removed by the recreational fishing sector annually. Considering the life history parameters, collapsed stock status and restricted movement behaviour, these catch levels are likely to result in rapid declines in the remaining population and require immediate management and conservation actions.

The marine fish assemblage of the East Kleinemonde Estuary over 20 years: declining abundance and nursery function?

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Background

One of the most important functions of estuaries is their contribution to fisheries by providing nursery areas for exploited fish species. Human impacts have, however, depleted species and habitats in estuaries. Temperate estuaries are inherently variable and, as such, the abundance of individual species (even common species) is characterised by large year-to-year variations. For marine opportunists this may be related to both variable recruitment from the marine environment and conditions in the estuary. Inter-annual changes in species richness and the abundance of certain marine species in intermittently open estuaries in South Africa and Australia have been attributed to the timing and duration of estuary mouth closure, and the loss of habitat from estuaries.

Interestingly, in such an unstable environment (in terms of physical conditions and species abundance), decadal studies in both the small intermittently open East Kleinemonde Estuary and the large permanently open Breede Estuary in temperate South Africa, have shown that the species assemblage (in terms of the dominance of species) remains fairly stable from year to year. This is probably because estuaries are dominated by a few persistent and core abundant species. Although common marine opportunist species are still found in high numbers in estuaries, decreasing populations of many of these common species are being documented globally, with fish populations impacted by overfishing, climate change, habitat loss and pollution. Unfortunately, the large year-to-year variability in species abundance makes it extremely difficult to detect directional changes in abundance in estuaries even with a decade of data.

Continuous long-term data is needed to determine whether ecological change is directional, rather than random fluctuations, or part of a cyclical change. Few long-term monitoring programmes have dealt with estuarine ecosystems, particularly microtidal estuaries. In order to address this, marine fishes in the intermittently open East Kleinemonde Estuary were sampled using seine nets over a twenty-year period between 1994 and 2014.

Methods

The marine fishes of the East Kleinemonde Estuary were sampled biannually in summer (December, January or February) and winter (June, July or August) from December 1994 to July 2014 using a large mesh (15 mm bar) seine net (50 m × 2 m). On each sampling occasion all possible littoral habitat types in the lower, middle and upper reaches of the estuary were sampled, with a minimum of two hauls in each reach. Daily estuarine mouth state for the East Kleinemonde has been recorded since 1993. Mouth phases include: open (estuary is connected to the sea), overwash (seawater enters the estuary when large waves wash over the sand berm) and closed. Macrophyte cover was visually assessed at the time of sampling (abundant, sparse or absent).

Results

Analysis of this 20-year dataset reaffirmed the importance of mouth state and habitat availability as drivers of abundance for marine fish in this estuary and other microtidal estuaries. For the first decade of monitoring, annual rainfall varied between a low of 482 mm in 1997 and a maximum of 706 mm in 2004. Rainfall was much more variable in the second decade, with high rainfall recorded in 2005, 2011 and

2012 (1 347 mm in 2012) and below average rainfall in 2008, 2009 and 2010 during a prolonged drought. During the first decade the mouth was predominantly closed (open on average for 10% of the year). Mouth opening was more variable in the second decade, with the estuary mouth either closed for up to 771 days during a prolonged drought from 2008 to 2010 or open much more frequently than previously, with the estuary mouth open for up to 42% of the time in 2012. In the 1990s submerged macrophytes occurred in a continuous band of varying width along both banks above the road bridge. A major flash flood in May 2003 resulted in an almost complete loss of most of these macrophyte beds. Recovery of the aquatic macrophytes was slow, with macrophytes only found in small patches along both banks by the end of 2008. By 2010 the macrophyte beds had expanded but never attained their pre-May 2003 abundance.

The marine species composition in the East Kleinemode Estuary remained fairly similar over the 20-year period, with seven species comprising over 90% of the catch each year. Kendall's coefficient of concordance (W = 0.65) indicated that the rank order of abundance of individual species within the fish assemblage was significantly similar between years (χ^2, r = 780, $p < 0.05$). As in earlier decadal studies of the fish assemblage, inter-annual changes in the abundance of some species could be attributed to habitat availability and mouth state. The overall species abundance follows a cyclical pattern with two to three years of low abundance and two to three years of high abundance. This pattern was evident for the first 15 years of the study, but it was only with 20 years of monitoring that overall declines in species abundance became apparent, with consistently low catches of almost all marine species recorded. A distance-based linear Model (DISTLM) showed that the amount of time the estuary mouth was open (%) explained the greatest proportion (17%) of the significant ($p < 0.01$) variation in the fish assemblage each year. This was followed by macrophyte state (abundant, absent, recovering) (9.3%, $p < 0.05$). Although not significant, mouth opening during peak recruitment opportunities and the average duration of mouth opening events explained 2.2% and 5.0% of the variation, respectively.

Conclusion

The consistently low catches in the last five years of the study may be related to variability in rainfall (and subsequently mouth state), habitat loss and possibly overfishing. When the East Kleinemonde Estuary opens on a very frequent or prolonged basis, this reduces the water area and volume within the estuary thus making it a less favourable nursery habitat for marine fish species. Consequently, the size classes of the marine fish usually captured by the large seine net may, under these circumstances, depart the East Kleinemonde system in search of larger, more suitable estuaries in the region. Determining the exact causes of ecological change is, however, challenging in estuarine systems because human and natural perturbations often interact. Further monitoring is required to determine if this trend has continued.

Can partial estuarine area protection reduce the vulnerability to capture of spotted grunter *Pomadasys commersonnii*?

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Background

Estuaries are highly productive ecosystems that provide an important nursery function to many marine-spawning fish species. Despite their ecological importance, these environments are amongst the most modified, being particularly threatened by anthropogenic activities resulting in habitat alteration or destruction. Overfishing also poses a major threat to estuary-associated fishes in South Africa. The formulation of effective management decisions for fishery species requires an understanding of their area use patterns, distribution and movement behaviour. Research in the marine realm has shown that Marine Protected Areas (MPAs) can be highly beneficial for the rehabilitation and management of fish stocks. Previous studies have indicated numerous benefits of MPAs, including that populations protected in MPAs can restock adjacent exploited areas through the emigration of post-larval fish – a process known as spill over. However, MPAs seldom provide protection for estuary-dependent fishery species, such as dusky kob *Argyrosomus japonicus*, leervis *Lichia amia* and spotted grunter *Pomadasys commersonnii*. Estuarine Protected Areas (EPAs) could therefore play a significant role in the protection of these fishery species. Despite a plethora of work conducted on MPAs and their benefits, very few studies have evaluated the benefits and efficacy of Estuarine Protected Areas (EPAs).

Spotted grunter is a popular angling species in South Africa, and given their high dependency on estuaries, along with extensive fishing pressure within these habitats, this species is now considered to be overexploited. Previous studies have revealed the resident nature of this spotted grunter and they are thus a suitable species with which to evaluate the efficacy of an EPA. Therefore, the aim of this study was to evaluate the area use patterns and movement behaviour of spotted grunter in the Goukou Estuary, Western Cape, and relate these findings to the efficacy of the no-take zone of the EPA present in the estuary. Specific objectives included (i) quantifying the amount of time tagged individuals spent at/near each of the receivers along the estuary to describe overall area use patterns, and (ii) quantifying the amount of time tagged individuals spent in the no-take EPA compared to the controlled angling zone.

