Fish, fishers and the future:

Proceedings of the 6th Southern African Marine Linefish Symposium, 19-23 August 2024

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6th Southern African **Marine Linefish** Symposium

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Cover photograph: Spawning aggregation of giant kingfish *Caranx ignobilis* in the Maputo National Park, Mozambique (BQ Mann)

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Fish, fishers and the future: Proceedings of the 6th Southern African Marine Linefish Symposium

Held at Mpekweni Beach Resort, Eastern Cape
19-23 August 2024

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A photograph of the 6th South African Marine Linefish Steering Committee against a backdrop of the linefish tapestry produced by the Keiskamma Trust. Top row from left to right: Bruce Mann, Judy Mann-Lang, Taryn Murray, Gareth Jordaan, Alex Winkler, Matt Farthing. Bottom Row: Amber Childs, Warren Potts, Michael Farquhar.

EXECUTIVE SUMMARY

The 6th Southern African Marine Linefish Symposium (6th SAMLS) was held at Mpekweni Beach Resort in the Eastern Cape from 19-23 August 2024. Held under the auspices of the Marine Linefish Research Group, the symposium was attended by 110 delegates from a variety of private, academic, non-government and government institutions, representing a 10% increase in delegate numbers from the last symposium held at the same venue in 2019. This was largely attributed to the generous student funding provided by SAIAB and Innovasea. While the symposium was well represented by researchers from a variety of academic institutes, the absence of most fishery scientists and managers from the Department of Forestry, Fisheries and the Environment (DFFE), was disappointing.

There were 57 scientific presentations, and three keynote addresses presented at the symposium. The three keynotes were given by Prof Colin Attwood from the University of Cape Town, Dr Keiran Hyder from the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) in the United Kingdom, and Dr Philile Mbatha also from the University of Cape Town. All three of the keynote speakers had substantial knowledge of linefish and/or fisheries management both locally and internationally and they provided some extremely important insights. These ranged from the value of long-term monitoring data (~40 years) acquired in the De Hoop Marine Protected Area to study the dynamics of fish densities and recruitment; the complexity of embedding marine recreational fisheries into fisheries governance; and highlighting the rights of small-scale fishers within the broader fisheries agenda.

Our linefish species in Southern Africa face many challenges brought about by a combination of overfishing, habitat degradation, pollution and climate change. Effective management continues to be complicated by the multi-species, multi-user nature of the linefishery and the difficulties associated with governing such complex socio-ecological systems. These factors influenced the session themes held at the 6th SAMLS, being based around fish movement studies, life history and ecological studies, fisheries monitoring, fisheries management, angler engagement, fisheries, genetics and climate change. Recent technological advances have aided in many aspects of linefish research and there was a strong representation of studies using acoustic telemetry, remote underwater video systems, metabolism-measuring equipment, as well as new genetic methods.

One of the highlights of the symposium was the celebration of the 40th anniversary of the Oceanographic Research Institute's Cooperative Fish Tagging Project (ORI-CFTP). Started in 1984 by former ORI Director Rudy van der Elst and now with more than 7 370 tagging members, 386 000 fish tagged and 24 600 (6.4%) tagged fish recaptured, this is one of the most successful volunteer tagging projects of its kind globally.

Besides the publication of this proceedings, the findings of this symposium have been widely communicated and shared on social media. Furthermore, selected studies have been submitted to the *African Journal of Marine Science* for a special edition that focusses on linefish research. Special thanks to the all the participants, especially to the keynote speakers and presenting authors, and to the sponsors for their financial support, without which, this symposium would not have been possible.

Note that these proceedings consist of a compilation of extended abstracts from presentations given at the symposium. Presenters were given two months after the symposium to submit their extended abstracts. For those presenters that failed to meet the deadline, only the original abstract is presented.

FOREWORD by Dr Kieran Hyder

Linefisheries in Southern Africa present significant challenges for monitoring, assessment and management. They are very diverse both in terms of fish species and fisheries, are cross-jurisdictional, and subject to pressures beyond fisheries (e.g. habitat loss, pollution, climate change). This means that sustainable management of the linefish stocks whilst maintaining the social and economic benefits generated can be challenging. This is likely reflected in the fact that management approaches have not changed since 2010.

The Southern African Marine Linefish Symposium (SAMLS) was established by the Marine Linefish Research Group (MLRG) and first held in 1989. It aims to bring together scientists, policy makers, and the fishing community to share knowledge of linefish and develop new initiatives to improve conservation and management of this important resource. The sixth SAMLS was held at Mpekweni Beach Resort in the Eastern Cape in 2024. It was attended by 110 delegates that gave 57 presentations alongside a workshop on collaborative monitoring and assessment of the shore-based fishery and a celebration of the 40th anniversary of the Oceanographic Research Institute's Cooperative Fish Tagging Project.

This was my first experience of the SAMLS – I was very impressed by both the quality and diversity of approaches being developed to support management of linefish. There was a fascinating combination of research and management covering all aspects of the linefishery alongside some holistic 'systems thinking' and transdisciplinary approaches. It was good to see that the fishing community were included and integrated in the approaches being developed.

The SAMLS and MLRG have an important role in developing the evidence, systems thinking, and transdisciplinary approaches needed to move forwards and support policy makers. Attending the 6th SAMLS, it was clear that there is a rich assemblage of amazing researchers doing world leading science with a passion to conserve linefish stocks for future generations to enjoy. It was great to see the number of talented early career researchers that are doing novel and innovative science to address the challenges in different ways. There is clear engagement with the fishing sector with co-design supporting the development of appropriate management.

The South African Marine Living Resources Act (MLRA) is currently under review. This provides a fantastic opportunity to address issues with the current linefishery management system and embed new, more effective approaches. The scientific and fisher communities need to work closely with policy makers from the Department of Forestry, Fisheries and the Environment (DFFE). This will allow the best science to underpin future decisions and ensure that this is embedded in the next MLRA.

Many pieces of the puzzle are in place and others are presented within this summary of the 6th SAMLS. I would encourage everyone to read the outputs and support putting the puzzle together. If linefish researchers, fishers, and policy makers all work together, the pieces of the puzzle can be assembled into a beautiful picture of a sustainable fishery with equitable access that maximises societal benefit within the new MLRA. It is my hope that this picture will be assembled at least in part and presented at the 7th SAMLS.

INSTITUTIONAL ACRONYMS

AEC – Anchor Environmental Consultants
AU – Aberystwyth University (United Kingdom)
CEFAS – Centre for Environment, Fisheries and Aquaculture Science (United Kingdom)
CSIR – Council for Scientific and Industrial Research
CSIRO – Commonwealth Scientific and Industrial Research Organisation (Australia)
DFFE – Department of Forestry, Fisheries and the Environment
DIFS – Department of Ichthyology and Fisheries Science, Rhodes University
DU – Deakin University (Australia)
ELM – East London Museum
FUP – Federal University of Pernambuco (Brazil)
GE – Gleneagles Environmental
HUB – Humboldt University Berlin (Germany)
IFREMER – French National Institute for Ocean Science and Technology (France)
IMR – Institute of Marine Research (Norway)
IOW – Leibniz Institute for Baltic Sea Research (Germany)
IRD – French National Research Institute for Sustainable Development (France)
IUCN – International Union for the Conservation of Nature
JCU – James Cook University (Australia)
LOT – Live Ocean Trust
MFMR – Ministry of Fisheries and Marine Resources (Namibia)
NMU – Nelson Mandela University
OCRI – Oceans Research Institute
OOH – One Ocean Hub
ORI – Oceanographic Research Institute
RSMAS – Rosenstiel School of Marine and Atmospheric Science (USA)
RU – Rhodes University
SAAMBR – South African Association for Marine Biological Research
SADSAA – South African Deep Sea Angling Association
SAEON – South African Environmental Observation Network
SAIAB – South African Institute for Aquatic Biodiversity
SANBI – South African National Biodiversity Institute
SANP – South African National Parks
SASAA – South African Shore Angling Association
SIMS – Sydney Institute of Marine Science (Australia)
SU – Stellenbosch University
TIBSF – Thunen Institute of Baltic Sea Fisheries (Germany)
TOAF – Two Oceans Aquarium Foundation
UCT – University of Cape Town
UDL – University de Lille (France)
UEA – University of East Anglia (United Kingdom)
UG – University of Gothenburg (Sweden)
UHI – University of the Highlands and Islands (United Kingdom)
UJ – University of Johannesburg
UM – University of Montpellier (France)
UNAM – University of Namibia
UP – University of Pretoria
US – University of Seychelles
USC – University of the Sunshine Coast (Australia)
USW – uShaka Sea World
UTAS – University of Tasmania (Australia)
UWC – University of the Western Cape
WCS – Wildlife Conservation Society

WO – Wild Oceans (a department of Wildlands Conservation Trust)
WWF-SA – World Wide Fund for Nature South Africa

A photograph of the participants at the 6th Southern African Marine Linefish Symposium taken in the grounds of the Mpekweni Beach Resort where the conference was hosted.

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FIRST KEYNOTE ADDRESS

Population dynamics deduced from 40 years of monitoring protected surf-zone fishes at De Hoop

Colin Attwood (UCT), Lieze Swart (DFFE), Denham Parker (CSIRO)

Marine protected areas (MPAs) offer an opportunity to understand the undisturbed population and community dynamics of fishes that are elsewhere exploited and depleted. A critical, but almost completely unknown, aspect of coastal fish population dynamics is the pattern in fish recruitment variability. We used time-series data from one of the longest standing MPAs in South Africa to examine patterns in recruitment of a few common shore-angling targets, following the cessation of fishing.

A catch-per-unit-effort (CPUE) survey of surf-zone fishes began at Koppie Alleen in De Hoop, one year before its proclamation as a 50 km-long coastal no-take MPA in September 1985. The survey was expanded in 1988 to include Lekkerwater, a second site in the MPA, 11 km away. Each site was sampled three times a year, but the sites were never sampled simultaneously. Total species counts amounted to 19 chondrichthyans and 38 Teleosts. Two teleost species, galjoen *Dichistius capensis* and blacktail *Diplodus sargus,* accounted for 72% of the total sample over the 40 years.

A cluster analysis of the catch composition per sampling event shows clear inter-decadal variation, which hints at post-protection recovery at a community level, but which could also be explained long-term environmental variation. The three different sampling protocols, targeting abundant species (1), targeting large teleosts (2), and targeting chondricthyans (3), resulted in separate clusters, which suggests that the standardisation of CPUE data derived from angler surveys will benefit from one of the methods used for accounting for the effect of targeting.

CPUE data for each species were standardised by way of fitting general linear models with a quasi-Poisson link to estimate an annual index of abundance for each site. Annual coefficients of variation in post-recovery abundance at each site ranged between 0.3 and 0.5, reflecting a combination of sampling error and natural fluctuation. Assuming that the populations of fish at De Hoop are widely distributed relative to the distance between the two sites, the non-simultaneous sampling at each site provided two data sources for the same populations.

Correlations in the abundance index between the two sites revealed R^2 values of 26% for galjoen and 25% for blacktail. Correlations in mean size between the sites were substantially stronger: 58% for galjoen and 44% for blacktail. Sampling error in abundance data was therefore greater than sampling error in length data. The better agreement in mean size suggests methods based on length data might prove more reliable for assessments than those based on an index of abundance for data-poor shore-angling species.

The apparent rapid initial increase in fish density at Koppie Alleen, following the cessation of shore angling, can partly be explained by a relaxation in fish vigilance. Evidence for such an effect was derived from a comparison of the CPUE obtained on each of the successive days of the four-day sampling events. Over the entire length of the time series, galjoen CPUE dropped consistently from day one of each sampling event to day four, at a rate of 5.3% per day, indicating that fish learned to avoid capture. After 1985, fish were not exposed to angling pressure, except for the short periods during sampling events, which amounted to 12 days a year split into three events at each site.

An age-structured model was fitted to galjoen catch-at-length survey data to estimate local recruitment strength from 1984 to 2023. Length-to-age conversions were based on an age-length key derived from otolith readings. Length-selectivity was estimated by fitting a logistic model to the ascending part of the catch-at-length data. Estimated parameters included annual recruitment strengths, and invariant post-recruitment mortality rate and catchability. Matrices of predicted survey catch per year and per age were converted to matrices of predicted catch per 10 mm length category. Natural mortality was estimated at 0.4 y^{-1}, a high estimate that could reflect genuine mortality or emigration at carrying capacity.

The CV on local galjoen recruitment estimates (per site) is in the order of 0.33. The estimated recruitment vectors revealed 52% agreement between sites, and fast Fourier tranformations revealed post-protection cycle periods of ~20 and ~6 years at both sites. The agreement between sites suggests that despite sampling and modelling errors, there is sufficient evidence to suggest that both sites receive recruits from a common pool. The cycles are more difficult to interpret. The shorter cycle corresponds closely to the generation time of galjoen, but the model suggests no relationship between recruitment and spawner biomass, at either site. There is no clear environmental correlate of recruitment. While it is tempting to dismiss the longer cycle, a previous study on galjoen catches dating from 1930 identified 20-year cycles in catch records suggesting that this is a persistent feature of this species. The existence of long period cycles would profoundly affect the way that the resource should be managed.

Two sparid species in the catch records which have known estuarine dependence, white steenbras (*Lithognathus lithognathus*) and white stumpnose (*Rhabdosargus holubi*), show clear abundance correlations between sites and between species, suggesting that the effects of rainfall and estuary condition have a distant influence on the fish community dynamics in the nearshore waters.

The De Hoop data set, now one of the longest time-series of fish abundances in South Africa, provides a remarkably powerful resource for disentangling the effects of fishing and the environment. It has provided a basis for testing hypotheses and for estimating vital rates that would not have been possible without the cessation of extractive use over such a large area. Over and above the value of protecting coastal resources for a variety of conservation, fishery sustainability and tourism objectives, there is substantial value to maintaining undisturbed sites for scientific enquiry.

1. FISH MOVEMENT STUDIES

Movement and management: How acoustic telemetry can aid in the management of important coastal linefish species

Taryn Murray (SAIAB), Matt Parkinson (SAIAB)

The linefish resources in South Africa are exceptionally important to several fishing sectors, including commercial, recreational and small-scale fishers. With each sector retaining fish, there is a clear need to manage these resources appropriately to ensure their sustainability for both consumption and recreational purposes. However, fisheries management, while straightforward in theory, is a complicated process incorporating multiple layers of data. The data collected through electronic tracking, which is a method providing unprecedented insights into the movement behaviour of aquatic species, forms one of these data layers. While fisheries science acknowledges the importance of these data (Crossin et al. 2017, Lowerre-Barbieri et al. 2019), the uptake of this information into fisheries management has been slow.

Acoustic telemetry is one such electronic tracking method and is currently the most popular method across the globe to study the movements of aquatic animals. Acoustic telemetry provides insight into habitat and resource use, behaviour, and population dynamics for tagged species, as well as the occurrence of segregation based on size and/or sex, site fidelity or seasonal migratory behaviour (Block et al. 2012, Crossin et al. 2017). Through monitoring animal movements, key knowledge gaps can be addressed, and the collected data can contribute to fishery planning and management, to population dynamics and interactions, and enables for more robust spatial planning in the marine environment (Crossin et al. 2017). Furthermore, identifying critical habitats for feeding, breeding and nursery grounds, and quantifying the degree of spatial and temporal overlap of movements of important fishery species and fisheries allows for the implementation of effective spatial management interventions.

The importance of incorporating movement data in the development of management regulations and strategies is often overlooked, making it largely underutilised as a fisheries management tool (Lees et al. 2021). South Africa's collaborative nationwide network of marine and estuarine acoustic receivers – the Acoustic Tracking Array Platform (ATAP) (Murray et al. 2022) – is currently monitoring the movements of 39 species of recreational and/or subsistence importance, including 13 fishes, 17 sharks, one skate and eight rays. These include large predatory sharks (white shark *Carcharodon carcharias*, raggedtooth shark *Carcharias taurus*, bull shark *Carcharhinus leucas*), important estuary-associated species (dusky kob *Argyrosomus japonicus*, spotted grunter *Pomadasys commersonnii*), commercially exploited sharks (bronze whaler shark *Carcharhinus brachyurus*, soupfin shark *Galeorhinus galeus*), resident reef species (black musselcracker *Cymatoceps nasutus*, flapnose houndshark *Scylliogaleus quecketii*), Critically Endangered rays and guitarfish (whitespotted wedgefish *Rhynchobatus djiddensis*, common eagle ray *Myliobatis aquila*, duckbill ray *Aetomylaeus bovinus*), wide-ranging sharks (blacktip shark *Carcharhinus limbatus*, silvertip shark *Carcharhinus albimarginatus*, spinner shark *Carcharhinus brevipinna*), large stingrays (leopard whipray *Himantura leoparda*, short-tail stingray *Bathytoshia brevicaudata*), and iconic angling species (giant trevally *Caranx ignobilis*, leervis *Lichia amia*), amongst others. Together, these animals have amassed more than 25 million detections, representing a significant amount of data. These data are useful to management authorities in that they provide presence/absence data over time, how important certain areas are to multiple species, information on connectivity between different habitats, stretches of coastline and between marine protected areas, and timing of longshore and/or inshore/offshore movements and/or migrations. Additionally, the environmental drivers behind these movements can be identified, which is important for understanding how the distribution and movements of coastal fishery species may change given a changing climate.

While acoustic telemetry data are actively being incorporated into management plans and regulations in other parts of the world (Crossin et al. 2017, Lowerre-Barbieri et al. 2019), South Africa is somewhat lagging. However, there are recent developments that are promising to see. For example, many layers of data were used in the development of a systematic conservation plan for identifying critical areas for improved chondrichthyan (sharks, rays, skates, chimaeras) protection in South Africa (Faure-Beaulieu et al. 2023). One of these layers was acoustic telemetry data in its most simple form – presence data i.e. location of receivers on which acoustically tagged sharks and rays were detected. Information from a total of 24 shark and ray species were incorporated into the greater ensemble models that were developed. A very successful example is a change in park legislation directly related to research conducted using acoustic telemetry. Between 2016 and 2018, 36 adult giant trevally were tagged and released at a site known as the Pinnacles in southern Mozambique (where they form the world's largest aggregation for this species, Daly et al. 2018), as well as along South Africa's east coast (between the Mtentu Estuary in the south and iSimangaliso Wetland Park in the north). Acoustic telemetry revealed not only ~~the~~ more about the multi-seasonal spatiotemporal dynamics of this aggregation (Daly et al. 2019), but also information related to their longshore movements and site fidelity (Dixon et al. 2023). As such, the importance of this site for the giant trevally aggregation was brought to light, and the Maputo National Park recently acknowledged this through a change in legislation related to the targeting and retention of this species during certain times of the year. Giant trevally can no longer be actively targeted or retained between 01 November and 30 March. This change in legislation would not have happened without the important information collected through acoustic tracking of this iconic angling species.

On a smaller scale in a more localised context, consider the De Hoop Marine Protected Area (MPA) and adjacent Breede Estuary along South Africa's south coast. One of the prized angling species found in this system is the dusky kob, whose stock is currently considered to be collapsed and between 1.5 and 4% of pristine spawning levels. As such, this system represents one of South Africa's large population strongholds for this species. However, the Breede Estuary is an exceptionally important system for numerous fish, shark and ray species that all support local recreational and subsistence fisheries, including spotted grunter, leervis, duckbill rays, diamond rays *Gymnura natalensis*, raggedtooth sharks and bull sharks. While the estuary is currently open to fishing, individuals are protected to some degree once in the boundary of the De Hoop MPA, which is currently no-take. The overarching management authority of the MPA, CapeNature, is currently considering expanding the eastern boundary of the MPA, which would then incorporate the mouth of the Breede Estuary and marine environment directly adjacent to it. The ATAP has a considerable acoustic receiver array positioned in the MPA, the Breede Estuary and adjacent marine environment, being in a good position to record important movement information on several tagged species, including residency to the estuary and MPA, estuary/marine connectivity, connectivity between the estuary and MPA, as well as between the marine environment and MPA. The ATAP had been recording movement information on seven species (mentioned above) for the past eight years, which allows for significant insights in the abovementioned movement behaviours. While not extensively analysed, the data show that there is a large degree of overlap between species, particularly the lower and middle reaches, which most likely fluctuate seasonally as well as with certain environmental variables such as river flow, and river and sea temperatures. Many more shark species, including white sharks, smooth hammerhead sharks *Sphyrna zygaena*, smoothhound sharks *Mustelus mustelus* and spotted gully sharks *Triakis megalopterus* make extensive use of the marine environment adjacent to the Breede Estuary, highlighting this to be an important corridor for movement along this stretch of coastline. Many of these species were also recorded spending significant amounts of time in the De Hoop MPA, highlighting the essential protective role this MPA plays for species while in its boundaries. As such, it is easy to see how movement data can be used to assist with the development of, or provide additional motivation for, MPA expansion.

Conclusions

While acoustic telemetry is a powerful tool to collect important movement information on multiple species, it remains a relatively underutilised fisheries management tool in South Africa. Moving forward, efforts on the parts of researchers and management authorities should be made to see these data being incorporated into management plans, whether it be proposed MPA expansions, estuary management plans, or for the identification of Important Shark and Ray Areas or Ecologically and/or Biologically Significant Areas, amongst others. The ATAP is a mature infrastructure platform, which with sufficient funding and staffing, will continue to collect important animal movement data into the foreseeable future.

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From movement to management: Results and applications from a longshore movement study on giant kingfish *Caranx ignobilis*

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Giant kingfish *Caranx ignobilis* are iconic, apex marine predators with high importance to tropical and subtropical ecosystems and fisheries. During summer, adults aggregate for spawning, making them vulnerable to overfishing. The world's largest *C. ignobilis* aggregation has been recorded in southern Mozambique, but the year-round movements of these fish required further investigation. To assess movement patterns of *C. ignobilis* along the southern African coast, 36 adult fish were acoustically tagged and monitored along the east coast between Santa Maria in southern Mozambique and Port St Johns in the Eastern Cape, South Africa, for over 5 years using an extensive passive acoustic receiver array. Outside the migration season, South African-based fish showed consistent inter-annual fidelity to individual linear areas of space use (mean = 92 km) equivalent to home ranges. All analysed fish were recorded in southern Mozambique between November and January each year (with minor exceptions), migrating distances up to a maximum of 632 km in one direction, highlighting the importance of the aggregation site for both Mozambican-based and South African-based fish. These movements were fast and direct, with maximum travelling speeds of up to 130 km per 24-hour period. Findings from this study are not only of global ecological relevance but have also contributed to improved local fisheries management. The recently imposed prohibition on targeting or keeping *C. ignobilis* during the summer spawning season in the Maputo National Park, Mozambique, where the aggregation occurs is an important intervention for evidence-based management and for the future of this species in southern African waters.

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The movement patterns of white musselcracker *Sparodon durbanensis* (Family: Sparidae) along the South African coast determined from dart tagging

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Background
The white musselcracker *Sparodon durbanensis* is an endemic reef fish found on the east coast of South Africa from south of the Thukela River in KwaZulu-Natal (KZN) to Cape Point in the Western Cape (WC). Adults inhabit high profile inshore reefs down to depths seldom exceeding 20 m, while juveniles are found in intertidal rock pools and subtidal gullies. They feed on a variety of benthic invertebrates including gastropods, echinoids and crustaceans which are crushed using their molariform teeth and powerful jaws. They are rudimentary hermaphrodites (functional gonochorists) that reach maturity at approximately 350 mm fork length (FL) and an age of 5.4 years (Buxton and Clarke 1991). Spawning occurs in spring to summer (August to January), primarily in the Eastern Cape (EC) and southern KZN and they are known to form spawning aggregations. They reach a maximum size of 1029 mm FL and a weight of 22.2 kg and have been aged up to a maximum of 31 years.

White musselcracker are a highly prized shore angling and spearfishing species and they are targeted throughout their distribution. Despite the importance of this species, relatively little is known about their movement behaviour with most past research having focused on the movement of juveniles (Watt-Pringle et al. 2013). The purpose of this study was to address this knowledge gap and to investigate their movement behaviour using tag-recapture data stored on the Oceanographic Research Institute's Cooperative Fish Tagging Project (ORI-CFTP) database (Dunlop et al. 2013).

Methods
This study took place along the eastern seaboard of South Africa between the Thukela River on the KZN coast and Cape Columbine in the WC. All white musselcracker that were caught and tagged in the study area between January 1984 and December 2023 were included. When a fish was tagged or recaptured, the angler recorded the following information: tag number, species, length, length type (FL or TL), locality, and date. Fork length was recorded for most tagged and recaptured fish. To examine the size structure of both tagged and recaptured white musselcracker, two size classes related to size at sexual maturity were assigned: juveniles (250-350 mm FL) and adults (≥ 350 mm FL). The distance moved (in kilometers) by a recaptured fish was calculated as the coastal distance between the tag release and recapture localities using the ORI-CFTP locality codes which only provide a resolution of ≥ 1 km. Fish movement was classified as either "resident" if it was recaptured within 5 km from where it was originally tagged, or "ranging" if it was recaptured > 5 km away. The mean distance moved and the direction of movement (either north-east or south-west along the coast) by juveniles and adults was compared and the relationship between distance moved and time at liberty for juveniles and adults was investigated. A monthly comparison of total tag releases and recaptures was conducted to detect possible trends in seasonality of catches. Two main periods were identified, namely austral summer (October-March) and winter (April-September).

Results
A total of 3378 white musselcracker were tagged between 1984 and 2023, of which 99 (2.9%) have been recaptured (including multiple recaptures). The core distribution of white musselcracker (in terms of tag-recapture data) extended from Mazeppa Bay to De Hoop. A total of 64 recaptures (66.7%) showed resident behaviour moving less than 5 km. The remaining 32 recaptures (33.3%) displayed ranging behaviour moving distances greater than 5 km. The greatest distance moved was recorded for a fish that was tagged at St Francis Bay in the EC and recaptured at Isipingo in KZN, a distance of 843 km over a period of 2231 days (6.1 years) at liberty. Juvenile fish were highly resident and moved considerably less than adults. Adults moved significantly more in a north-easterly direction and appeared to move greater distances in this direction. There was some evidence of a seasonal pattern in catches of white musselcracker with highest catches taken from September to

December. However, there was no clear evidence that catches varied spatially with season for either juveniles or adults. Regarding seasonal movement, it did appear that adults tended to move more in a south-westerly direction during summer and in a north-easterly direction during winter.

Conclusions

The results of this study clearly showed the high level of residency and site fidelity displayed by white musselcracker (66.7% moved less than 5 km). This was particularly true in the case of juveniles < 350 mm FL. This tendency of certain sparid species to display high levels of residency as juveniles is relatively common and has been described for several species. The establishment and effective management of a network of well-sited no-take MPAs in areas of appropriate habitat is thus critical for the protection of both resident juveniles and adults of this species. This study also produced convincing evidence of greater movement behaviour in adult white musselcracker compared to juveniles. Of the adult fish that moved, a significantly greater number moved in a north-easterly direction with a higher proportion of such movements recorded during the winter months. This supports the hypothesis that adult white musselcracker undertake a north-eastward seasonal migration to spawn. There was also some evidence to support a southward return movement of adults during the summer months following spawning, suggesting that adults may occupy discreet home ranges to which they return after spawning. This site fidelity would account for the high percentage of adults recaptured with limited movement. Such northeast-ward movements to spawn would facilitate the southward dispersal of eggs and larvae inshore of the Agulhas Current as has been described for several South African linefish species. Spawning aggregations of white musselcracker during spring and early summer (August to December) have been anecdotally reported by anglers and spearfishers from various sites along the South African coast from Mossel Bay in the WC to just south of Durban in KZN (Hewett 2020). This suggests that adult movements to spawn may be more localised than one large migration to a single spawning site. High fishing pressure on known spawning aggregations can result in localised overfishing and be extremely detrimental to the stock. As such, identification of key spawning areas along the coast and implementation of species-specific spatial and temporal closures in such areas may be warranted to improve long-term sustainable use. Such a study could be greatly facilitated by the use of fisher environmental knowledge (FEK).

Based on the results of this study there are still clearly large gaps in our knowledge on the movement behaviour of white musselcracker. To remedy this situation, it is proposed that a passive acoustic telemetry study be undertaken focusing on larger adult fish (> 600 mm FL) and by using a strategically placed array of receivers in relatively shallow water (~10 m).

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Assessment of the movement behaviour of dusky kob (*Argyrosomus japonicus*) using 39 years of tag-recapture data from the ORI-CFTP

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Background

Argyrosomus japonicus is a large coastal sciaenid that is one of the most heavily targeted species by commercial and recreational anglers. Its complex life history includes a juvenile estuarine phase, late maturity, slow growth and predictable behaviour. These traits make it extremely susceptible to exploitation. The stock status of *A. japonicus* in South Africa was categorised as collapsed more than 25 years ago and, in recent years, has been assessed at 1-3% of pristine spawner biomass.

Conserving *A. japonicus* is challenging due to cryptic morphology and range overlap with three other *Argyrosomus* species, having different life histories and being hard to identify using external anatomy. The separate life histories of the *Argyrosomus* species were never fully accounted for in the design of management measures and regulations until 2005, when the size and bag limits of *A. japonicus* were changed to 60 cm TL and one fish per angler per day. These impacts have led to over-exploitation as a result of growth overfishing. Consequently, it has been suggested that a marine spatial planning approach may be a route to achieve these conservation goals. To do this, understanding *A. japonicus* movement behaviour is critical for effective conservation planning (e.g., Marine Protected Area Establishment). Previous work using catch-per-unit-effort (CPUE) data suggested *A. japonicus* undertake annual spawning migrations from the Eastern Cape and Western Cape provinces to KwaZulu-Natal (KZN). Acoustic telemetry studies done in Algoa Bay, Great Fish River, Breede River, and De Hoop MPA provided evidence that *A. japonicus* may consist of two separate subpopulations (one in Southern Cape [SC] and the other between KZN and the southeastern Cape [SEC]), which display partial migration where most of the adult population is resident to these areas and a smaller proportion migrates to KZN. Furthermore, Childs (2013) found that in Algoa Bay, *A. japonicus* juveniles also showed signs of partial migration with the presence of marine and estuarine behavioural contingents. When looking into the Oceanographic Research Institute’s Cooperative Fish Tagging project (ORI-CFTP) data on *A. japonicus*, Childs (2013), with support from a previous study by Maggs and Bullen (2010), showed how partial migration and higher residency supported the idea of two sub-populations existing along the South African coastline. This study, therefore, intended to investigate the following objectives: i) Develop a logical decision tree based on the best available knowledge to screen records in the ORI-CFTP database for accuracy and to refine the database to an acceptable level of taxonomic reliability; ii) Determine the extent of the *A. japonicus* movement along the South African coast; and iii) Identify the influence of body size, time at liberty and region on *A. japonicus* movement patterns.