Methods

The Goukou Estuary (15 km long, ~150 ha open water area) is part of the 64 km-long Goukou River system which enters the ocean at Stilbaai, Western Cape at 34.378611 °S and 21.423333 °E. There is an existing partial no-take zone (starting from 4 km upstream of the mouth, including the remaining 11 km of estuary, ~90 ha) which was gazetted as part of the Stilbaai Marine Protected Area on 14th October 2005. In this study, 14 spotted grunter ranging in length from 330 – 650 mm fork length (FL) (average ±

SD: 437 ± 84 mm FL) were tagged with acoustic transmitters and monitored using passive acoustic telemetry in the estuary. Eleven acoustic receivers, spaced approximately 1.5 km apart, were deployed in the Goukou Estuary in February 2013. Receivers were placed in non-overlapping ranges such that when tagged fish passed through the array, the logged date and time stamps of detections could be used to determine directionality of movements along the estuary. The proportion of time spent in the vicinity of each receiver was quantified and equally weighted to ensure a standardized contribution by each fish. A fish was considered to be in the vicinity of a particular receiver station when two (or more) consecutive detections were recorded within 60 min. The total time spent at each receiver was calculated as (a) the sum of time between consecutive detections at a single receiver, and (b) half the time spent between consecutive detections at neighbouring receivers. A Wilcoxon-Mann-Whitney test was used to compare the time spent in the open access area versus the no-take zone.

Results

The tagged fish displayed extreme residency with most (71%) fish spending the highest proportion of time closest to their respective release sites. The total number of detections per individual ranged from 83 to 348 632 and their respective monitoring periods ranged from 8 to 382 days. Of the total fish tagged in the EPA (n = 6), 83% spent more time in the no-take zone compared to the adjacent open access area, while 75% of those fish tagged outside the EPA (n = 8) spent the most time in the controlled angling zone. The average time spent in the no-take EPA by all tagged individuals was 60 ± 16.43%; however, there was no significant difference in the time spent in the no-take EPA compared to the open access area (U = 71.5, p = 0.23). Connectivity between estuaries was also observed, with one individual travelling approximately 190 km eastwards in 4 months, being recaptured in the Knysna Estuary. Two individuals were recaptured (and reported) by anglers, one in the Goukou Estuary and the above-mentioned individual in the Knysna Estuary. However, transmissions from four other tags also ceased prior to the battery expiry date while the fish were in the estuary's no-take zone, suggesting that these individuals were also recaptured and killed by anglers fishing illegally in the no-take zone. Consequently, it is possible that six (43%) of the 14 fish tagged were captured in the fishery.

Conclusion

The results of this study further confirm the high site- and estuarine-fidelity by spotted grunter and the potential value of estuarine no-take area closures as a management option. The high site fidelity suggests that the closure of even a section of an estuary has the potential to reduce the vulnerability to capture of a portion of the locally resident population. The vulnerability of this species to fishing pressure within estuaries was highlighted by the loss of 43% of the tagged fish. While this study revealed the potential benefit of no-take EPAs, the possible capture of several tagged fish in the no-take zone suggests that compliance is low and that law enforcement is inadequate at the Goukou Estuary.

Novel methods to distinguish among stocks of spotted grunter *Pomadasys commersonnii*: an overexploited estuarine small-scale fisheries target

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Background

Estuaries are productive ecosystems which provide food to many organisms as well as to local human communities. In South Africa, estuaries are important to small-scale fishers whose livelihoods depend on these productive ecosystems. However, many of the estuarine-dependent fish species on which they depend are overexploited, such as *Pomadasys commersonnii*, the spotted grunter. Despite the importance of estuarine-dependent fish species, not much is known about their stock status, which negatively affects effective management and utilization of these species. It is hypothesised that there are different stocks of spotted grunter among different South African estuaries, and thus it is crucial to determine connectivity among estuaries and to identify sub-populations with significantly different traits. Effective management requires stock delineation with possibly spatially explicit management strategies. To determine if spotted grunter have multiple stocks, a holistic approach was used to identify morphological and ecological differences between individuals from different estuaries. The aim of this study was to determine whether the Breede River population differs from the Kei River population by comparing otolith shape morphology and vocal 'grunt' dialects between spotted grunter from each estuarine system.

Methods

Otoliths were removed from individuals captured in the Breede River estuary and the Kei mouth estuary. To capture images of the otoliths, each otolith was raised, with the use of a small pipe, on a black background and captured using a Leica camera. The otoliths (left hand side) were positioned with the rostrum to the left and the sulcus facing upward. The images were captured in full colour and saved as a jpeg file. An R-package software, known as ShapeR, was used to detect the outlines and shape coefficients of the otoliths. ShapeR uses an outline analysis approach which can extract and generate shape data. By quantifying the boundary shapes of the otoliths, we are able to determine the patterns associated within or among groups in terms of stocks. ShapeR has built in functions which are able to transform the outlines using either normalized elliptic Fourier analysis or a discrete wavelet analysis. These analyses will generate coefficients for the otolith outlines. A canonical analysis of principal coordinates (CAP) was conducted to analyse the variation in shape among the populations, this result was displayed on a cluster plot. An ANOVA test was also performed to determine the partition of variation among groups. ShapeR is also able to plot the mean shape of otoliths from each area to compare the outlines visually.

For the acoustic method of stock discrimination, a 'proof of concept' study was conducted using recordings downloaded from Fishbase. These short recordings (<10 seconds) were used to determine if soundings from different fish families, genera and species could be differentiated. Acoustic parameters (amplitude, frequency and time) were measured using Raven Pro and then run through a principal component analysis (PCA) to determine whether individual species could be identified via call types. To determine if different families could be distinguished, the vocal sounds of a dusky kob *Argyrosomus*

japonicus were compared to those of multiple Haemulidae species. Next, multiple species within the Haemulidae family were compared and lastly species from within the *Haemulon* genus were compared. Finally, recordings of spotted grunter captured in the Breede River estuary and Kei Mouth estuary were taken using an HTI 96-min hydrophone and a Tascam recorder. These recordings were analysed using RavenPro and parameters were displayed in a PCA.

Results

The ANOVA test suggested that there are significant differences ($p < 0.05$) in otolith shape morphology among spotted grunter populations, this was further substantiated by the CAP analysis which also suggested a significant difference in otolith shape parameters among spotted grunter populations.

For the proof of concept, there were significant differences ($p < 0.05$) in the acoustic parameters of the dusky kob compared to the Haemulidae species, between different Haemulidae genera and lastly between *Haemulon* species. Frequency parameters (peak frequency, delta frequency and centre frequency) had the highest variable importance contributing to the spread of each species. The recordings taken from the Breede and Kei spotted grunter populations appear to have different acoustic parameters and cluster out in a PCA. However, the size range captured for each population is not comparable and further recordings need to be taken.

Conclusion

The significant differences in otolith shape morphology are most likely influenced by the variability in environmental conditions among the spotted grunter populations. This result suggests that there are multiple stocks of spotted grunter within South Africa. Given the significant differences in the morphology of their hearing apparatus (otoliths) we have further reason to believe that there may be differences in their acoustic repertoires.

The differentiation of vocalisations among *Haemulon* species was successful despite limited data and it is hypothesized that extended recordings should provide enough information to differentiate subpopulations within a species. Recordings from the Breede River and Kei Mouth estuaries indicate that there could, in fact, be differences in the acoustic outputs of these two populations. However, studies have shown that acoustic parameters differ significantly between different size ranges and so it is important for further recordings to take place to determine whether differences observed are between populations and not different size ranges.

Acoustic parameters may be a useful method of stock discrimination for vocal species such as the spotted grunter. This project adopts acoustics in a novel way, providing a proof of concept for the use of fish vocalisation and acoustics for stock discrimination. This study will hopefully expand the implementation of fish acoustics in South African marine research with the aim to eventually develop a measure of fish abundance using acoustics to provide alternative density estimates to catch-per-unit-effort (CPUE).