Methods

To eliminate misidentifications of *A. japonicus* by ORI-CFTP taggers, a logical decision tree was developed to focus on the key non-physiological characteristics that separate *A. japonicus* from the other *Argyrosomus* species due to morphological confusion and overlap. Location of capture and recapture was the first priority, with the first screening criteria (screening criteria 1) being if the fish was caught East or West of Cape Agulhas; if caught West of Cape Agulhas (although found to Cape Point, most abundant from Cape Agulhas, they would be eliminated from the data set. Screening criteria 2 was if fish were caught in an offshore locality code, they would be eliminated due to *A. japonicus* being mostly caught from a shore or estuarine location, and when caught offshore, they could likely be confused with *A. inodorus* and *A. thorpei.* Screening criteria 3 investigated the anglers' chosen facet for fishing, with all that had selected estuarine, and rock and surf facets kept, and others eliminated. This was done for the same reasons as in screening criteria 2, in that *A. japonicus* is the most commonly caught *Argrosomus* species in east coast estuaries. Lastly, all the eliminated records were reinvestigated to determine if sufficient evidence suggests the tagger could correctly identify the species (i.e., research tagger or ORI employee), if found, the record was re-included, with all others being discarded. Following screening, tagging and recapture locations were assigned to 1 of 5 coastal zones encompassing *A. japonicus* known distribution (northern KZN (NKZN), southern KZN (SKZN), Wild Coast (WIC), southeastern Cape (SEC), Southern Cape (SC)). Each fish was assigned to a sexual maturity size class based on their length: juvenile (0 to 725 mm total length [TL]), sub-adults (726 mm to 1050 mm TL), and adults (>1051 mm TL) to assess ontogenetic changes in movement behaviour during maturation. Next, comparison of size class composition was made between geographic regions for tagged and recaptured fish to assess potential movement trends on size distribution; the distance moved (km) by all size classes of fish was calculated and assigned an easterly or westerly direction and relationship between time at liberty and sexual maturity class size was also examined.

The ORI-CFTP database (1984-2022) contains ±24500 *A. japonicus* tagging records, with ±1600 (6.5%) of them being recaptured. The data was then run through the logical decision tree where ±18500 (75%) records with 1420 recaptures (7.7%) were retained. When screening the database for potential misidentifications using the logical decision tree, screening criteria step 1 eliminated 3726 (15%), with 85% of the records retained. In the second step in the screening, we eliminated 1475 (6%), and 19320 (79%) were retained. In the third step, we eliminated 1488 (6%), with 17832 (73%) retained. Of the 6689 (27%) tagging records eliminated, 656 (3%) were re-included.

Results

From the 1420 recaptures, the average distance moved was 24.2 km, and the average time at liberty was 364 days. Out of the 1420 recaptures, 483 (34%, $\bar{x}$ recapture length = 427.67 mm TL) were juveniles, 746 (52.68%, $\bar{x}$ recapture length = 650.34 mm TL) were sub-adults, and 183 (12.96%, $\bar{x}$ recapture length = 968.3 mm TL) were adults. Of those recaptured, 84% of juveniles and 80% of sub-adults showed no movement, with limited movement in the remainder (juvenile $\bar{x}$ = 13 km; sub-adult $\bar{x}$ = 21 km), suggesting low dispersal before maturation. Of the 184 tagged-and-recaptured adults, 101 (55%) showed movement ($\bar{x}$ = 65 km). When assessing the relationship between time at liberty and sexual maturity class size, the relative proportion of fish recaptured in the same zone they were captured and tagged revealed the SC coastal zone across all size classes (juveniles 98%, sub-adults 98%, adults 94%) displayed the highest relative proportion. The WIC coastal zone (juveniles 87%, sub-adults 75%, adults 0%) shows a decrease in relative proportion with an increase in size class; notably, no adults were recaptured in the same zone they were captured and tagged. To assess whether adults undertook a spawning migration to KZN, fish at liberty <365 and all-time were mapped on QGIS, showing that one adult fish was captured in the SC and recaptured again in the SEC region. Apart from the SC region, all other regions were seen to have multiple captures and recaptures within them for adult fish during the known spawning seasons. Doing the same and excluding any spawning season parameters revealed one adult fish recaptured outside the SC where it was tagged.

Conclusions

The results showed that the ORI-CFTP database could be refined based on the best available knowledge to mitigate misidentifications by citizen anglers due to morphological confusion and distribution overlap. The study showed trends and evidence into the movement behaviour of *A. japonicus* and further support of higher levels of residence than first assumed and provided further evidence of partial migration with low levels of migration in adult fish (55% of adult recaptures showing movement >100 km). This study also suggests that residency is high in juveniles, as previously assumed and shown in other studies. This study also provides evidence that not all adults move to KZN to spawn. Low connectivity between the SC and other coastal zones was also noted. This aligns with the idea that a separate sub-population of *A. japonicus* exists in the SC region. This means that we must adequately protect these different regional and behavioural sub-populations to ensure conservation of the genetic and behavioural diversity of *A. japonicus*. Protection across the range of sub-populations, habitats and behavioural contingents is important, considering that the population of *A. japonicus* is endangered, the stock has collapsed, and there is evidence of significant genetic bottlenecking, which has constrained the diversity in the population as a whole. Genetic and behavioural diversity is key to resilience in the face of a variable and unpredictable climate, and continued pressures from fishing and declining nursery habitat quality and quantity. With the high use of estuaries as nursery habitats for juveniles and sub-adults and the adjacent surf zone being occupied by larger sub-adults and adult fish, there is a need to spatially protect these areas. The idea of marine and estuarine protected areas (MEPA's) was suggested by Childs et al. (2015), where estuaries and adjacent surf zones would be protected. To align this with the higher residence and partial migration, multiple MEPAs would need to be set up on estuaries and their adjacent surf zones along the South African coastline, focusing on large estuaries, typically with a permanently open mouth, that are used as nursery habitats for *A. japonicus*.

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Movement behaviour and habitat-use of four mullet species in the Kowie Estuary, South Africa

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Animal movement behaviour is a complex phenomenon in ecology as it involves the interaction between the biology of the individual (life history, physiology) and their environment (resource availability, environmental conditions) (Van Moorter et al. 2013). Studying these movements gives insights into complex spatial dynamics at different levels of organization (i.e., communities, populations and sub-populations) which can further help understand impacts of anthropogenic activities and climate change on the movement behaviour and habitat use of important fish species (Bowler and Benton 2005, Van Mooter et al. 2013).

Estuaries are important habitats and critical transition zones connecting freshwater and marine ecosystems. Globally, members of the Mugilidae family, commonly known as mullet, dominate most estuaries in terms of abundance, and are recognised for their importance to both subsistence and recreational fisheries. Mullet species generally co-occur in marine and estuarine environments, and are morphologically similar in many aspects, often feeding on similar items. For morphologically similar species to successfully co-occur, they often display resource partitioning (slightly different diets), which may in turn lead to habitat or niche partitioning (occupying slightly different areas) (e.g., Moulton et al. 2017). While mugilids dominate estuarine and coastal waters, little is known about their movement behaviour and habitat use patterns in South Africa, and how these may differ between species, which ultimately allow them to co-exist. Given that mullet exhibit diverse and complex movements and have shown considerable variability in their ecological strategies (Rangely et al., 2024), understanding how similar species with different life history strategies adapt to the variable estuarine environment is essential for understanding the ecological processes that govern their distribution and abundance within these environments. As such, this study aimed to better understand the movement behaviour and habitat use of four mullet species with varying life history traits, which co-occur in the Kowie Estuary, South Africa.

The Kowie Estuary is a permanently open estuary situated in the warm temperate biogeographic region of South Africa. The estuary is approximately 21 km in length with a catchment of approximately 576 km^2. For this study, 26 acoustic receivers were moored 1 km apart from the estuarine mouth through the lower reaches (1 - 4 km), middle reaches (5 - 14 km) and upper reaches (14 - 21 km) of the Kowie River (21 – 25 km from the mouth). Sampling was conducted between December 2022 and June 2023 using cast nets at night. A total of 53 individuals comprising 21 flathead mullet *Mugil cephalus*, 14 striped mullet *Chelon tricuspidens*, 12 grooved mullet *Chelon dumerili*, and six southern *Chelon richardsonii* were tagged with acoustic transmitters (69 kHz, Innovasea, Halifax, Canada) and monitored by deployed acoustic receivers (VR2W-69 kHz, Innovasea, Halifax, Canada) for a period of one-year (June 2023 to July 2024).

Time spent in each estuarine reach and home range (Kernel Density Estimates, 50 and 95% KDE) sizes were calculated for each species. Results showed that each species made use of the entire length of the Kowie Estuary; however, there was variability in time spent within each reach as well as size of home ranges among the four species. *Chelon tricuspidens* (n = 9) predominantly used the lower-middle reaches, with only a few individuals recorded moving into the upper reaches. *Chelon dumerili* (n = 9) were recorded primarily in the middle-lower reaches of the estuary. *Chelon richardsonii* (n = 4) spent most time in the lower reaches, with short forays into the middle and upper reaches of the estuary. *Mugil cephalus* (n = 12) on the other hand made extensive use of the entire estuary throughout the monitoring period. The affinity of the tagged mugilids to different regions in the estuary suggested that these species may be exhibiting habitat partitioning.

Although the majority of tagged fish spent most of the monitoring period in the Kowie Estuary, some individuals displayed connectivity to other estuaries and were recorded undertaking sea trips to visit nearby estuaries for a short period of time. These included four *M. cephalus,* two *C. richardsonii* and two *C. tricuspidens* which were detected in nearby estuaries and inshore coastal areas, including the Kariega (approximately 22 km west) and Bushmans (approximately 24 km west) estuaries, and inshore coastal receivers at Kleinemonde (approximately 16 km east) and Port St Johns (approximately 330 km north-east).

The results of this study suggest that these four closely related mugilid species exhibit habitat partitioning. These findings are consistent with the literature, which documented partitioning in Mugilidae species in Northwestern Atlantic (e.g. Rangeley et al., 2014). Furthermore, the extensive movements of *M. cephalus* across diverse temperature and salinity gradients (lower, middle and upper reaches of the estuary), is likely attributed to an adaptive strategy that facilitates their widespread distribution (Whitfield and Durand 2023). Therefore, studying the movement behaviour and habitat use for multiple species that co-occur in similar habitats allows for the identification of species-specific life history strategies, which are important for management and conservation of different species and their critical habitats.

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Residency and movement behaviour of blacktail in a shallow rocky cove using acoustic telemetry

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Background

To understand the ecology of a certain species, it is essential to understand the movement behaviour and connectivity among different habitats of the species, especially when it comes to identifying areas that are important for different life-history stages such as the early-life stage. Previous studies have shown that adults of the species blacktail *Diplodus capensis* are highly resident to their preferred habitat, only moving a few kilometres within these areas (Attwood and Bennett, 1995). Less work has been done on juveniles of this species with one visible implant fluorescent elastomer (VIFE) tagging study showing that juvenile blacktail are the least resident species compared to zebra and white musselcracker in a shallow rocky subtidal nursery habitat comprising of small gullies, with a degree of residency of only 10% (Watt-Pringle et al., 2013). We thus aimed to investigate the residency of blacktail to a bigger shallow coastal cove within Algoa Bay. The aims of this study were to determine (1) how juveniles are using an inshore nursery area and their residency to it, and (2) the home range of this species within the nursery area.

Blacktail is an endemic sparid subspecies that can be found along the southern-African coast ranging from Mozambique in the Indian Ocean to Angola in the Atlantic Ocean. They are primarily marine inshore species with juveniles utilizing tidal pools, gullies and inshore reefs as nursery areas. They are, however, also often associated with seagrass beds in warm-temperate estuaries as well as sandy surf zones (Whitfield and Mann, 2023). Although they are mainly targeted by recreational and subsistence anglers, this species has recently been classified as overexploited with a depleted stock status (DFFE, 2023).

Flat Rocks is a shallow subtidal cove located off the eastern shore of Cape Recife just inside of Algoa Bay. It is the only cove within the calcareous sandstone rock platform, with an average depth of approximately 1.5 m during spring low tides. Semi-diurnal tides occur in the area with a mean range of between 1.6 m during spring and 0.5 m during neap tides. The wave action at Flat Rocks is light, making it a good environment to deploy acoustic telemetry receivers. Two main benthic habitats are present in the cove; high profile reef comprised of rocky outcrops dominated by canopy forming algae and low-profile reef dominated by low growing algae morphotypes interspersed with small sand patches. Previous studies have shown that the mosaic of habitats within the cove provide both shelter and food for juvenile sparids, especially blacktail (James et al. 2024, Mkhize et al. 2024).

Methods

Three acoustic receivers were moored in the cove in high-profile reef (High Reef), low-profile reef (Flat Reef) and a sandy patch (Sand), and two receivers were deployed outside the cove in deeper reef (Deep Reef) and in a small adjacent cove (Small Bay). For the tagging procedure, Vemco V5 180 kHz tags (12.7 x 5.73 mm, 0.64 g in air, power output: 143 dB, nominal 60 second delay: Innovasea, NS, Canada) were used. Fish were caught using hook and line during the months of August to October 2021. Twenty-five blacktail ranging in size from 80-258 mm fork length (FL) were caught during this period. Once fish were captured, they were placed in a holding tank and anaesthetised using 2-phenoxy ethanol at a concentration of 0,4 ml per litre of sea water. Once anaesthetised, fish were transferred to a wetted cradle surgery where they were operated on. Each tag was activated and cleaned before surgery and placed inside the body cavity of the fish after which two CliniSilk USP 2/0 (24 mm 3/8 Circle) silk sutures were used to close the incision. Fish were kept wet and oxygenated throughout the surgery period. The fish were then placed in a recovery bath with fresh sea water and aerators and monitored to ensure full recovery before being released back into the shallow coastal cove.

Results
There were over 650 000 detections between the five receivers during the four-month tracking period. The detection of all tagged individuals within the cove, and a small proportion of individuals in the adjacent habitat, suggests high levels of residency and habitat connectivity by blacktail within this shallow seascape. Ontogenetic habitat preference was also observed, with smaller individuals mainly utilizing the red algae-dominated high reef, and larger individuals were more often observed near the deep reef at the mouth of the cove and in the adjacent small bay. The residency index (I_R) showed that blacktail were highly resident to the cove. A one-way ANOVA showed that there was a significant difference in the residency index between habitats (F-value 25.99, $p > 0.05$). High Reef and Flat Reef had the highest I_R, followed by Deep Reef and Sand. For most of the blacktail the lowest I_R was seen for Small Bay. When considering the size classes of individuals, I_R for each site varied considerably. A One-Way ANOVA showed that there was a significant difference in I_R between habitats for young of the year (YOY) (F-value 10.81, $p > 0.05$) as well as late juveniles (F-value 36.02, $p > 0.05$). Young of the year, which are fish less than a year old, preferred High Reef greatly followed by Flat Reef and Deep Reef. Late juveniles also preferred High Reef and Flat Reef but stayed more within the cove preferring Sand more than Deep Reef. Adults, although there were only two individuals, still preferred High Reef, but Deep Reef played a bigger role in their habitat use, along with utilizing all of the other habitats.

The home ranges for YOY blacktail were mainly based around High Reef and Flat Reef.
These individuals had fragmented home ranges utilizing three habitats mainly High Reef, Flat Reef and to a lesser extent Deep Reef. Three individuals had their core hotspot around High Reef. One individual had their core hotspot around Flat Reef and utilized High Reef to a lesser extent. Two individuals had two core hotspots, B03 utilized Deep Reef the most followed by High Reef, while B08 had the opposite, preferring High Reef the most followed by Deep Reef. These individuals had very differing sizes in home range, ranging from 0.04 to 1.66 km^2. The home ranges for late juvenile blacktail were also mainly based around High Reef and Flat Reef. These individuals also had fragmented home ranges utilizing all five habitats but mainly High Reef, Flat Reef and Sand, while Deep Reef and Small Bay was utilized to a lesser extent by certain individuals. Five individuals had their core hotspot around High Reef. Two individuals had their core hotspot around Flat Reef. One individual, B12 had two core hotspots, utilizing High Reef the most followed by Flat Reef. The late juvenile cohort also had very differing sizes in home ranges, ranging in size from 0.1 to 2.46 km^2. The biggest fish, B15 at 258 mm FL had the biggest home range of 4.54 km^2 and had three core hotspots. This individual utilized Deep Reef the most, followed by High Reef and Small Bay, but was seen to utilize all of the habitats. B19 at 207 mm FL had one core hotspot around High Reef and had a home range of 0.27 km^2.