Settlement habitat and use of an estuary-ocean ecotone by linefish species in Algoa Bay

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Background
Shallow coastal marine environments, including estuaries and nearshore areas, are well known as nursery habitats for many marine fishes including commercially and recreationally important fish species. In South Africa, the stocks of numerous linefish species are considered depleted or collapsed due to ineffective management regulations and reduced habitat availability during their juvenile phase. Therefore, understanding how settlement and associated processes occur at different time and spatial scales is crucial for the management of coastal fisheries, both from a conservation and from a socio-economical point of view. Few studies have concurrently compared the composition of fish assemblages in estuaries with those in nearby protected marine waters in order to determine the relative roles of these two habitat types as nursery areas for settlement stage fishery species found in the same region. This approach has only been undertaken for larval fish assemblages in South Africa.

Methods
In this study, fish faunas associated with soft substrata in two permanently open estuaries and the nearby, sheltered nearshore waters (5–10 m deep) in a large coastal embayment, Algoa Bay, South Africa, were studied between February 2018 and April 2019. A 1.5 m, conical shoeless beam trawl net (1 m × 4 m × 14 mm bar mesh body and 7 mm bar mesh bag) was used for sampling. Physico-chemical characteristics including water temperature (ºC), salinity, turbidity (NTU), pH and dissolved oxygen (mg.l^{-1}) were recorded using a YSI (6290) multi-parameter probe at each site (Algoa Bay, Sundays and Swartkops) during each sampling event. At each site, sediments were also collected seasonally using a cone dredge for organic content and sediment particle size analysis.

Results
A total of 1 843 individuals from 16 species were collected in the nearshore waters of Algoa Bay and the adjacent estuaries. Seven species were caught only at sea, five were caught in the estuaries and four were recorded in both habitats. These comprised of larvae, early juveniles, juveniles, late juveniles and adults. Settlement stages of the important marine fishery species including olive grunter *Pomadasys olivaceus*, silver kob *Argyrosomus inodorus* and redspotted tonguesole *Cynoglossus zanzibarensis* were only captured in the nearshore habitats of the bay. In contrast, dusky kob *Argyrosomus japonicus* and spotted grunter *Pomadasys commersonnii* settled only in the estuarine environment. There was a slight overlap in the distribution of settlement stages of two estuarine-dependent sparids, Cape stumpnose *Rhabdosargus holubi* and white steenbras *Lithognathus lithognathus* between the estuaries and sites located in close proximity to the estuary mouths. Fish assemblages from the estuaries were associated with high organic content and clay and the marine environment fish communities were associated with high salinity, silt and low organic content.

Conclusion

Our results show that although there is some degree of overlap, fish assemblages from the marine environment differs markedly from that of the estuarine environment. This was attributed to the fact that most species were only caught in the ocean. The identification of transient settlement habitats is critical for fisheries species, as many species when recruiting into estuaries, settle in the first available habitat before subsequently moving to their preferred habitat. Our results confirmed the importance of both estuarine and non-estuarine soft substrata habitats in Algoa Bay as nursery areas for fishery species. Therefore, these areas should be given high conservation importance as they maintain connectivity between inshore and offshore ecosystems.

Shallow-water seascape connectivity: Micro-habitat utilization by an important linefish species in the estuary-ocean ecotone

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Background

Currently there is very little information available on the connectivity between habitats and the importance of multiple habitats or habitat mosaics as nursery areas in both estuarine and coastal environments in what is referred to as the seascape nursery. A common feature of many fish populations is the simultaneous occurrence of individuals in multiple habitats, during a given life stage, and it is suggested that the divergence of juveniles in different habitats could represent population contingents. Rather than looking at coastal nurseries as isolated homogenous habitats for specific species, we must evaluate the interconnectedness and complexity of these shallow-water seascape habitats as an integrally-linked coastal area important for species assemblages. Although mobile species, such as fish, move between connected core areas of structurally complex habitats through tidal movements, shelter seeking and foraging, there has been very little work done on finer scale movements of fish species between habitat patches. In order to identify important nursery seascapes, techniques such as otolith microchemistry can be used to first identify the importance of estuary versus coastal habitats. Smaller-scale habitat usage within the broader seascape can then be identified using techniques such as chemical markers and tagging. The aim of this project is to quantify the ontogenetic shift in habitat use and degree of connectivity of Cape stumpnose *Rhabdosargus holubi* across the estuary-ocean ecotone and between connected vegetated habitats. Much is known about the biology and ecology of this species, but no empirical evidence exists quantifying the ontogenetic shift in habitat use from the estuary to ocean seascape, and the movement between structural complex habitats such as seagrass beds and interspersed sand/rock-macroalgae reef. The overall objective of this study is to adopt a multi-method approach and use a combination of acoustic telemetry, visible implant fluorescent elastomer (VIFE) tagging combined with stereo baited remote underwater video (sBRUV) sampling, and otolith microchemistry to quantify the inter-connectivity and/or explicit usage of these habitats. The three main objectives are as follows: 1) to assess the 'real-time' and continuous movement of *R. holubi* in the estuary-ocean ecotone using acoustic telemetry, 2) to assess the residency of *R. holubi* to seagrass beds and macroalgal reefs using VIFE tagging, and 3) to assess the life history of *R. holubi* using otolith microchemistry.

Methods

Forty individuals will be surgically equipped with VEMCO V7 acoustic transmitters to assess the movement of *R. holubi* using acoustic telemetry. VEMCO VR2W acoustic receivers will be deployed in the selected vegetated habitats in the estuarine and adjacent coastal zone. This project will make use of existing acoustic receivers of the South African Institute for Aquatic Biodiversity's Acoustic Tracking Array Platform. Two hundred and fifty (250) individuals will receive silicon-based VIFE tags to assess habitat residency of *R. holubi* using sBRUV sampling. Firstly, 50 individuals will be used for the pilot study to test for the best colour combinations and tag placements to be viewed using sBRUV sampling. Two hundred