Conclusions
As the first national marine spatial plan in South Africa is currently being developed for Algoa Bay, determining the ecological importance of the coastal region is needed so that the correct conservation and management measures can be highlighted. The southern African coastline provides few alternative marine environment nursery areas, which implies that deterioration of these valuable habitats would have a remarkable effect on the fish species using them. It is thus critical to identify and value nursery habitats if they are to be beneficially managed and conserved. Contrary to previous studies in subtidal gullies, where juvenile blacktail show a lower degree of site fidelity, this study shows that juvenile blacktail are highly resident to Flat Rocks, utilizing all the habitats within the cove and is thus an important nursery habitat for this species.

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Smooth-hound shark *Mustelus mustelus* movements dictated by context: higher residency in South African Marine Protected Areas

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(Note this talk was not presented at the symposium)

The movement patterns of commercially valuable smooth-hound sharks, *Mustelus mustelus*, within and outside Marine Protected Areas (MPAs) in the southern Cape, South Africa were investigated using seven years of passive acoustic telemetry data. This study assessed the impact of individual, ecological, and environmental factors on the distances travelled per day by 43 tagged sharks (10 male and 33 female). Results indicate that most sharks exhibited high residency within MPAs, with home ranges typically less than 1 km, punctuated by sporadic long-distance movements of up to 12.3 km per day. However, significant intra-specific variability in movement behaviour was observed, with some individuals demonstrating responsiveness to upwelling events, resulting in extended excursions beyond MPA boundaries. These excursions increase the vulnerability of these sharks to fishing activities once outside protected areas. The findings suggest that MPAs, if strategically located to encompass nursery areas, could yield considerable benefits to fisheries through spill-over effects. However, it is noted that existing MPAs often fail to overlap spatially with habitats critical for threatened chondrichthyans globally. Successful conservation efforts thus necessitate MPAs that not only target specific species but also incorporate context-specific knowledge of movement and habitat use. This study underscores the importance of integrating ecological, environmental, and individual factors in MPA design and management to effectively conserve marine biodiversity and sustainably manage fisheries.

AcousNomaly: Learning to detect anomalies in acoustic telemetry data using machine learning and deep learning

Siphendulwe Zaza (RU, SAIAB), Marcellin Atemkeng (RU, SAIAB), Taryn Murray (SAIAB)

Background

Studying fish movement and behaviour is crucial for understanding ecological dynamics and implementing effective conservation strategies (Crossin et al. 2017). Acoustic telemetry is currently the most popular method for studying the movements of aquatic animals, providing valuable insights into their movements, habitat use and survival (Matley et al. 2022). One of the biggest strengths of acoustic telemetry is the amount of data collected, which in some instances can reach millions of individual data points of numerous individuals from various species (Dhellemmes et al. 2023). However, this is also one of its biggest challenges, because these datasets can often contain anomalous (false) detections that can pose challenges in data analysis and interpretation. Anomalous movements are generally identified manually, which can be extremely time-consuming, and sometimes entirely unrealistic in large datasets. As such, this study focused on automating the process of anomaly detection in a large telemetry dataset using Machine Learning (ML) and Deep Learning (DL). The ML and DL models explored include neural network autoencoders (NN-AE) as well as traditional models such as Isolation Forest and DBSCAN. These models were trained on data from dusky kob (*Argyrosomus japonicus*) tagged and tracked in the Breede Estuary between 2016 and 2021, allowing for the automated detection of anomalies in the movement and behaviour of tagged fish. This automated detection approach not only saves time but also improves the reliability of data analysis, enabling researchers to focus on interpreting findings.

Methods

Dusky kob (*Argyrosomus japonicus*) is an important coastal fishery species with a South African distribution along the southeast coast from Cape Point to northern KwaZulu-Natal) (Griffiths and Heemstra 1995). This species is both a prized recreational angling species but also one of the most popular species targeted by small-scale fishers throughout their distribution. It also has biological characteristics which make it extremely vulnerable to overexploitation, including late maturation and slow growth. As a result of intense overexploitation, this species is now considered collapsed, with current spawner biomass per recruit estimated to be between 1.5 and 4% of pristine levels. Juveniles are dependent on estuaries as nurseries, but adults have also shown to spend extensive periods of time within these systems. Given their long-term residency to estuaries (as both juveniles and adults), and their wide-scale use of most estuaries in which they occur (i.e. lower to upper reaches) (Næsje et al. 2007, Cowley et al. 2008, Childs 2013, Childs et al. 2015), acoustic telemetry data of dusky kob collected in estuaries form the ideal time series dataset for ML and DL model training. Between 2016 and 2021, 50 dusky kob, ranging in length from 660 to 1720 mm total length (TL) (average ± 279 mm TL) were caught and tagged with individually coded acoustic transmitters (V13 and V16 69 kHz, Innovasea, Halifax, Canada). The movements of the tagged dusky kob were monitored using an array of 16 acoustic receivers strategically placed along the large permanently open Breede Estuary situated in the Western Cape Province, South Africa between 2016 and 2021. Over this five-year period, the dataset accumulated more than three million individual detections, representing extensive movement data for these fish.

These detection data were then incorporated into ML and DL models, including neural network autoencoders (NN-AE) and traditional models such as Isolation Forest Local Outlier Factor (LOF), and Density-Based Spatial Clustering of Applications with Noise (DBSCAN). Pre-processing this large dataset involved several important steps. First, cleaning was required to remove noise and duplicate detections often caused by environmental factors such as signal collisions. The data were then normalized to ensure consistency across all entries, and additional features were developed to improve the performance of the model. These included variables such as the duration at a single station, the number of stations visited, and the time spent at each station. This feature engineering was crucial for isolating patterns that could indicate potential anomalies, such as fish staying at a single station for an extended period of time, or missing detections at consecutive stations, which may signal tag malfunction, mortality or other issues. The dataset was split into training, validation, and test sets, ensuring a robust evaluation of model performance. Anomalies were identified based on specific criteria, such as unusually long stays at a single station or unexpected gaps in detection, and these were manually labelled. The NN-AE model was then trained to detect such anomalies by learning the normal movement patterns of dusky kob. In parallel, traditional unsupervised models, including Isolation Forest (IF), Local Outlier Factor (LOF), and DBSCAN, were also employed and their performances compared to the NN-AE model.

Results

Overall, all 50 kob were detected at least on once, together accumulating 3013930 detections. The average number of detections recorded per individual was 60278 (± 63276), ranging from 23 to 259676 detections, and individuals were detected for an average of 184 (± 217) days throughout the monitoring period, ranging from 2 to 1061 days (Table 1). The average number of detections recorded per day ranged from 11 to 854 average ± SD: 336 ± 128).

The results showed that the NN-AE model significantly outperformed traditional ML models in terms of accuracy, precision, recall, and F1 score, and was able to capture complex temporal dependencies in the data, something the traditional models struggled with, leading to higher false positive and false negative rates (Chen et al. 2021, Schindler et al. 2023). The model’s ability to learn and distinguish normal movement patterns allowed it to pinpoint anomalies more effectively. These included irregular fish movements or prolonged stays at certain stations, which may have indicated potential tag malfunction, unnatural fish behaviour, mortality or ecological shifts. The accuracy of the NN-AE model exceeded 90%, a marked improvement over models like DBSCAN, LOF and IF, which struggled to capture the complex movement patterns of dusky kob due to their inability to handle temporal dependencies effectively (Benova & Hudec, 2024).

Despite the NN-AE model’s high accuracy, challenges remained in identifying anomalies that exhibited slow, gradual deviations from expected patterns. For example, changes in movement behaviour that occurred over an extended period were not always detected by the model. To address this limitation, data augmentation techniques were applied, including resampling the dataset at various rates. This resampling allowed the model to better handle these slow-developing anomalies and significantly improved its ability to detect more subtle deviations from normal behaviour. The application of these augmentation techniques demonstrates that while the NN-AE model was highly effective, there is still room for improvement. Specifically, future iterations of the model could incorporate attention-based techniques with a larger dataset combined with LSTM which are better equipped to recognize long-term dependencies and gradual changes in movement patterns. This refinement would likely improve the model’s sensitivity to these types of anomalies, making it even more useful for ecological research.

Conclusions

The results show that the NN-AE model is a robust tool for the automatic detection of anomalies in acoustic telemetry data. Its ability to process large, complex datasets with high accuracy makes it suitable for ecological studies that require detailed analysis of animal movements and behaviour. However, the NN-AE model also has its limitations, particularly in detecting anomalies that gradually deviate from expected patterns. Such deviations could be important indicators of environmental changes, species health status or behavioural changes. Therefore, future efforts should focus on refining the sensitivity of the model to such subtle anomalies. A promising direction is the integration of memory-based techniques such as Long Short-Term Memory Autoencoders (LSTM-AE), which could improve the model’s ability to recognize long-term dependencies and slow changes in movement patterns. In addition, exploring adaptive thresholds and more sophisticated data augmentation techniques would likely improve the robustness of the model.

Beyond improving detection accuracy, future research could also explore the application of NN-AE models in different environments and species to provide broader ecological insights. Extending the datasets to different habitats, environmental conditions and species will improve the generalizability of the model and ensure its applicability in different aquatic ecosystems. In addition, the integration of real-time anomaly detection capabilities would enable a more dynamic and immediate response to changes in aquatic species behaviour, making this tool invaluable for conservation management. Overall, with further refinement and extension, the NN-AE model can serve as a foundation for more effective and efficient ecological monitoring and detection of anomalies in acoustic telemetry data.

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2. LIFE HISTORY AND ECOLOGICAL STUDIES

Mapping essential fish habitats of seventy-four *Polysteganus undulosus*

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Mapping marine biodiversity is essential and underpins the marine spatial planning process and the implementation of representative networks of protected and conserved areas. Essential fish habitats are the waters and substrate necessary for a fish to reproduce, grow and feed. Knowledge on the benthic habitats and invertebrate communities that support the life history of threatened reef fish species such as *Polysteganus undulosus* is known anecdotally but not identified or described using empirical evidence. This study aims to map the essential habitat for *Polysteganus undulosus* on the eastern continental shelf of South Africa. Archived remote underwater camera imagery will be processed and computer vision will be leveraged to optimise image processing efficiency for benthic invertebrate communities and a reef fish. The objectives are threefold. The first objective will be to build and use computer vision models for *P. undulosus* and transferring the models between remotely operated vehicle images and BRUV. The second objective will be to use computer vision to map benthic invertebrate communities (habitats) from remotely operated vehicle imagery. The third objective will combine the outputs from the computer vision models and habitat mapping exercise to identify, describe and map the essential fish habitats of *P. undulosus*. It is anticipated that this project will advance the understanding of habitat and benthic invertebrate community affinities of this threatened linefish and present a model that can be applied to other priority fish species in South Africa. The outputs of this project will also be relevant to offshore marine protected area management and expansion in South Africa.

Life history traits of the false jacopever *Sebastes capensis*

Taahir Mohamed (UCT), Colin Attwood (UCT)

Background
The genus *Sebastes* (rockfishes) is a group of live-bearing (viviparous) marine scorpionfish represented by at least 110 species worldwide. These fishes are morphologically diverse and cover a range of niches on cold temperate continental shelves. Benthic species are characterised by bright colouration, deep and robust body forms, and prominent head spination, whereas pelagic species tend to be dull and elongated with reduced spination. Generally, rockfishes are slow-growing and late-maturing fish, and some species (such as the yellow-eye rockfish, *Sebastes ruberrimus*) may be extremely long-lived and have been aged to over 120 years old. The vast majority of rockfish are found in the North Pacific. Four species are found in the North Atlantic, and only two in the southern hemisphere, of which *Sebastes capensis* (the false jacopever) is the only South African member.

Sebastes capensis is found from the west coast of South Africa (Cape Point to Orange River Mouth Delta) to the islands of Tristan da Cunha and Gough, and across the South Atlantic to the Argentinian coast and Falklands Islands, where they are sympatric with *Sebastes oculatus*. These two rockfish were once considered to belong to the *S. capensis* species complex until proven genetically distinct in 1999. The confusion between the two species off South America led to the false notion that *S. capensis* occurred off South America's western coasts, and references to this species from this region are now considered erroneous.

The false jacopever gets its name from its similarity to and confusion with the jacopever, *Helicolenus dactylopterus*. Although both species are reddish coloured scorpionfish, *S. capensis* is discernible by the 5 to 6 pale blotches on the upper part of its body, as well as being a more reddish-brown colouration once dead, while *H. dactylopterus* tends to have a more orange colouration. The two species are exploited by different fisheries, largely as a result of their difference in depth preference. *S. capensis* is found from 20 m down to perhaps 200 m, but is most common above 100 m. They are caught almost exclusively by hook and line in the recreational sector and as bycatch in the snoek and cape bream handline fishery. *H. dactylopterus* is a deeper dwelling species, most abundant from 200 to 500 m, and is a common bycatch in the demersal trawl sector.

The name 'jacopever' comes from the name of a Dutch ship captain of the 1700s, Jacob Evertson, who was said to have a striking resemblance to this fish being caught in the Cape. There is evidence to suggest that *S. capensis* was the original 'jacopever', because in the time of Jacob Evertson trawling was non-existent in the Cape, and so *H. dactylopterus* were quite a rare catch in comparison to the more common line-caught S. *capensis*. The confounding of these names occurred during the late 1900s, when the advent of industrial scale trawling off South Africa put vast tonnages of *H. dactylopterus* on the market. We suspect that the jacopever name was usurped for the marketing of *H. dactylopterus*. The prefix "false" was later incorrectly attributed to *S. capensis*.

Methods
As a result of its long history of confusion with *H. dactylopterus* and *S. oculatus*, very little is truly known about *S. capensis*. We aim to describe the life-history of this important reef fish on South Africa's west coast. Biological data were extracted from 269 specimens collected by hook and line from Table Bay and Hout Bay, and were used to describe the morphology, growth, reproduction, and feeding habits of the species.

Results
Total lengths (TL) ranged from 205 to 372 mm, with a mean of 287.95 (±3.67 SD) mm TL for females and 310.1 (±2.32 SD) mm TL for males. Total body weight (W) ranged from 150.9 to 917.5 g, with a mean of 465.72 g (±18.85 SD) for females and 543.73 g (±11.51 SD) for males. The length-weight models indicated hyper-allometric growth for female fish ($W = 5.08 \times 10^{-6}\ TL^{3.23}$), while that of males

and all fish was determined to be isometric ($W = 1.39 \times 10^{-5}\,TL^{3.04}$ and $W = 1.57 \times 10^{-5}\,TL^{3.02}$, respectively). Fish ranged from 3 - 23 years old. Differences between von Bertalanffy growth models (VBGM) fitted to female and male data were determined to be statistically significant ($\chi2 = 5.64$, df = 3, $p < 0.001$), and so separate growth models for each sex were selected over a combined growth model. The best fit VBGM for females was $TL = 358.1 \times (1 - e^{-0.105}\,(t + 5.70))$, and that for males was $TL = 355.4 \times (1 - e^{-0.138}\,(t + 3.21))$.

The overall sex ratio of females:males was 1:2.68, which differed significantly from 1:1 ($\chi2 = 56.24$, df = 1, $p < 0.00001$). The sex ratio differed between the two localities ($\chi2 = 2.17$, df = 1, p = 0.14 and $\chi2 = 57.26$, df = 1, $p < 0.00001$, respectively) (In Table Bay it was 1:1.56 ratio and in Hout Bay it was 1:3.05. Length at 50% maturity for female and male fish were estimated to be 251.2 mm and 216.3 mm, respectively (approximately 6 and 4 years old, respectively). The smallest mature female was 240 mm and the smallest mature male was 215 mm; both of these fish were estimated to be 4 years old. Trends in seasonal GSI and the frequency of reproductively ripe fish point towards a reproductive season extending from the start of winter into early spring. The presence of both eyed-larvae and unfertilised eggs inside the ovaries of pregnant specimens point towards a multiple brooding reproductive strategy, likely producing 2-3 broods per reproductive season. Batch fecundity was estimated to be between 50 000 – 100 000 embryos and appeared to be positively correlated with the size of the female.

Sebastes capensis have large mouths lined with hundreds of tiny villiform teeth, adapted for grasping and swallowing prey whole. The great overall diversity of prey observed, as well as the high proportion of specific prey species within certain sampling trips, point towards the false jacopevers opportunism in feeding. A total of 38 different prey species were identified, including 19 species of crustacean and 14 species of fish. Diet was found to primarily consist of Malacostraca (79.6%), with fish only making up 17.3% of the total prey items. The single most important prey species was the cape mantis shrimp, which alone accounted for a third of all prey in stomachs. The high proportion of crustacean prey is likely a result of the close association of S. capensis to the benthos. Small pelagic species (such as anchovy and sardine) made up the bulk of fish prey, although they all came from a single sampling trip, while The most commonly occurring fish prey were juvenile hake, but one sample fish were dominated by small pelagic fishes.

Conclusions
The findings of this study point towards *S. capensis* being a slow growing, late maturing and opportunistic benthic predator, making the species potentially vulnerable to overfishing, as is the case with many *Sebastes*. There currently exists no stock assessment or specific fishing regulations for the species, and the extent to which they are currently exploited is largely unknown. More research is thus required to inform the future sustainable management of the species.

An assessment of physiological metrics to inform the classification of phenotypes within fish populations, using dusky kob *Argyrosomus japonicus* as a case study

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Background

Climate change is a major driving factor in the redistribution of species across the globe. The overall global trend of ocean warming has already driven fish distribution to higher latitudes and deeper depths. This shift in fish distribution can have several negative implications on coastal communities that rely on these fisheries as a source of food and income. The South African linefishery is comprised of several different sub-sectors, including boat-based commercial and recreational sectors and shore-based recreational and small-scale sectors. The shore-based recreational fishery is the largest of these sectors with roughly 340 000 participants. Their activities generate roughly R9.7 billion per year in economic activity, of which approximately 6% benefits low-income households (Potts et al. 2022).

South Africa's coastal marine ecosystems are threatened by multiple anthropogenic stressors including the exploitation of renewable and non-renewable resources and their associated impacts. These impacts are aggravated by ever-increasing pressures of climate change, such as ocean acidification, increasing global sea surface temperatures, and intensifying of upwelling events. Anthropogenic pressures combined with climate change are thought to have serious negative implications for coastal fish populations in South Africa. Since coastal fisheries are important socially, economically, and ecologically, their sustainability directly impacts coastal communities that rely on these fisheries for a livelihood.

As ectotherms, fishes will respond rapidly to changes in coastal temperatures. The first response of fishes to thermal change is normally behavioural, however, we have limited information on the response of wild fishes to changing thermal conditions. However, advanced techniques, such as biotelemetry has allowed scientists to track fish in their natural environments providing important information such as movement ecology, and the response to changes in environmental conditions. While this technique provides valuable information, it is not able to determine the mechanisms driving the observed patterns. To understand the mechanisms driving fish behaviour, it is necessary to link the behaviour in the wild with the physiological attributes of individual animals. However, clear methodologies to do this have been elusive.

This project aimed to develop appropriate laboratory techniques for rapidly assessing the physiological attributes of individual fish without compromising their health prior to an acoustic telemetry study. Importantly, the physiological technique should provide information with which to categorize the physiological phenotype of an individual before it is tagged.

The dusky kob, *Argyrosomus japonicus* (Sciaenidae), was selected as a candidate species because it was available from a hatchery (Kingfish Enterprises) and has shown extensive diversity in behaviour in the wild. The distribution of *A. japonicus* spans temperate and subtropical coastal waters across the Indo-Pacific region. In South Africa, it is primarily found between Cape Agulhas and the Mozambique border. *A. japonicus* has a complex life history, which includes marine spawning, recruitment into estuaries, increasing utilization of the marine environment with maturity and partial migration to spawning grounds in KwaZulu-Natal. It is a prized species amongst recreational and commercial fishermen and a critical component in the catch of small-scale fishers, especially in estuarine systems. Like several of South Africa's coastal fishery species, the wild populations of *A. japonicus* have been categorized as collapsed. With the population increasingly facing extreme temperatures associated with a changing climate, the identification of methods to identify the mechanisms driving behavioural change in this species is necessary not only to further our scientific knowledge and make predictions of expected change, based on future scenarios, but is critical for understanding the expected consequences for the coastal communities dependent on this species for their livelihoods.

Methods
A total of 40 juvenile dusky kob were obtained from Kingfish Enterprises in East London and transported back to the SAIAB's Aquatic Ecophysiology Research Platform housed at Rhodes University. All specimens were housed in two separate cylindrical holding tanks (5900l each) where water temperature was maintained by a heat pump set at 18°C. An air conditioner was used to maintain the ambient air temperature at 18°C. Water quality parameters were monitored daily which included dissolved oxygen, ammonia, nitrite and nitrate.

To test the relationship between different physiological metrics, each fish was subjected to thermal tolerance and respirometry trials. Thirty fish were selected from the original 40 and randomly split into two groups (Batch A and Batch B) and housed separately in the two 5900L tanks. For individual identification, each fish was tagged with a passive integrated tag (PIT) and was given a colour coded (either red, blue or white) spaghetti tag for visual identification. Both batches were fed every second day, with a formulated pellet feed acquired from Kingfish Enterprises.

During thermal tolerance trials, three fish of different tag colours, (red, blue, and white) were housed in each experimental tank. Fish were housed in groups of three to examine their behavioural responses as a shoaling species. The rate of temperature change was set to simulate a marine upwelling or downwelling experienced in the wild at 1°C per hour. At each degree change the opercular beats (OB) rate was measured as beats per minute and was recorded for 5 min for each individual using a GoPro camera attached to each of the experimental tanks. The Gopro Quik mobile app was used to remotely turn the cameras on and off to ensure the fish were not influenced by human interaction. Once the temperature extremes approached (above 30°C and below 9°C). A team of volunteers monitored their behaviour closely from a distance, noting any signs of distress of instability, such as erratic swimming, or loss of equilibrium. Once these signs were observed, the fish was removed from the tank using a silicone landing net, where the time and temperature was recorded.

During respirometry experiments, the rate of oxygen consumption was recorded every five seconds over a 15-minute measurement period followed by a 15-minute flush period at 18°C. At 12°C the measurement period was adjusted to 20 minutes followed by a 10-minute flush period. At 24°C the measurement period was adjusted to 5 minutes followed by a 15-minute flush period. The oxygen measurements for SMR were taken at night between 11PM and 5AM when fish were less active and not disturbed by human activity. Once SMR trials were terminated, individual fish were removed and placed in a well-oxygenated seawater tank where it was then chased with a net for 10 minutes and exposed to air for 30 seconds before being returned to the respirometer where oxygen concentrations were measured immediately for eight minutes. Following this eight-minute measurement period, the flush phase was turned on and fish were left in the respirometers for a further 4 hours until they had recovered from the MMR procedure. Following this, individuals were removed from the respirometers and placed in their housing tanks. The empty respirometers were then sealed, and oxygen was measured for three hours after each MMR measurement to account for any background respiration.

Results
The CTmax of individuals ranged from 31.7°C to 33.7°C with a mean of 32.7°C. The CTmin of individuals ranged between 7.5°C and 8.6°C with a mean of 8.2°C. Thermal breadth among the sampled fish ranged between 23.3°C and 26°C with a mean thermal breadth of 24.5°C. there were no significant difference between fish length and thermal breadth (P>0.05). Opercular beat (OB) rates ranged from 6 beats min^{-1} at 11°C to 107 beats min^{-1} at 33°C A piecewise linear breakpoint analyses indicated there was departure from linearity at 12°C and 30°C . A slight increase in OB rates was recorded below 12°C where signs of thermal stress such as loss of coordination, decreased movement, and occasional surface bobbing was observed. These activities continued and got progressively worse until CTmin was reached. Opercular beat rates above 28°C increased rapidly in conjunction with increased swimming activity and decreased orientation until CTmax was reached.

The SMR of *A. japonicus* ranged from 0.265 to 1.848, 0.807 to 2.749, and 1.511 to 4.672 O2 mg. min^{-1} $.kg^{-1}$ at 12, 18 and 24°C respectively. The MMR of *A. japonicus* ranged from 2.009 to 3.122, 3.062 to 5.54, and 4.82 to 6.216 O2 mg. min^{-1} $.kg^{-1}$ at 12, 18 and 24°C respectively. The AS of *A. japonicus* ranged from 0.862 to 2.508, 0.797 to 3.84, 1.191 to 4.121 O2 mg. $min^{-1}.kg^{-1}$ at 12, 18, and 24°C, respectively.

Conclusions

Although the construction of an aerobic scope curve provides an excellent technique to categorise individual physiological phenotypes, the traditional respirometry techniques required to do this are highly stressful and time-consuming. In contrast, the CTmin and CTmax experiments are shorter in duration but stress the fish because they are required to lose equilibrium. The next step will be to determine whether there are relationships between the AS curve and any of the more benign measurement metrics (e.g. opercular beat breakpoint, SMR) for individuals. If these metrics are related and can be used to accurately classify the physiological phenotype of individuals, they can be incorporated into the methodology for linking physiology and wild behaviour of fishes.

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Seagrass density and macroalgal heterogeneity influence nursery quality for sparids in nursery seascapes

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Recruitment is a critical process in regulating fish populations, with the proximity and availability of nursery habitats linked to adult fish abundance of certain reef fish species (Wilson et al. 2017). As such, identifying essential habitats used by the early-life stages of fishes is increasingly important in the ecosystem-based management of fishery species. Within coastal seascapes structurally complex habitats are important as nurseries for many marine fish species, with much of the three-dimensional structure important for nursery provision in temperate seascapes provided by macrophytes (aquatic plants large enough to be seen by the naked eye), with seagrass providing structure on soft sediment and macroalgae providing structure on rocky reefs.

Juvenile fish are thought to actively use/select habitat within nursery seascapes based on food availability and predation risk, with high quality nurseries providing both shelter and food for juveniles. The nursery function of seagrass is well documented, with seagrass meadows providing important nursery habitat to over one fifth of the world's fishery species (Unsworth et al. 2019). Although less well documented, canopy-forming macroalgae may perform a similar nursery function to seagrass (James and Whitfield 2022). However, not all seagrass and macroalgal habitats function equally as nurseries for particular fish species on a local or regional basis. For example, plant cover (or density), canopy height (which is often dependent on the species of macrophyte present) and heterogeneity (variety of species and functional forms) all affect nursery quality in terms of provision of food and shelter (reviewed in James and Whitfield 2022).

We used a multi-disciplinary approach to focus on the nursery function of littoral habitats dominated by submerged macrophytes (seagrass and red algae) in warm-temperate South Africa for several sparids exploited in the shore-based linefishery and habitat features that determine high quality nursery habitat (James et al. 2024; Mkhize et al. 2024; Welch et al. 2024).

Stereo remote underwater video systems (sRUVs) as well as habitat complexity indices (density, canopy height, leaf/blade width and fractal dimension) were used to examine nursery use of eelgrass *Zostera capensis* and canopy-forming *Plocamium corallorhiz*a beds by juvenile fish in the Algoa Bay shallow water seascape (Swartkops Estuary and a shallow (< 2 m), sheltered rocky cove). Although the two macrophyte habitats had a similar density, canopy-height was greater in *Z. capensis* beds and fractal dimension (shape complexity) and leaf/blade width greater in *P. corallorhiza* beds. *Plocamium corallorhiz*a beds had a higher juvenile total abundance, dominated by young-of-the year sparids (particularly *Diplodus capensis* and *Sarpa salpa*). Although total juvenile abundance was lower in *Z. capensis* beds, the abundance of the estuarine-dependent sparid *Rhabdosargus holubi* (all young-of-the-year recruits) was higher in *Z. capensis*. Exhibited behaviours by juveniles in both habitats were dominated by slow meandering and feeding, behaviours associated with a high level of habitat use. In terms of species composition, fish communities were different and *P. corallorhiz*a beds had a higher species richness compared to *Z. capensis* (detailed in Mkhize et al. 2024).

Differences in species composition (abundance and richness) may be associated with high habitat heterogeneity in macroalgal sampling sites. In contrast to seagrass beds, which are often overwhelmingly dominated by one macrophyte species, on sublittoral reef several different macroalgal species may occur offering a variety of resources, camouflage and refuge spaces (Mkhize et al. 2024). Macroalgal heterogeneity (patchiness and variety of functional forms) plays an important role in nursery provision in coastal seascapes, with macroalgal habitats comprising several functional forms (a mixture of canopy and understory taxa) having the potential to support higher juvenile diversity and abundance rather than a single homogeneous habitat type covering the same area; with this linked to both shelter (protection from predation) and food provision (James and Whitfield 2022). The importance of both macroalgal heterogeneity and specific macroalgal species or morphotypes to different fish species is still, however, poorly understood.

The rocky cove in Algoa Bay is comprised of a mosaic of two main benthic habitats; *P. corallorhiza* beds on rocky outcrops (high profile reef) and flat reef (low profile reef) dominated by low growing algae morphotypes, allowing us to assess the importance of different algae species and morphotypes in nursery provision (food and shelter) for juvenile sparids within the cove (detailed in James et al. 2024). We assessed macroalgal communities and the trophic ecology (stomach contents and isotopes), abundance and size structure of *D. capensis* and *S. salpa* in the two different benthic habitats and the resources/food associated with the dominant macroalgae species/morphotypes. Ten macroalgae species/morphotypes were found to occur on high profile reef and six on low profile reef. *Plocamium corallorhiza* was found predominantly on high profile reef, with *Laurencia* spp. (foliose algae) and coralline algal turf dominating the algal cover on low profile reef patches.

Within this habitat mosaic resources (epiphytes and macroinvertebrates) were more abundant in the non-canopy forming low growing macroalgae (*Laurencia* spp. and coralline algal turf) and these algae were also assimilated in the diets of both sparids. The assimilation of *Laurencia* and coralline turf over other algae in both sparids may point to the high nutritional value and availability of carbohydrates from *Laurencia* and coralline turf. Canopy forming *P. corallorhiza* on high profile reef although not a major component of the diet of either species offers more refuge from predation (both in terms of cover and height) than low growing *Laurencia* and coralline turf algae, which together dominate low profile reef. Although recently recruited (young-of-the-year) sparids were abundant on low- and high-profile reef, the herbivorous *S. salpa* dominated the fish assemblage in the high-profile reef and the omnivorous *D. capensis* on the low-profile reef. The high abundance of both juvenile *S. salpa* and *D. capensis* in high profile and low-profile reef, suggests that within this mosaic of habitats these species may be using canopy-forming algae in the high-profile reef for shelter and non-canopy forming algae in both the high- and low-profile reef for food. This shows that macroalgal habitats comprising several morphotypes have the potential to support higher juvenile diversity and abundance through both food provision and shelter.