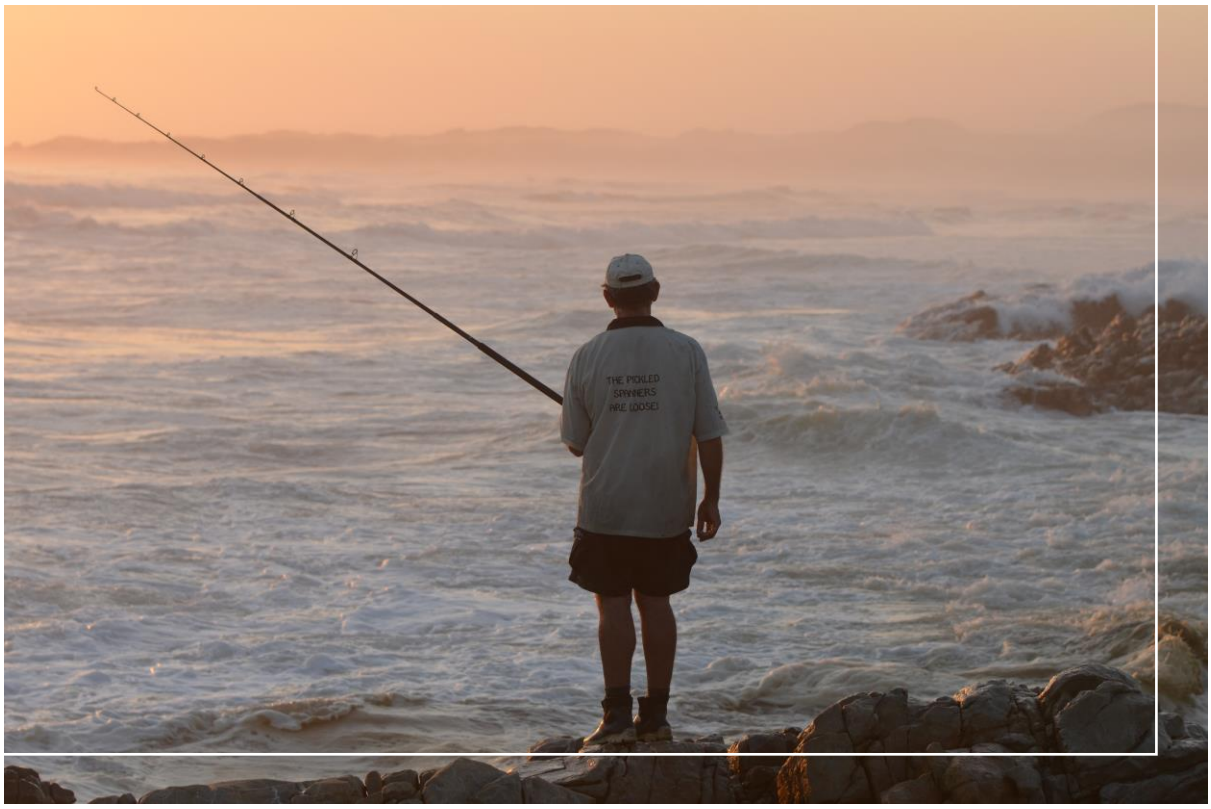
(200) individuals will then be tagged using the optimal colour and placement combinations in the selected estuarine vegetated habitats and sand/rock macroalgae reefs in the adjacent ocean seascape. One hundred (100) individuals will be captured and euthanized before being transported to the lab for otolith extraction These otoliths will be used for otolith microchemistry analyses to assess the ontogenetic shifts of *R. holubi* between marine and estuarine environments. Year 1 (months 7–12) will include collecting fish for otolith microchemistry and the analysis and interpretation of results. Year 2 (months 12–24) will include the deployment of acoustic receivers and range testing in the selected habitats. Additionally, fish will be acoustically and VIFE-tagged for monitoring in the estuary and adjacent coastal zone. Year 3 (months 24–36) will involve frequent downloading of acoustic receivers, data analysis and write-up and preparation of publications. During the data analysis phase, acoustic telemetry data will be analysed in R, in conjunction with habitat data and video footage collected in supporting projects to fully understand connectivity patterns between structurally complex habitats and the nursery seascape concept of this important estuarine-associated species.

Conclusion

As the first national marine spatial plan in South Africa is currently being developed for Algoa Bay, determining the nursery function of coastal and estuarine habitats for fishes in Algoa Bay is particularly relevant. Part of Algoa Bay has also been designated as a marine protected area (MPA), and thus important resource management questions also exist. With the increasing demand on marine resources in Algoa Bay, there is a need to determine the ecological importance of the coastal region so that the correct conservation and management measures can be highlighted. Identifying highly productive areas (especially nursery areas) affords managers the evidence-based resources needed to target and protect or restore these areas. A better understanding of the nursery value of different types of habitats is also critical to understand what effect climate change and other anthropogenic drivers may have on the nursery provision of these habitats. The southern African coastline provides few alternative marine environment nursery areas which implies that deterioration of these valuable estuarine and coastal habitats would have a remarkable effect on the local fish and fisheries. In this light, it is critical to identify and value nursery habitats if they are to be beneficially managed and/or conserved.

SESSION 11

Catch-and-release



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SESSION 11 | Catch-and-release

Evaluating the effects of catch-and-release angling on the health and survival of dusky kob (*Argyrosomus japonicus*) in South African estuaries

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Background
Catch-and-release (C&R) angling is becoming increasingly popular as a strategy to manage recreational fish stocks and among conservation-conscious recreational anglers. However, many studies have shown mortality in released fish, these studies also show that the effects of C&R are species-specific. Little research has been done on the effects of C&R on South African line-fish species. Therefore, we examined the effects of C&R angling on dusky kob *Argyrosomus japonicus*, which dominate the catch numerically and provides a vital source of food for many subsistence fishers. Initially, angler observations were conducted, whereby real-world average air exposure and fight times were obtained.

Methods
To determine the time course of the stress response, *A. japonicus* were captured from the Kowie River estuary and placed into tanks (n = 3 fish per tank) for a minimum of two weeks in order to acclimatize. Fish were then exposed to a simulated C&R event, involving chasing the fish for 45 s and exposing them to air for 75 s (based on the average air exposure from angler observations). Blood glucose, lactate and cortisol concentrations were taken at different time treatments; 0, 30, 60, 90 and 150 min (n = 9 fish per treatment) to determine when the peak disturbance occurred. In our field study, *A. japonicus* were experimentally angled from the Great Fish River estuary using traditional estuarine rods and tackle. Fight times were recorded, and captured fish were measured and then exposed to one of three air exposure treatments, 10 s, 75 s or 240 s (based on the minimum, average, and maximum air exposures from angler observations). Blood glucose and lactate concentrations were examined in the field using point-of-contact devices and rapid assessment mortality predictor (RAMP) tests were performed on all fish to determine the level of reflex impairment. Short-term survival was monitored by placing fish into survival tanks for a minimum of 12 hours.

Results
For the time-course experiment, it was found that time had a significant effect on the concentration of blood glucose ($p < 0.05$) and lactate ($p < 0.05$) and that they both peaked between 30 and 40 minutes after the stressor. Plasma cortisol did not peak, and it was found that time after the stressor did not have a significant effect on the concentration of plasma cortisol ($p > 0.05$). This is unusual as it is well known that plasma cortisol concentrations change with time. This result is likely due to the unusually high amount of individual variation we observed during our study. Thus, it is recommended to have a larger sample size when examining plasma cortisol for this species. By the 150-minute time treatment, blood lactate and glucose concentrations had decreased almost back to the same concentrations as were observed in the 0-minute time treatment, indicating recovery from the stress event. In the experimental angling study fish in the 240 s (5.46 ± 1.58 mmol.ml^{-1}) air exposure treatment had significantly higher blood glucose concentrations than those in the 10 s (4.02 ± 0.97 mmol.ml^{-1}; $F_{(2,22)}$ = 4.029, p = 0.004) and 75 s (4.30 ± 1.20 mmol.ml^{-1}; $F_{(2,22)}$ = 4.3, p = 0.016) air exposure treatment. Fish in the 240 s air exposure treatment also had lactate levels (8.25 ± 4.60 mmol.ml^{-1}) that were significantly higher than those in the 10 s (4.61 ± 2.91 mmol.ml^{-1}; $F_{(2,22)}$ = 4.61, p = 0.018) air exposure treatment. However, it was found that fish in the

75 s (7.68 ± 4.66 mmol.ml^{-1}) air exposure treatment had blood lactate levels that were not significantly different to either fish in the 240 s ($F_{(2,22)}$ = 8.25, p = 0.89) or 10 s ($F_{(2,22)}$ = 4.61, p = 0.054) air exposure treatments. Reflex impairment was observed for 41.6% (n = 10) of the individuals in the 10 s air exposure treatment, 52.3% (n = 11) in the 75 s and 69.5% (n = 16) in the 240 s treatments. Fish in the 240 s air exposure treatment were significantly more impaired than fish in the 10 s air exposure treatment (p = 0.004). However, there was no significant difference in reflex impairment between 240 s and 75 s (p = 0.07) and 10 s and 75 s (p = 0.14) air exposure treatments. We observed a 7.35% post-release mortality rate, mortality was highest in the 75 s and 240 s air exposure treatments (n = 2 each). Of the fish that died during the course of the experiment, 40% died the day after capture, indicating the high percentage of hidden mortality caused by C&R.