Within a homogenous vegetation type, such as seagrass, habitat complexity is an important determinant of fish assemblage structure. For example, high density seagrass often has a higher abundance, biomass and species richness of fish than sites with less dense seagrass (detailed in Welch et al. 2024). In the laboratory, we used artificial vegetation units (AVUs) to test habitat choice (dense seagrass (*Z. capensis*), less dense saltmarsh (*Spartina maritima*) or sparse *Z. capensis* and habitats with no complexity e.g. sand flats.) for *R. holubi*. *R. holubi* is one of only a few vegetation-associated marine fish species in South African estuaries. We found that *R. holubi* significantly prefer dense seagrass over less complex habitats (sparse seagrass/saltmarsh and sand), in both the absence and presence of a predator and for both small and large juveniles, showing that *R. holubi* actively chose more complex structure and are attracted to the structure per se irrespective of the threat of predation or the availability of food. This highlights the importance of dense seagrass as nursery areas for this species and demonstrates how the loss of these habitats could impact the nursery function of estuaries (detailed in Welch et al. 2024).

The location of sparid nursery habitats at the interface between the terrestrial and aquatic environment makes these habitats particularly vulnerable to anthropogenic impacts. Loss or modification of habitat features that promote juvenile fitness may ultimately impact adult population viability.

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The long-term growth rate changes of west coast steenbras (*Lithognathus aureti*) caught by anglers off Namibia

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Scientists agree that climate change is affecting the entire planet, including both land and sea (Denechaud et al. 2020). However, how these changes impact the biology and ecology of marine life is often not well understood due to a lack of long-term data. Otolith biochronologies allow us to reconstruct long-term growth series from otoliths in the absence of the collection of past biological data and assess the response of marine fish populations to environmental variability and fishing pressure simultaneously. With Namibian water being home to the highly environmentally variable Benguela current system which is impacting individual physiology, growth and survival of the marine species in this area it is essential to document the physiological responses of species within this area to be able to predict potential consequences of climate change. Linefish research in Namibia seemingly only recently picked up again with a lot of focus on *Argyrosomus inodorus* (locally known as silver kob / kabeljou (Pringle et al. 2023, Jagger 2023). It is important that the other species such as West coast steenbras' growth responses to the highly varying BCLME's environmental conditions are documented as well. The West coast steenbras (*Lithognathus aureti*), is a marine linefish species endemic to southern Africa and mostly found within Namibia (Holtzhausen & Kirchner 2001a). They inhabit the surf-zone of the Namibian coast and are rarely found deeper than 10 m (Van der Bank & Holtzhausen 1998; Holtzhausen & Kirchner 2001b). A few studies were conducted during the late 1990s on West coast steenbras, and no known study has been published on the species since then despite being the second most targeted species in the linefish sector. Consequently, given the lack of long-term biological data and gaps in knowledge such as the current status of the stock and its response to a highly variable and warming environment in the northern part of the northern Benguela, this study therefore aimed to use annual otolith growth increment width measurements, as a proxy of growth variability to study the effect of environmental variables (SST and upwelling) and catches and catch-per-unit effort on the annual growth variability of Namibian West coast steenbras.
Historically collected fish otoliths from the years 1995-1998 were obtained from the Ministry of Fisheries and Marine Resources (MFMR) archives. These otoliths were collected in a previous study conducted by Holtzhausen and Kirchner. The collection included otoliths from both northern Namibia (1995-1998) and southern Namibia (1995-1996). Additionally, random and opportunistic samples were collected from recreational anglers at fishing competitions. Otoliths were gathered from locations spanning from the Kunene River mouth up to Meob Bay, covering the period from August 2022 to August 2023. In addition to these recent samples, otoliths collected in 2021-2023 from another study conducted by a Master student, Arariky Shikongo, were also used. Shikongo's study focused on assessing the growth rate of West coast steenbras in Meob Bay, specifically within a closed pristine area. The total sample size for this study included 384 fish sampled along the Namibian coast. Of these, 126 otoliths were collected from fish in the north, ranging in fork length (FL) from 21 to 89 cm. In contrast, 258 otoliths were collected from fish in the south, with fork lengths ranging from 26 to 67 cm.

For the otolith chronology, growth increment width of 241 otoliths (North = 103, South=138) were measured on photographs of the cross section of the otolith from the dismal end of one translucent zone to the dismal end of the following translucent zone using an image processing package ImageJ. To determine the age of a fish from its otolith, growth increments, constituted by one translucent zone and one opaque zone, were assigned to a growth year. This was done by back-calculating from date of capture starting at the edge of the otolith to the centre. Subsequently, estimates of Age by calendar year, age-at capture, and year class (Cohort) were designated. This was done using the automated age-reading plug-in from the ImageJ macro ObjectJ, which allowed for the counting and measuring of annual growth increments on the otolith. The measurements were converted to mm by a different pixel-to-mm ratio for each microscope and each magnification. The number of translucent zones were counted and then validated by an experienced reader to minimize possible reader bias. If no consensus was reached or the zone pairs were not clearly defined, the sample was discarded. The mean annual otolith growth (from increment width measurements) was calculated for *L. aureti*. Prior to the modelling, otolith increment width in mm (Inc), Age (at increment formation) and Age-at-capture (AAC) were log-transformed (Morrongiello & Thresher, 2015). This was done to satisfy the model assumptions. To relate the increment width (Inc), which is also the response variable, linear mixed effects models were performed in R to test for intrinsic (individual-specific) and extrinsic (environmental and catch-per-unit-effort [CPUE]) sources of variation for the *L. aureti* annual growth rates (e.g. Morrongiello & Thresher, 2015; Wilhelm et al. 2020). Intrinsic factors included Age, AAC, Sex (either male or female or unsexed), allowing for the interaction between Age and Sex, and FishID (each specific fish had a unique identification). The Age, AAC and Sex were treated as fixed intrinsic effects. The intrinsic factors Cohort, Area (North or South) and Year (of increment formation) and FishID were treated as random effects. A method modified from Morrongiello and Thresher (2015) was used to test for the best possible combination of the explanatory variables, testing all possible combinations of fixed effects and random effects, and intercept or slope for random effects (Morrongiello & Thresher, 2015). The lowest Akaike's Information Criterion (*AIC*) corrected for small sample sizes (AICc) was used to select the most parsimonious model – fitted with maximum likelihood. To produce the best linear unbiased predictor of annual otolith growth (BLUP). The 64-year (1960–2023) BLUP, developed from mixed linear models of mean annual growth (mm) calculated from 1491increment measurements, was compared to sea surface temperature (SST) and upwelling (wind) indices as well as annual CPUE and total catches to indicate which factors significantly influence growth variation of West coast steenbras.

There was a positive correlation between the growth rate and SST from south and central areas in February to April, and March to May, respectively ($r = 312$, $p > 0.05$, $n = 41$). Unlike, the trend observed in *A. inodorus* by Jagger (2023) where significant positive growth was observed with cooler temperatures. This was augmented by Pringle (2024) that reported the thermal threshold for the species to be between 15 and 17 °C. Although there was no significant correlation between the upwelling index and growth, an overall positive correlation was observed for the northern, central and southern regions during June and July (Winter). No relation with southern oscillation index or steenbras CPUE. In conclusion, temperature seemed to be the most influential on the growth of West coast steenbras rather than other external factors such as upwelling and fishing pressure. However, a concern now would be whether a further increase in temperature would eventually negatively impact its growth and whether the species, like its co-target species, sliver kob also has a thermal threshold. Otolith chronologies proved as a promising monitoring tool of consequences of changing environmental conditions on the linefish species of Namibia.

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3. MONITORING ESTUARIES AND MARINE PROTECTED AREAS

Unravelling the mystery of a unique giant kingfish *Caranx ignobilis* aggregation in the Mtentu Estuary

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A globally unique and unexplained recurring summer aggregation of up to ~1 000 giant kingfish *Caranx ignobilis* in the surface waters of South Africa's Mtentu Estuary, which forms part of the Pondoland Marine Protected Area, has warranted investigation for both scientific intrigue and management purposes. With the aim of understanding various aspects of their movement patterns, 10 individuals ranging from 430 to 1030 mm fork length were tagged with acoustic transmitters in the estuary and subsequently monitored by passive acoustic receivers in the estuary and adjacent coastal environment for up to 3.6 years. Results showed clear patterns, including repeated daily migrations between the upper estuary (~4km upstream) during the day and the sea or mouth region at night. Statistical modelling revealed that sea temperature was the main environmental variable influencing their daily presence/absence in the estuary. During summer, the daytime temperature in the surface waters of the deep and thermally stratified Mtentu Estuary may be 3 to 6 °C warmer than subsurface waters, providing a more suitable thermal environment for this tropical to subtropical species. Notwithstanding the possibility of other drivers, we propose the hypothesis that adult *C. ignobilis* utilise the near pristine Mtentu Estuary during periods of cold coastal upwelling primarily as a thermal refuge, specifically for daily re-warming after nocturnal feeding in cold water. The maintenance of this site as a no-take (no fishing) zone, as well as encouraging tourism-linked incentives to increase local custodianship, are strongly recommended to protect this vulnerable aggregation.

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Port Ngqura: Concrete seascapes and the fish that took advantage of them

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The Port of Ngqura, located 20 kilometres east of Gqeberha (previously known as Port Elizabeth), underwent significant transformation through extensive dredging of the Coegha River mouth, resulting in its completion in April 2006 and operational status by the end of 2009. This development has created a diverse range of microhabitats within the port including dolosse, rock armour, shallow profile reefs, vertical quay walls, and a small sandy beach at the mouth of the Coegha River. The incredible diversity of fish species recorded within the Port bears no resemblance to what previously existed along this coastline. These species likely utilise the warmer, calm, deep waters of Port Ngqura, where adjacent shores are typically rough. A long-term dart tagging programme has produced a massive dataset and shown incredible biodiversity in this artificial man-made seascape. A total of 12987 catches have been recorded across 71 species, with 7722 of those fish tagged. Port Ngqura has become a significant habitat for fish species, serving diverse roles. These roles include enhanced estuarine services, open niches, nursery habitats, and refuge during unfavourable conditions in Algoa Bay. Visual observations and the use of stereo-BRUVs continue to add to the species list and our understanding of why fish species have identified Port Ngqura as a critical habitat. Overall, the Port of Ngqura presents a compelling case study of how human-made alterations to coastal environments can profoundly impact local marine biodiversity, particularly for at-risk species. Understanding the dynamics and ecological roles of linefish within an artificial seascape is crucial for informed conservation efforts in the face of changing coastal landscapes.

Linefish species in the Algoa Bay estuarine to marine seascape: Nursery areas and their response to low dissolved oxygen events

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Assessing fish distribution and abundance across estuarine and marine nearshore habitats is vital for identifying ecologically important nursery habitats and developing effective management strategies for coastal fish populations, many of which are important fishery species. Although these coastal ecosystems serve as important nursery areas, they are vulnerable to stressors such as changes in climate and anthropogenic perturbations, all of which lead to environmental degradation and a loss of valuable ecosystem services (van Niekerk and Turpie 2012). Pollution from human settlements as well as agricultural and industrial activities is a major cause of deteriorating water quality in estuaries (Freeman et al. 2019, Adams et al. 2020). An increase in anthropogenic nutrient loading leads to eutrophication which has negative effects on the ecological functioning of estuaries and can result in increased macro and microalgal biomass, harmful algal blooms (HABs), and dissolved oxygen depletion (e.g., hypoxia). Hypoxia is a major threat to the functioning of coastal ecosystems, particularly estuaries.

This study assessed the soft-bottom benthic shallow-water seascape in Algoa Bay (inclusive of the Swartkops, Sundays and marine nearshore) to determine core nursery hotspots for demersal linefish species. In addition, given the ever-increasing anthropogenic pressures facing our fish resources within coastal habitats, with the two study estuaries (Swartkops and Sundays) being heavily polluted, the effect of hypoxia and associated shifts in the spatial distribution of fish species was also investigated.

Soft-bottom habitats in both the estuaries and the nearshore were dominated by early-life stages (postflexion larvae, settlement stage and young-of-the-year fishes), but a significantly greater density of early-life stage fishes was found in the estuarine environment, highlighting the importance of estuarine habitats for linefish within the Algoa Bay nursery seascape. Settlement and nursery habitats also differed by estuarine-association, with the marine nearshore environment dominated by marine and marine estuarine-opportunists, with core settlement and nursery areas for these species located close to estuary mouths, freshwater outlets and harbours. In contrast, the estuarine environment was dominated by marine estuarine-dependent and estuarine and marine species. In these two estuaries, low oxygen, hypoxic waters (DO; 0.5 mg/l) were recorded in the middle reaches of the Sundays Estuary mostly during summer, and in the Swartkops Estuary, the lowest dissolved oxygen (DO; 2.4 mg/l) was recorded in the upper reaches during spring. These low DO conditions decreased fish abundance and diversity in both estuaries, with zero catches at hypoxic areas in the Sundays Estuary.

The occurrence of low DO and hypoxic conditions, are predominantly confined to these core nursery areas and, thus, pose a significant threat to the nursery functioning of these systems. It is therefore suggested that management interventions should focus on protecting the nursery areas of similarly eutrophic estuaries to prevent further occurrence of these low DO and hypoxic conditions. This can be achieved by incorporating the important regions into current estuarine management and restoration plans, while simultaneously increasing measures that serve to reduce anthropogenic nutrient loading.

These results provide much-needed insights into core nursery habitats for demersal linefish species in Algoa Bay and the impact of low DO and hypoxic conditions on the abundance and distribution of linefish species in estuaries.

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Long term, low budget data from a pair of anglers provide evidence of closed area effectiveness for South Africa's national fish

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Background

The galjoen (*Dichistius capensis*) is endemic to South Africa's coastal waters. It is a medium-sized fish, which attains a maximum mass of 6kg, and is confined mostly to shallow water where it is often found among rocks close to the shore along turbulent, wave-exposed parts of the coast. It is less frequently found beyond the surf zone on shallow reefs and wrecks, and then often in large shoals. Galjoen is popular with recreational shore-anglers and has been well studied compared with other linefish species. Research has shown that they are mainly a resident species, although a small percentage of the population has been shown to be nomadic. As such, it can be expected that marine protected areas (MPAs), in particular no-take zones, will be effective for the conservation and recovery of local populations of galjoen, and also allow for spill-over to adjacent unprotected areas. We used data from a long-term tag-and-release monitoring programme in the Table Mountain National Park (TMNP) MPA to test whether "no-take" (closed) MPA zones are effective for galjoen conservation.

Methods

Since 1999, tag-and-release fishing of galjoen has been conducted by a pair of anglers on the western shore of the Cape Peninsula, in the TMNP MPA. Both anglers had previously fished for galjoen in their personal capacity, including at the Pegram's Point area in the MPA, which is open to recreational fishing ("fished"), contributing meticulous records to the Oceanographic Research Institute's Cooperative Fish Tagging Project (ORI-CFTP). In 1999, what was then the Department of Environmental Affairs and Tourism granted the anglers a permit to fish in the Olifantsbos no-take area. Subsequently, the anglers have conducted tag-and release angling at both sites, which have comparable inshore habitat favoured by galjoen. This was done on an unpaid and *ad hoc* basis in their own personal time and as a result, fishing effort has varied somewhat between years. However, allocation of effort between the two sites was standardized throughout the study, to allow for comparison of data between the no-take and fished areas. Data collected included size of fish, tag number, location, fishing effort (hours fished), and the weather and sea conditions.