Conclusion

It appears that the best time at which to take blood glucose and lactate samples from *A. japonicus* is 30 to 40 minutes after the stressor as this will give more accurate and reliable results on the physiological stress response of this species. It also appears that *A. japonicus* are able to recover relatively quickly from a C&R event. Our results indicate that extended air exposure results in a greater physiological stress response, reflex impairment and short-term mortality for *A. japonicus.* However, it appears that 75 s is a threshold of air exposure for this species. Although post-release mortality for *A. japonicus* was relatively low, we were not able to take post-release predation into account, thus our mortality rates are likely underestimated. The results of this study will have implications for the management of *A. japonicus* as well as providing best practice handling guidelines for recreational anglers. Hooking injury is also a problem for this species thus the use of barbless circle hooks is advocated as these have been found to reduce the amount of severe hooking injury. Reducing the stress experience by *A. japonicus* during C&R is also strongly recommended, this can be done by minimizing fight times and air exposure times. The use of a bucket filled with water during un-hooking will likely drastically reduce air exposure time. Allowing the fish to recover from the physiological stress response in a bucket filled with water is also recommended as this could reduce the amount of post-release predation, as it has been found that stressed and injured fish attract predators. Ultimately, we hope that the results of this study will lead to better management and protection of this important species.

Does exposing a fish to sand during a catch-and-release event negatively affect its health and survival?

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Background
The development of best practice guidelines to improve recreational fishers handling during catch-and-release (C&R) events are critical to improve the conservation and management of recreational fish stocks worldwide. Recently there has been an increased drive to practice C&R by fishers. Releasing fish does not, however, guarantee their survival. This has initiated the growth of research into C&R guidelines, however, there are still knowledge gaps, such as the effects of sand exposure on fish mucous membranes. The aim of the study was therefore to determine if exposing a fish to sand, during a C&R event, negatively affects the health and survival of fish using juvenile Cape stumpnose *Rhabdosargus holubi* as a test case.

Methods
Fish were subjected to a simulated fight by chasing them for 15 seconds, and then exposing them to air for 45 seconds during which they were either held with wet hands (WH), dry hands (DH), held with wet hands and placed in either wet sterilized sand (WS), dry sterilized sand (DS), wet unsterilized sand (WU) or dry unsterilized sand (DU). When fish were reintroduced to the recirculating system, they were videoed for 10 minutes and then for 10 minutes daily thereafter. Fish were maintained in a recirculating system for two weeks after which they were euthanised and their health assessed by examining the condition of the mucous layer (bacterial counts, abrasion counts and percentage of abrasion/infection area) and conducting an internal biological assessment. Fish were swabbed along their lateral lines; the swab was then streaked on agar plates and the bacteria was allowed to grow for three days. Fish were photographed to assess abrasion and effects of possible infection. Finally, fish were dissected, and livers were removed and weighed, and the hepatosomatic index was calculated from this.

Results
Most fish appeared to be healthy after the two-week treatment period. Upon reintroduction to the tank, the fish performed a shaking and squirming motion. All fish had removed any discernible sand on them within a 24-hour period. No significant differences were observed between the six treatments and fish size, water quality parameters, number of abrasions, percentage of abrasion area, liver colour rank, the hepatosomatic index and total bacterial colonies. The eight mortalities observed prevented any significant assumptions being made on post-release survival.

Conclusion
The findings suggest that exposure to sand did not appear to have negatively affected the health and survival of the fish. However, future research should place emphasis on determining the optimal sampling duration of such experiments as in this case, the experiment may have run too long allowing fish to recover from abrasive injuries, or too short for bacterial or liver results to be significant. Few serious injuries were observed on the fish and the abrasions did not appear to be discernible or detrimental to the fish. The mortalities were deemed to be due to a combination of factors and not the sand exposure

specifically. One of the major confounding factors of this experiment was the small size class used. In future looking into the effects of fish size and sand exposure may provide more robust results. *Rhabdosargus holubi* appear to be a very resilient species when it comes to sand exposure, this may be due to the habitat in which they live. The microbiological aspect of this experiment can be considered a preliminary study as looking at the effects of bacteria on fish in a C&R event is new and needs to be further explored. Although not significant, there was a higher number and higher variability of bacterial colonies observed in the unsterilized sand treatments. This was attributed to the sand abrasions and subsequent exposure to foreign bacteria in these treatments. The large number of bacteria observed was attributed to the variability of bacteria observed in beach sand. When looking further into the effects of C&R, adding an aspect of post-release predation, as well as testing responses of different species could aid in improving understanding of post-release survival. Looking into the effects of polluted and unpolluted beaches may also provide interesting results.

Poster contributions

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Poster contributions

The National Marine Linefish System (NMLS): Thirty-five years of commercial catch and effort data

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The National Marine Linefish System (NMLS) is a database housed with the Inshore Research Section of the Fisheries Research and Development Branch of the Department of Environment, Forestry and Fisheries. The Linefish Research section was established in 1983 and the NMLS was developed as a joint venture between the then Sea Fisheries Research Institute and the Oceanographic Research Institute between 1983 and 1985 and is still operational today. Although the linefishery has existed for over a century, cohesive national management of this sector was only established in 1985 and catch returns were made mandatory for all commercial linefishers.

As per the current Linefish Total Allowable Effort (TAE), 423 vessels are allocated, of which 324 are active. Commercial catch returns are submitted by Rights Holders operating in the Traditional Linefish sector on a monthly basis as required by their permit conditions. These catch returns can be separated into active (with fishing activity) and non-active (no fishing activity i.e. a zero return) as Rights Holders are obligated to submit data once their permit is activated, regardless of catch. Commercial linefishers have the option of submitting these catch returns to the department either via customer services, compliance officers and/or directly to the Linefish Research section. Linefish staff processes these data, capturing it onto the NMLS. These commercial catch returns record the catch (in kilograms) per species per day for each fishing trip the Right Holder undertakes, which is georeferenced by a shore location and distance offshore. This catch and effort information represents the largest and most important dataset within the NMLS.

The NMLS consists of two components including the Linefish data program and the Linefish reports program. The Linefish data program is used for capturing all facets of data and the Linefish reports program is used to extract the information that has been entered onto the system. The NMLS contains over 4 million records of commercial catch and effort data and 1 million records of species-specific biological and/or size composition data. The data are categorised into seven different data types such as; Commercial catch returns, Harbour returns, Dealer returns, Recreational angling, Observer data, Length frequency data and Biological data. Most of the data were collected from 1985 onwards, however, some size frequency and dealer data go back to the 1950s.

A total of 212 species have been recorded in the NMLS. Since 2007, all NMLS data are exported to Microsoft Access format for scientific analysis and reporting as well as to allow easier analysis by the user. The NMLS is well utilised for scientific research and is the main source of information when species-specific studies are undertaken. It also constitutes the fundamental source of data for stock assessments. From 2007 to present, a total of 316 reports have been extracted, to fulfil scientific, resource management, student and compliance data requests.

The period 2014 – 2016 reflected a decrease in the amount of monthly returns received primarily as a result of a lack of compliance by Right Holders due to disenchantment and uncertainty stemming from the Fisheries Rights Allocation Process (FRAP) in 2013/2014. The finalization of the FRAP 2013/2014 appeals process, in conjunction with the introduction of catch return verification letters as a requirement for renewal of permits, resulted in increased submissions of catch returns to the department for 2017 and 2018.

The NMLS database allows the user the flexibility to analyse the performance of both the right holder and the catch trends by species. This flexibility makes the NMLS a useful tool for compliance and for determining the performance of the fishery. As such, the NMLS database remains a fundamental source of information when making management decisions for the Linefish sector. This report aims to provide a general overview of the NMLS database by examining input (catch and effort submissions) and output (data extractions to inform research, management and compliance) trends that the NMLS has been subject to over the past 35 years of data collection.

The National Marine Linefish System (NMLS): Thirty-five years of commercial catch return data

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INTRODUCTION

The National Marine Linefish System (NMLS) is a database housed and maintained by the Inshore Research Section of the Department of Agriculture, Forestry and Fisheries (DAFF). The NMLS was developed by the Sea Fisheries Research Institute and the Oceanographic Research Institute between 1983 and 1985 and is operational to this day. Commercial catch returns are submitted by Rights Holders operating in the Traditional Linefish sector on a monthly basis as required by the permit conditions. These commercial catch returns record the catch (as kilograms) per species per day for each fishing trip the Rights Holder undertakes, which is geo-referenced by a shore location and distance offshore. The NMLS contains over 4 million records of commercial catch and effort data and 1 million records of species-specific biological and/or size composition data. A total of 212 fish species have been recorded in the NMLS. The NMLS is well utilised for scientific research. It is the primary source of information for assessing the status of Linefish stocks and provides valuable information for species-specific biological and ecological studies.

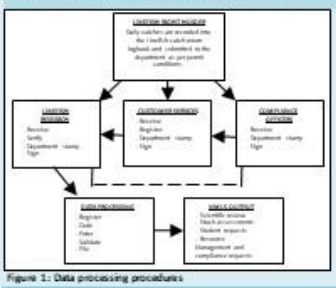


Figure 1: Data processing procedures

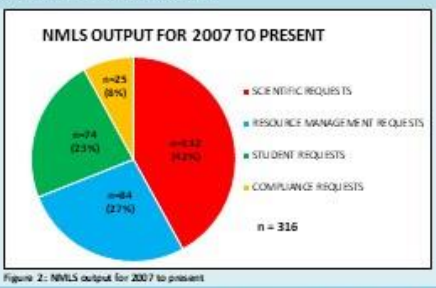
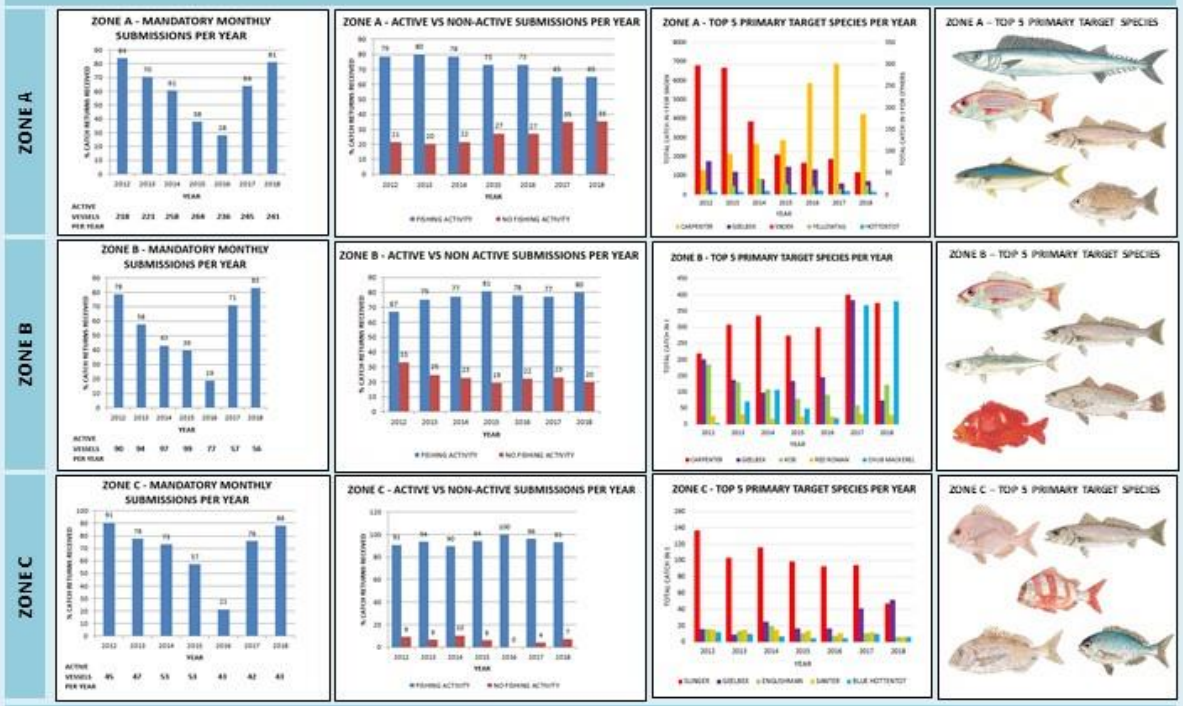


Figure 2: NMLS output for 2007 to present

Figure 3: Linefish Management Zones

CATCH RETURN DATA FOR EACH MANAGEMENT ZONE FOR 2012 TO 2018



CONCLUSION

Catch returns can be separated into active (with fishing activity) and non-active (no fishing activity i.e. a zero return) as Rights Holders are obligated to submit data once their permit is activated, regardless of catch. The poor monthly catch return submissions for the period 2014 - 2016 is a result of a lack of compliance by Right Holders due to uncertainty in the Fisheries Rights Allocation Process (FRAP) in 2013/2014 which alienated fishers. The finalization of the FRAP 2013/2014 appeals process, in conjunction with the introduction of catch return verification letters as a requirement for renewal of permits, resulted in increased submissions of catch returns to the department for 2017 and 2018. The NMLS database allows the user the flexibility to manipulate data in various manners. This flexibility makes the NMLS a useful tool for compliance and for determining the performance of the fishery. As such, the NMLS database remains a fundamental source of information when making management decisions for the Linefish sector.

SAIAB – A living example of responsible research and innovation (#Living RRI)

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Background

The South African Institute for Aquatic Biodiversity (SAIAB) is a Research Facility of the National Research Foundation (NRF). From 2017–2019, SAIAB was an Embedded Nucleus on the NUCLEUS project (http://www.nucleus-project.eu/) through the consortium South African Agency for Science and Technology Advancement (SAASTA). Originally presented at the Annual NUCLEUS Conference in Malta in October 2018, this infographic poster aimed to illustrate how SAIAB was a Living example of Responsible Research and Innovation (#LivingRRI), helping grow and transform the research agenda in aquatic biodiversity in southern Africa.

Methods

Using SAIAB's geographical position at the southern tip of the African continent as its focal point, an infographic representing the research platforms SAIAB provides in inland fisheries and freshwater ecology, and estuarine, coastal and marine biodiversity research in southern Africa was compiled.