Data was sorted and analysed using pivot tables and data analysis functions in Microsoft Excel. Comparisons were made between the sites and over time for the size of individuals, the proportion of mature individuals in the catch (galjoen is considered mature if the fork length > 330 mm, or if total length > 349 mm), and CPUE.

Results

Comparison of average size and the distribution of catch into size classes (2 cm size classes) between the no-take and fished areas, showed that average size of individuals was consistently larger in the no-take area, where there were greater numbers of fish in larger size classes with a greater proportion of mature fish, than in the fished area. This is related to the size limit for galjoen, which is 350 mm TL, such that recreational anglers remove sexually mature individuals in the fished area. With larger sized fish and a greater reservoir of sexually mature fish, the no-take area can be expected to provide spillover to fished areas through larval dispersion. Average CPUE in the no-take area was also significantly higher than in the "fished" area in most years and was significantly higher overall. This indicates that there is greater availability of galjoen in the no-take compared to fished areas. The difference in CPUE between the sites was greater in some years than in others, and in two years (2008 and 2016) CPUE was greater at the fished site. The long-term trends in CPUE were similar between the sites, showing an overall decline, with both sites showing considerable inter-annual fluctuations in some years. This may be caused by effects of environmental variability on recruitment, but the timing of fluctuations in CPUE did not always correspond between the two zone types. This suggests that the relationship of environmental variability to CPUE patterns is not that clear-cut and may be affected by levels of fishing pressure. CPUE patterns may also be affected by movement of galjoen from areas of higher abundance (no-take area) to areas of lower abundance (fished area). A priority for further analysis will be to investigate the movements of tagged individuals within and between the zones.

Conclusions

Given the disaggregate nature of the line fishery and the recreational line fishery in particular, monitoring and managing it is extremely challenging and costly. Long-term time series of surf-zone fish catches such as the time series considered in this study, can be very useful for providing a reliable index of population status. Here we have shown how a long-term dataset contributed by just two dedicated anglers in a standardized, low cost, fisheries-independent monitoring programme can inform linefish assessment and management, including the effectiveness of MPAs for linefish management. Conservation and recovery of linefish species such as galjoen was a key objective for designating several of South Africa's coastal MPAs, and it is essential both for the resource and for adaptive MPA management to assess the effectiveness of this measure. The results of this study support that the MPA no-take zone benefits the resident galjoen population, in relation to a nearby fished area, providing a refuge for sexually mature individuals. It is recommended that initiating similar long-term, low key monitoring studies between other no-take and fished sites can help to address MPA monitoring needs.

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SECOND KEYNOTE ADDRESS

Embedding marine recreational fisheries in stock assessment and management

Kieran Hyder (CEFAS, UEA)

Fisheries are complex social-ecological systems that have strong cultural significance, support livelihoods, and provide food. Marine recreational fishing (MRF) is an important component of this system as it is high-participation activity with large economic value and social benefits globally but can impact on fish stocks. The diverse and dispersed nature of the activity alongside the variety of motivations, means that these fisheries are often not well studied. Recreational and commercial fisheries exploit common stocks, bringing them into conflict due to competing and different needs, especially where stocks are depleted and boundaries between sectors are unclear. Despite their importance, MRF can be excluded from fisheries assessment and management, which may impact on the ability to manage fish stocks within sustainable limits and maximise societal benefits generated from this common pool resource. This talk will examine the challenges associated with embedding MRF in fisheries governance and provide examples of successful approaches from across the globe. Bespoke solutions are needed that may vary between species and locations. A lens will be thrown on Europe to illustrate learning from recent attempts to embed MRF. However, there is no simple solution with similar challenges resulting in common problems and few solutions across the. The South African linefishery is uniquely complex making embedding MRF particularly challenging. As a result, co-designed social-ecological systems approaches are needed to effectively manage stocks and maximise societal benefits.

4. FISHERIES MONITORING

Anglers as eyes, determining the utility of recreational competition data to monitor the size frequency and abundance of coastal elasmobranchs in South Africa

Alexander Winkler (RU, SAIAB), Matthew Farthing (RU), Matthew Parkinson (SAIAB), Amber-Robyn Childs (RU), Warren Potts (RU)

Background

The marine shore-based linefishery (MSBF) in South Africa is the largest (in terms of participation) fishery in South Africa and generates enormous economic activity. Sharks and rays are frequently captured in this fishery by anglers who specifically target them or through incidental capture. Although some anglers retain sharks and rays, most are released. However, as the catch and release handling practices are poor, their post-release mortality may be relatively high. With recent studies suggesting that many coastal sharks and rays are at risk from impacts of overexploitation, it is critical that their populations be monitored. Presently, the MSBF is not monitored, however competition angling data may provide a valuable source of information to monitor the population trends of these species. In this study we attempt to examine the utility of two competitive recreational competition datasets, the Rock and Surf Super Pro League (RASPPL) and the South African Shore Angling Association (SASAA). Both these organised angling groups periodically fish throughout the South African coastline with catch data going back ten years for RASSPL and for some franchises up to 30 years for some of the SASAA provinces. Here we contrast the RASSPL and SASSA data and examine their utility for monitoring shark populations. As the RASSPL scoring system motivates anglers to target a diversity of sharks, has no minimum size limit and does not reward highly for weight, this dataset may provide information to monitor the size frequency and relative abundance of smaller shark (including several endemics) and ray species, and the juveniles of the larger sharks. In contrast, as the SASAA scoring system does not count sharks smaller than 2 kg and rewards anglers for total weight caught, this dataset may provide standardised information to monitor the size frequency and relative abundance of coastal shark species.

Methods

Individual angling event records (per competition day) were calculated as catch-per-unit-effort (CPUE) and expressed as the number of elasmobranchs.angler^{-1}.day^{-1} and calculated using the following equation: $CPUE_{l.i} = \frac{catch_{l.i}}{effort_{l.i}}$
where catch $l.i$ is the number of a specific species of elasmobranch captured on the ith fishing event, at locality l and where effort $l.i$ is the number of angler days recorded during the ith fishing event at locality l.

Following the calculation of the CPUE for each species per competition day, a running average per species was calculated and ranked by CPUE to get the top ten ranked species per competition format. For each of these top ten species, heatmaps were produced using QGIS™ based on the georeferenced CPUE, the heatmaps are a way to visually identify an area of peak abundance, it must however be noted the offshore extent of the kernels is not an accurate depiction of offshore elasmobranch abundance.

Results

In total, data was acquired from 1061 individual competition days between 2011 and 2023, of which 744 and 317 individual competition days were SASSA and RASSPL competitions, respectively. The total number of individual angler days for SASSA was 10356 vs 16227 for RASSPL, where SASSA competitions were fished between 2011–2020 and RASSPL which was between 2013–2023. Spatially, the SASSA data represents 26 different localities between Varkenvlei on the West Coast and Noggies in northern Kwazulu-Natal, the RASSPL data represents 73 different fishing locations between Rietfontein on the West Coast and Haga Haga in the Eastern Cape. In total 27194 individual elasmobranchs were captured, measured and released by SASSA anglers between 2011–2020, while RASSPL anglers captured 19688 individuals between 2013–2023.

Of the 41 different elasmobranch species captured in the SASSA dataset, lesser guitarfish *Acroteriobatus annulatus* was the most commonly captured species with an average CPUE of 1.35, meaning that on any given competition day, every angler fishing in a competition would on average catch at least one. A close relative of this species, bluntnose guitarfish *Acroteriobatus blochii* came in second, but with a much lower overall average CPUE of 0.54. This was followed in descending order of ranking by blue stingray *Dasyatis chrysonota,* diamond ray *Gymnura natalensis,* whitespotted smoothhound shark *Mustelus palumbes,* bronze whaler shark *Carcharhinus brachyurus,* smooth hammerhead *Sphyrna zygaena,* common eagle ray *Myliobatis aquila,* spotted gully shark *Triakis megalopterus* and raggedtooth shark *Carcharias taurus*. Of these top 10 ranked species, *M. aquila* and *C. taurus* are the only two species that are of severe conservation concern according to the IUCN redlist. Of the five highest-ranked species by average CPUE, spatial abundance estimates vary between species. The highest-ranked species (*A. annulatus*) is primarily captured east of Cape Agulhas, with peaks in their abundance being centred around the Southern Cape coast. The second-ranked species, *A. blochii*, is only captured on the West Coast, with a peak in their abundance centred around Saldanha Bay and Varkenvlei. The third-ranked species, *D. chrysonota,* has peaks of abundance around Algoa Bay but higher catches are also made off the West Coast and Varkenvlei in particular. Both the 4th and 5th ranked species, *G. natalensis* and *M. palumbes* respectively, are more likely to be captured and therefore in higher abundance along the Overberg coastal area in the Western Cape.

Of the 33 different elasmobranch species captured in the RASSPL dataset, brown shyshark *Haploblepharus fuscus* was the most commonly captured species with an average CPUE of 0.68. The next highest-ranked species was *T. megalopterus*, with a CPUE of 0.28, closely followed by *A. annulatus* with a CPUE of 0.27. This was followed in descending order of ranking by *Poroderma spp,* striped catshark *Poroderma africanum, D. chrysonota,* smoothhound shark *Mustelus mustelus, M. aquila, C. taurus and* leopard catshark *Poroderma pantherinum*. Of these top ten ranked species, *M. aquila*, *C. taurus* and *M. mustelus* are the only three species that are of severe conservation concern according to the IUCN red list. Of the five highest-ranked species by average CPUE, spatial abundance estimates vary between species. The highest-ranked species (*H. fuscus*) is primarily captured east of Algoa Bay, with a peak abundance being centred around Port Alfred. The second-ranked species, *Triakis megalopterus*, follows a similar spatial pattern to *H. fuscus* with a centre of abundance being around Port Alfred. The third-ranked species, *Acroteriobatus annulatus,* also has peaks of abundance around Port Alfred. Both the 4th and 5th ranked species, *Poroderma spp* and *P. africanum*, respectively, deviate from the above-mentioned pattern, with peaks in their abundance being found off the Southern Cape as well as east of Algoa Bay in the vicinity of Port Alfred.

Conclusions

The findings of this study highlight geographical areas along South Africa's coastline that are of high importance to the majority of the country's competitive shore angling fraternity. It also identifies the primary elasmobranch species that are targeted by these anglers, their conservation status and strategies that may aid in reducing the impact of these competitions going into the future.

The utilisation of competitive angling catch-and-effort data is a cost-effective monitoring method to gain an understanding of coastal marine resource users. In this case study we evaluated the efficacy of two separate competitive shore angling formats, to better understand their efficacy at identifying areas of elasmobranch abundance along the South African coast. To this end, we have found that the different angling formats and their associated scoring systems influenced the species that are captured. RASSPL anglers focus on catching a diverse array of species to gain maximum competitive points, while SASSA anglers fish for any species that will cumulatively increase their overall catch weight, which equates to maximum competitive points. The result of this difference in scoring is clearly articulated in our findings. RASSPL anglers catch higher numbers of smaller endemic shark species Scyliorhinidae family (three species in the top five ranked species) when compared to SASSA anglers who primarily capture two species of Rhinobatidae and three other larger bodies species. While we are aware that these datasets do have both spatial and temporal gaps, with us only having access to ~ 10 years of recent data, the historical SASSA data is potentially available and busy being acquired. This data would also have better spatial resolution but will not provide information on what is happening along the Wild Coast in the Eastern Cape as competitions are not held in these areas. Regarding the RASSPL dataset, we are confident that we cannot improve on this data as we have access to all their historical and novel information, unfortunately, this competitive format only emerged in 2011.

The easiest way to reduce the effect of recreational fishing-related post-capture mortality is through effective stakeholder engagement and angler education drives. This report has geographically highlighted areas along the South African coastline where management efforts should be prioritised based on competitive recreational angling effort distribution patterns. This includes the following areas and surrounds for SASSA anglers: Mtinzini, Hamburg, Jeffery's Bay, Mossel Bay, Arniston, False Bay and Varkenvlei and for RASSPL anglers: the Sunshine Coast (Boknes – East London), Gqerberha, Mossel Bay, Arniston and False Bay. Areas of commonality between the effort distribution of both fishing formats where management effort should be prioritised should be: The Sunshine Coast, Mossel Bay, Arniston and False Bay.

Estimating the natural mortality of dusky kob from length-frequency data: A simulation-based approach

Dylan Rowell (UCT), Ben van Huyssteen (UCT), Res Altwegg (UCT), Colin Attwood (UCT)

The natural mortality rate (M) for a species of fish can be defined as the instantaneous rate of death due to all natural factors, excluding fishing. In this report, we explore the Von Bertalanffy growth model (with consideration for fish greater than the asymptotic length, L_∞) and log-linear regression as they pertain to dusky kob (*Argyrosomus japonicus*). These models are fitted to historical age-length data from Griffiths and Hecht (1995) and are subsequently used to predict an age distribution from the length-frequency data spanning multiple decades, obtained via the shore-based angling programme in the De-Hoop Marine Protected Area. This length-frequency data is considered a random sample from the length distribution of an unexploited population, such that the mortality estimate obtained from the catch-curve analysis applied to the predicted age distribution can be considered an estimate of M. Distributions for M are obtained through various model-specific simulation-based techniques. The M distributions overlap heavily between model simulations and the collation of the simulation results returned a distribution with mean estimate of 0.164 yr^{-1} with 95% interval of (0.12, 0.22) for M along the full descending limb of the catch-curves. The simulation results for dusky kob older than 6 years, returned a mean estimate of 0.108 yr^{-1} with 95% interval of (0.07, 0.15). We propose that these methods can be extended to other species (in particular resident reef species where migration outside of the MPA will not have a large effect on estimated M) and can also be used to calculate total mortality in exploited areas, without necessitating an age distribution.

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An encouraging first attempt at applying deep learning methods to electronic monitoring data: automated catch event detection for longline fishing

Charlene da Silva (DFFE), N. Chapman (WO), M. Rio (UDL), W. West (DFFE), A. Booth (RU), S. Lamberth (DFFE), S. Kerwath (DFFE)

(Note this talk was not presented at the symposium)

Accurate fisheries catch data are essential if fisheries are to be sustainably managed. In South Africa, many fisheries have compulsory observer programmes but the coverage is low (<5%) and with poor spatial coverage. Smaller fisheries, such as the demersal shark longline fishery, have been historically bereft of observer coverage except for a few months in 2008/2009. This gap in observer data could be filled by an electronic monitoring system (EMS). The demersal shark longline fishery has been controversial since its inception and has been the focus of negative press around allegations of high mortality rates of Endangered, Threatened and Protected (ETP) species. To improve observer coverage and to monitor ETP species, the DFFE in collaboration with WildTrust and the fishery initiated a collaborative project to install an EMS on an active vessel. To date, 13665 videos have been collected since December 2023 with 3538 videos processed for still images. An initial run analysed 113 still images of sharks, batoids, and teleosts from the processed videos were uploaded to BIIGLE, resulting in 337 annotations and then analysed in YOLOv5, an object recognition algorithm. The initial model was trained using 75% of the images and tested with the remaining 25%. Unannotated images were also used to evaluate the model's performance and feasibility. Species-level identification was not feasible due to the limited number of images. The model, however, successfully differentiated batoids, sharks, and teleosts from each other with a precision of about 72% and recorded a higher species diversity than logbook data. The precision and rate of recall will improve with additional training images. The next stage of the project will use additional deep learning methods to automatically extract video segments of catch events, which would substantially reduce storage space and review time by analysts.