Results

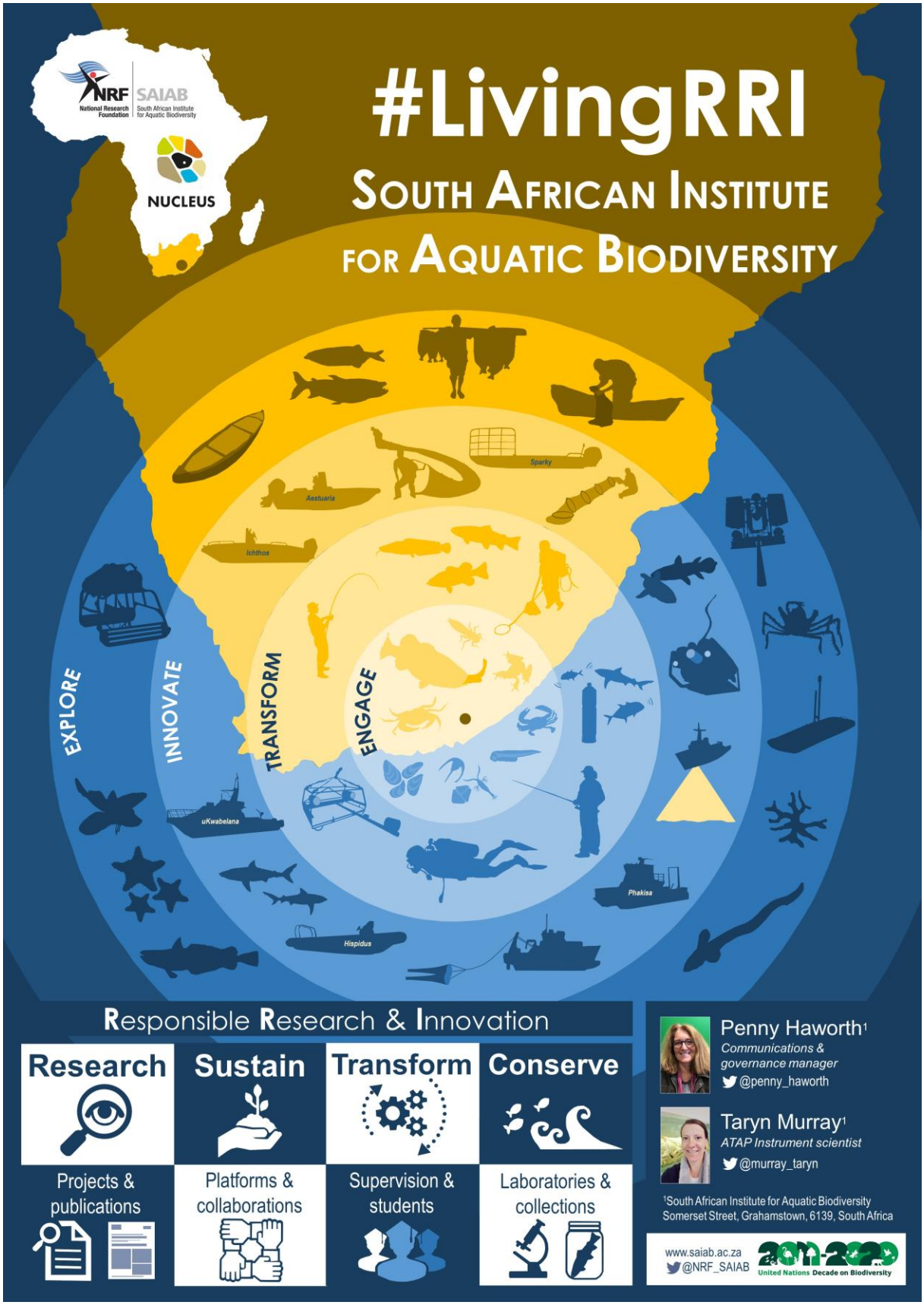
The infographic revealed the research that SAIAB undertakes to address key aquatic and water management issues in the country and regionally, and to meet key objectives associated with international (e.g. Sustainable Development Goals – SDGs) and national research (e.g. Marine and Antarctic Research Strategy – MARS) priorities in the aquatic domain.

SAIAB aligns itself to demand-driven, collaborative research through three core research areas: (i) taxonomy and BioDiscovery, (ii) ecology and (iii) global change. Several research platforms which are extensively used throughout the National System of Innovation support these research areas, with the platforms now playing a highly significant role in marine research infrastructure provision in southern Africa. These platforms include: Bioinformatics, Ecophysiology, Genomics, Biodiversity Information, coastal research craft, the Acoustic Tracking Array Platform (ATAP), the Marine Remote Imagery Platform (mar-RIP), Geophysics and the Collections facility. Additionally, research has a strong alignment with Higher Education, contributing to education and training of young emerging and future scientists.

SAIAB's platform provision is integrated and complements two South African Research Infrastructure Roadmap (SARIR) platforms: (i) the Department of Science and Technology (DST) Shallow Marine and Coastal Research Infrastructure Platform (SMCRI), which comprises an array of instruments (coastal craft, ATAP, mar-RIP) and physical research platforms around the coast of South Africa, and (ii) the National Science Collection Facility (NSCF) which aims to secure natural science collections in South Africa and increase accessibility to and use of collections for research.

Conclusion

Founded on a legacy of marine research dating back to the discovery of the enigmatic coelacanth in 1938, SAIAB serves as a hub for aquatic biodiversity research, exploration, data collection, specimen curation and preservation, education and learning. The depth and range of SAIAB's research platforms provided to the Aquatic NSI is not matched by any other research institution in South Africa, putting SAIAB, and its associates, in an excellent position to conduct demand-driven collaborative research supporting the National Development Plan, MARS, Phakisa Programme and the SDGs.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United Nations Decade on Biodiversity

Joining the dots: how absence data can influence the interpretation of movement patterns

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Background

Monitoring has been recognised to be important in the field of research mainly because it allows many studies to be undertaken and disturbances in ecosystem can be evaluated thus providing an improved understanding of complicated ecological systems. The Acoustic Tracking Array Platform (ATAP) is a long-term monitoring programme that utilises passive acoustic telemetry to collect data on the movements and migrations of tagged aquatic animals around the South African coastline. Since its inception in 2011, the platform has grown significantly with more than 100 receivers currently deployed in the nation-wide array. In addition to ATAP receivers, different researchers maintain their own receivers to address the needs of their localised research projects. The data from these receivers is also shared with the greater biotelemetry community via the ATAP database, managed by the South African Institute for Aquatic Biodiversity (SAIAB). The strength of the platform lies in its ability to provide long-term, continuous movement data collected over a large spatial scale (approximately 2 200 km of coastline); however, unpredictable sea conditions, flooding events in estuaries and other unforeseen events can lead to the displacement or loss of receivers. This creates “listening gaps” within long-term datasets, which could influence the interpretation of movement patterns. This study aimed to reveal (i) how the listening power of the ATAP has been influenced by lost or displaced receivers over the past 8 years, and (ii) how missing data can influence the interpretation and drawing inferences about animal behaviour.

Methods

We looked at ATAP’s database for a suitable example and settled on an example of the movements of an estuary-dependent fish species, leervis *Lichia amia*. The chosen species is known to spend a lot of time in estuaries but also frequents the marine environment. Therefore, with the appropriate placement of receivers one should be able to detect multiple habitat connectivity and the movements of tagged animals between these environments. Two scenarios were created; one where multiple estuarine receivers and a single marine receiver moored offshore of the estuary mouth were present, and another where the marine receiver was missing, which is a likely situation in the event of a loss. The outcomes of each scenario are discussed below.

Results

Scenario A (with a marine receiver present) revealed that with receivers placed in both the estuary and at sea, the movement of a tagged fish between these environments can be confirmed, including the approximate time of departure from the estuary. This provides more accurate information about fish movements. Scenario B (with a marine receiver absent) revealed that despite detections on the estuarine receivers, a visit to the marine environment (sea trip) could not be confirmed, ultimately casting doubt on the whereabouts of the tagged fish. In this case, the fish could either be at sea or still in the estuary where it possibly remained stationary between receivers in the estuary. Therefore, Scenario B does not provide accurate information about fish movements.

Conclusion

The collection of data from large-scale acoustic telemetry arrays has the ability to collect valuable information on the movements, migrations and habitat use patterns of tagged animals. However, unforeseen losses of moored receivers create “listening gaps” that can lead to the misinterpretation of

movement data. Consequently, it is vitally important to keep accurate records of receiver deployment and retrieval metadata, including the recording of lost receivers. The example used in this study revealed that not only presence data, but also absence data are important when interpreting long-term data collected by large-scale acoustic telemetry networks such as the ATAP.

Joining the dots:

How absence data can influence the interpretation of movement patterns

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Introduction

The Acoustic Tracking Array Platform (ATAP) is a long-term monitoring programme that utilizes passive acoustic telemetry to collect data on the movements and migrations of tagged aquatic animals around the South African coastline. Since the inception of ATAP in 2011, the platform has had substantial success in terms of the number of receivers deployed. ATAP currently has approximately 100 receivers moored along the South African coastline.

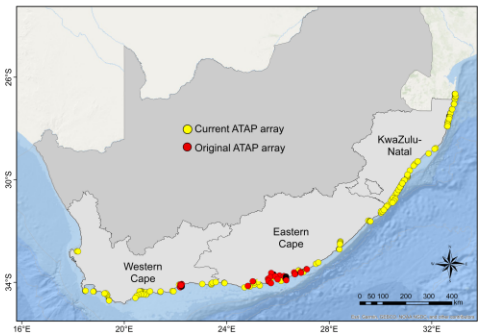
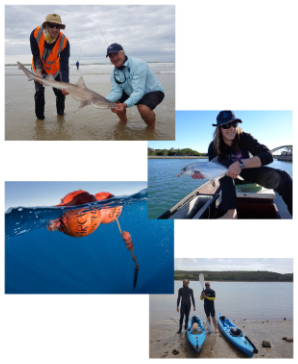


Figure 1: Map of the current and original ATAP array



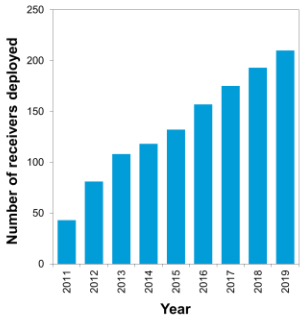
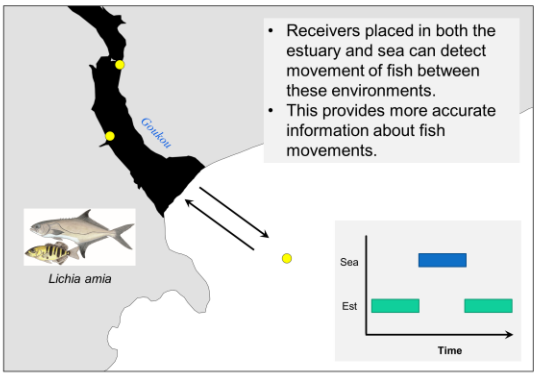


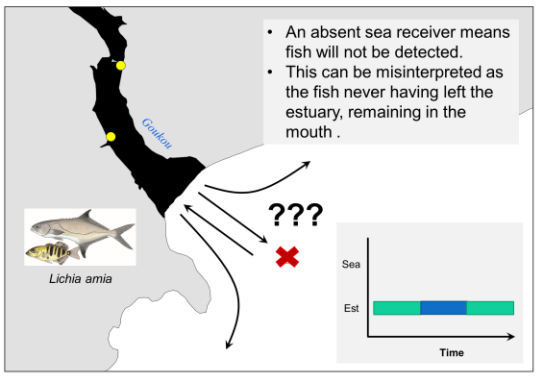
Figure 2: Growth in the number of ATAP receivers deployed over an eight-year period

The strength of the platform lies in its ability to provide long-term, continuous movement data; however, unpredictable sea conditions, flooding events in estuaries and other unforeseen events can lead to the displacement or loss of receivers. This creates "listening gaps" within long-term datasets, which could influence the interpretation of movement patterns.

Aim: To illustrate how missing data can influence the interpretation of movement patterns and inferences about animal behaviour

Scenario A (with marine receiver)

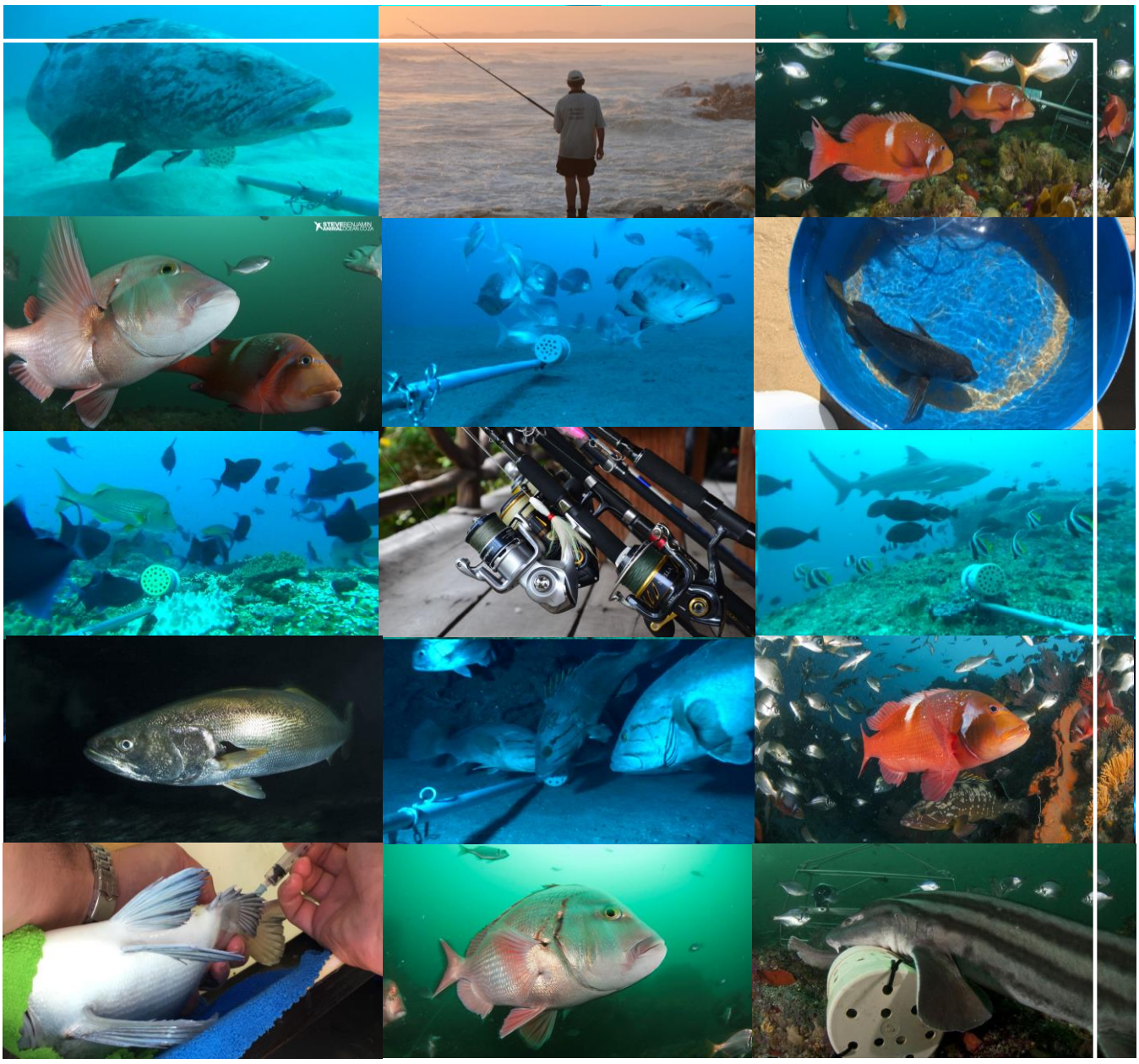




Scenario B (no marine receiver)

Conclusion

It is vitally important to keep track of both deployment and retrieval metadata. Presence data are important, but absence data are just as important, especially if it leads to the misinterpretation of movement behaviour.



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