Comparisons of contemporary and historical catch and effort estimates of the recreational marine shore-based fishery

Kyle Hewett (RU), Christopher Bova (RU), Warren Potts (RU)

Background

Regular monitoring of the spatiotemporal patterns in the distribution of angling effort and catch is critical to careful fisheries management and governance. Brouwer et al. (1997) set a baseline for monitoring catch and effort in the recreational fishery through a collation of regional roving-creel surveys conducted in the late 1990's along the South African coastline. Despite recommendations of five-year repetitions of linefish surveys, regular follow-ups have been lacking. Subsequent to Brouwer et al. (1997), a few regional surveys have been conducted. However, the majority have been focused on KwaZulu-Natal with no follow ups occurring along the Eastern and Western Cape (Dunlop and Mann 2012; Mann and Mann-Lang 2020). In the absence of regular monitoring and assessment of management efficiency, fisheries management will be based on outdated information and may become compromised. Nearly 30 years have passed since the monitoring by Brouwer et al. (1997) and numerous changes have been made to regulations and management of the South African recreational marine shore-based fishery during this time. Therefore, an update on the spatiotemporal patterns in the distribution of angling effort and catch is way overdue and provides an opportunity to assess the progress of the fishery over the changes in regulations. The aim of this study was to determine estimates of catch and effort of the recreational marine shore-based fishery on the Eastern and Southern Cape coast of South Africa mostly replicating methods by Brouwer et al. (1997) to retain comparability.

Methods

Catch and effort data were collected using roving-creel survey techniques following methods implemented by Brouwer et al. (1997). Eastern Cape sampling sites included Kei Mouth, East London, Port Alfred, Port Elizabeth, Jefferies Bay/St Francis, Plettenberg Bay/ Mosselbay, Stilbaai and Witsand and sampling sites in the Southern Cape included Infanta, Struisbaai, Gansbaai, Hermanus, Bettys Bay, and False Bay east/False Bay west. Within each sampling site, an area that could be covered in a sampling period of four hours was chosen randomly, starting times were 06:00, 10:00 or 14:00 and the direction of travel was chosen randomly (where possible). Two sampling sessions were completed each day (no sampling was conducted at night for safety reasons) and sampling trips to the sites consisted of seven days. School holidays and public holidays were treated as weekend days. Participation in the questionnaire was voluntary (declines were recorded) and anglers <12 years old were recorded but were excluded from the questionnaire interview. All retained catch were identified, measured and recorded in 50mm size classes and converted from length to weight using standard length-weight regressions. Released catches that were witnessed by survey clerks were identified, numerated and recorded but these data were not included in catch and effort data. As a means to retain comparability, estimation of angler effort and catch per unit effort methods by Brouwer et al. (1997) were followed. Angler effort was calculated using instantaneous counts obtained during the patrols.

Results

A total of 325 four-hour roving-creel survey patrols covering 1620 km and 216 four-hour roving-creel survey patrols covering 1161 km were conducted from May 2022 to April 2023 in the Eastern (Kei Mouth to Witsand) and Southern Cape (Infanta to False Bay West), respectively. The surveys consisted of 185 weekdays and 87 weekend days in the Eastern Cape and 148 weekdays and 154 weekend days in the Southern Cape. In all, 1386 anglers were counted in the Eastern Cape and 1081 in the Southern Cape. A total of 1099 (91% acceptance rate - AR) and 713(74% AR) anglers were interviewed in the Eastern and Southern Cape, respectively. The modal age class of participants was 41-50 years of age and 97% were Male. Angler density increased from 0.39 anglers km^{-1} in 1997 to 0.86 anglers km^{-1} in the Eastern Cape but decreased from 1.29 anglers km^{-1} (1997) to 0.93 anglers km^{-1} in the Southern Cape. East London (1.35 anglers km^{-1}), Mosselbay (1.18 anglers km^{-1}) and Witsand

(1.18 anglers km^{-1}) had the highest effort in the Eastern Cape and False Bay west (2.46 anglers km^{-1}), False Bay east (1.30 anglers km^{-1}) and Struisbaai (0.89 anglers km^{-1}) in the Southern Cape. Dusky kob *Argyrosomus japonicus* remained the most commonly targeted species in the Eastern Cape, however, the most commonly targeted species in the Southern Cape changed from galjoen *Dichistius capensis* in Brouwer et al. (1997) to kob *Argyrosomus* spp. The catch-per-unit-effort (CPUE) was found to have decreased from the historical estimates of 0.41 (fish $angler^{-1}$. $hour^{-1}$) to 0.28 (fish $angler^{-1}$.$hour^{-1}$) in the current study in the EC and from 0.28 (fish $angler^{-1}$.$hour^{-1}$) to 0.05 (fish $angler^{-1}$.$hour^{-1}$) in the SC. Blacktail *Diplodus capensis* (n=184), shad/elf *Pomatomus saltatrix* (n = 105) and white steenbras *Lithognathus lithognathus* (n = 65) were the most commonly caught species in the Eastern Cape and galjoen (n = 59), blacktail (n = 53) and lesser guitarfish *Acroteriobatus annulatus* (n = 51) were the most common species caught in the Southern Cape. Number of contemporary catches observed were significantly lower compared to historical catches.

Conclusions

The results of this study provide much needed contemporary catch and effort data for the MBSF in the Eastern and Southern Cape. The changes in effort distribution, species distribution and CPUE between the historical and contemporary surveys reflect a highly dynamic fishery that requires careful and regular monitoring for management. The implementation of the beach driving ban in January 2002 will have had an influence on angler effort, essentially causing a concentration of fishing effort to access points and more accessible areas (Mann and Mann-Lang 2020). At the same time, less accessible areas or areas that require more effort to reach have received less angler effort. Unfortunately declines in safety and security from 1997 to present, particularly in areas in and around metropolitan areas such as Cape Town, may have attributed to the observed declines in effort. Fortunately, greater awareness of the benefits of catch-and-release angling has increased drastically since late 1990s and the number of anglers that practice catch-and-release has increased. Thus, observed declines in the CPUE based on retained catch only from Brouwer et al. (1997) to the present may be influenced by the increased pro-environmental approach of anglers. Nevertheless, the declines in CPUE do highlight the need for regular monitoring. More regular roving-creel surveys in conjunction with various other methods such as aerial surveys will allow for updated estimations of total catch of the MSBF which fisheries scientists and managers can use to make sound management decisions.

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Monitoring and measuring illegal gillnet catches in South Africa

Stephen Lamberth (DFFE), Charlene da Silva (DFFE), Jennifer Olbers (WO), Santosh Bachoo (EKZNW), Sven Kerwath (DFFE)

(Note this talk was not presented at the symposium)

Gillnets were introduced to South Africa in 1885 for the targeting of large nomadic, migratory fish such as geelbek *Atractoscion aequidens* on the West Coast. Shark directed gillnetting began in the 1940s driven by the demand for shark liver oil and Vitamin A. The harder *Chelon richardsonii* gillnet fishery expanded in the 1960s as cheaper monofilament gillnets became available. Management became more formal in the 1970s, gillnetting was then restricted to harders and St Joseph *Callorhinchus capensis* with limited bycatch allowed. There were several "exploratory" marine and estuarine gillnet fisheries throughout the coastline until the early 2000s, whereupon it became policy to phase out all estuarine gillnetting and restrict the legal marine gillnet fishery to Yzerfontein northwards on the West Coast. Since then, the illicit gillnet fishery has increased substantially throughout the coast in estuaries and the sea. The illicit estuarine gillnet fishery has more participants due to accessibility and less sophisticated gear and vessel requirements than for the sea. However, targeting of large linefish and sharks has increased on the West and South coasts driven by a lucrative market, no restrictions on net ownership or sales and cheap availability of large-mesh gillnets imported from elsewhere. Catch data are limited by the illicit nature of the fishery so comprise mostly that from confiscated nets and catches. Catch estimates are bolstered by extrapolating known catch-per-unit-effort (CPUE) catch from comparable research gillnetting to lengths (and mesh) of nets confiscated. From 2010 to 2018, mean annual estuarine gillnet catch doubled from 1 134 t to 2 267 t or 60% of the total estuarine catch across all fisheries. Most of this increase occurred in KZN. Since then, there's been a similar increase in gillnetting throughout the Eastern Cape and total estuarine gillnet catch is now likely to exceed 3 000 t per annum. Illegal marine gillnetting is more sophisticated, concealed and difficult to measure. Nets are deployed permanently as well as stored at sea to avoid detection, with catches being laundered through other fisheries. Each operation may work more than 2 km or more of nets and confiscated catches suggest individual catches of up to 200 t per annum.

5. FISHERIES MANAGEMENT

Review of recent recreational fisheries research to identify critical revisions needed to improve governance

Warren Potts (RU), Christopher Bova (RU), Kieran Hyder (CEFAS), Kyle Hewett (RU), Aidan Du Preez (RU), Alexander Winkler (RU), Matthew Farthing (RU), Amber-Robyn Childs (RU)

The South African linefishery is a complex socio-ecological system that has a considerable impact on the coastal marine environment while generating social and economic benefits for fishers in the commercial, small-scale and recreational sub-sectors. Although the recreational sub-sector is the largest in the linefishery, there is a dearth of information on the distribution of its effort, its catch, the status of its target species, the characteristics of its participants, the societal benefits that it generates, and this is reflected in the poor governance of this sector. This presentation gives a summary of the body of recreational research work done as part of the One Ocean Hub (OOH) Project that aimed to fill the gaps in our knowledge of South African recreational fisheries and provides several recommendations to strengthen policy and governance of this sector. Important findings included considerable changes in the effort distribution and catch composition of the shore-based sector since the last national survey in the mid-1990's, the broad demographic composition and motivations of recreational fishers, the massive potential for socio-economic development through the economic spend of the fishery, and the existence of policy, management agency structures and processes that limit effective governance. The OOH project also co-developed two long-term catch and effort databases for current and future stock assessments of the shore-based fishery. Together this work is used to make recommendations for policy reform, structural changes, and management guidelines that, if implemented, should promote sustainability in the entire linefishery.

The South African linefishery in 2024 - An overview

S. Kerwath (DFFE), D. Yemane (DFFE), C. da Silva (DFFE), S. Lamberth (DFFE)

(Note this talk was not presented at the symposium)

"Linefishing" is used loosely as a term describing a multitude of fishing sectors in South Africa and includes commercial fishing from large cabin boats with a dozen crew as well as recreational estuarine angling. In its broadest definition, the linefishery is South Africa's largest fishery, by spatial extent, species and number of participants: Its footprint spans from estuaries up to 50 km inland, to the border of the EEZ, around the entire South African coast. Its catch contains ca. 300 species and approximately 0.5 million fishers participate in linefishing in its various forms. Keeping track of the population status of linefish species is a formidable task and only around 20% of species in the linefishery have ever been assessed. Given the varying availability of input data, the linefish stocks are assessed on a tiered system. Eight linefish- and two shark species can be assessed with tier 1 type models JABBA and JABBA-select, as catch and effort time series from multiple fisheries, length frequency and biological data are available. Another 20 to 30 species can be as assessed by tier two assessment models e.g. JARA, using abundance time series and biological information, as their total catch is unknown. For the remaining species, tier three length-based assessment models are the only option to assess their stock status. In this contribution, we will provide an overview of the current status of the linefishery, its dynamics, the data and the methods available to assess it, as well as opportunities and challenges for the linefishery in the future.

Global systematic review of the lethal and sublethal impacts of catch-and-release fishing

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There is burgeoning global consensus that recreational fisheries (RFs) are of conservation concern. Evidence now suggests that RFs are larger and more impactful than previously assumed. While harvest by RFs is acknowledged as a source of significant biomass removal, the lethal and sublethal impacts of catch-and-release (C&R) fishing are generally poorly understood. This hampers effective management by: limiting the incorporation of RFs into stock assessments and quota allocations; precluding incorporation of C&R as a management tool in strategic conservation planning; and by driving stakeholder conflict in regions where welfare concerns affect RFs social license and the societal acceptance of C&R as a sport or management measure.

It is known that the impact on fishes subjected to C&R depends on many factors including: fish biology and physiology, environment and context, fishing techniques, and the angler's behaviour, attitudes and practices. Since the last seminal reviews (ca 2005-2007) of C&R impacts, interest in assessing the impact and factors associated with C&R has grown exponentially. Recent works have expanded the list of species and factors assessed, as well as the experimental methods used to assess impacts. This study aims to build on methods of previous C&R literature assessments to undertake a global systematic review of trends and factors associated with lethal and sublethal impacts of C&R across taxa, gears, techniques, fisheries and environmental conditions. It will include peer-reviewed and grey literature using structured and reproducible database searches. Following this, we will undertake a quality assessment of C&R studies to date using the ICES WGMEDS critical review framework for discard studies (ICES 2021). This work is expected to provide the most comprehensive synthesis of C&R research to date and will provide a much-needed database of quality-weighted post-release mortality estimates for various species, fisheries and environments.

Following the collation and screening of the primary academic literature, 193 independent mortality estimates were obtained for 131 species from 47 families. For the Chondrichthyes, the Carcharhinidae were the most commonly studied family, with 11 post-release mortality (PRM) estimates. For the Osteichthyes, the Sparidae were the most studied family (34 estimates), followed closely by Scorpaenidae (20 estimates) and Sciaenidae (15 estimates). Using a random effects meta-analysis model with traditional inverse variance weighting, preliminary results suggest that overall PRM in global recreational fisheries is tentatively predicted to be 18% (95% CI: 9-31%) for Chondrichthyes and 10% (95% CI: 8-13%) in Osteichthyes. However, inverse variance weighting is not ideal considering the variability in PRM study methodologies and quality. Bayesian meta-analysis models are more suitable for incorporating the error associated with individual estimates and are currently being explored in ongoing analysis. Additionally, a "back-and-forth" literature search is underway to enhance the dataset and better incorporate grey literature to ensure the goal of comprehensive representation of all recreational fisheries PRM research. While these results are subject to change, it is clear that the extent of PRM in recreational fisheries is sufficiently impactful to warrant incorporation into stock assessments, management and conservation planning.

The informal synergy between subsistence and recreational fishers on the Wild Coast

Christopher Bova (RU), Michael Pyle (RU), Gavin Fraser (RU), Warren Potts (RU)

Researchers are often focused on the negative interactions between fishing sectors. This is especially true in South Africa, where competition for various linefish species between those that fish for fun and those that fish for provisions and livelihoods result in impulsive calls for resource allocation. However, often missing from the context is the relationship between recreational fishers and rural coastal communities. Using structured face-to-face surveys with recreational fishers and semi-structured interviews with local fishing community members in the Wild Coast region of South Africa, a very different narrative was revealed. Here, recreational fishers support local economic development through tourism expenditures that would not otherwise inflow to the communities. However, much of the money spent in these communities immediately flows back out due to economic leakage. Interestingly, the expenditures that are retained in the area are directly linked to the subsistence and small-scale fishers in the area that sell fish and bait to the recreational anglers or provide guiding services. While there may be limited competition between the sectors for fisheries resources in the region, the beneficial economic relationship is clear. Recreational fishers rely on the local informal fishing communities for food and bait, and the informal fishing communities rely on the recreational fishers for livelihoods. This relationship underscores the importance of examining conflicts between fishing sectors through a more holistic lens and can provide important information to contribute to the much-needed redevelopment of small-scale fisheries policy in South Africa.

Development of a management strategy for Endangered, Threatened or Protected (ETP) species encountered in the albacore tuna pole and line fishery, South Africa.

Adam Rees (AEC), Ken Hutchings (AEC)

The albacore (a.k.a. longfin) tuna (*Thunnus alalunga*) pole and line (TPL) fishery in South Africa is a socio-economically important fishery, contributing to the local economy and providing employment opportunities. The fishery was selected as one of five WWF South Africa Fisheries Improvement Projects, which take a multi-stakeholder approach to improve fishing practices and management so that species, habitats, and people can all thrive. The fishery is regarded as a relatively 'clean' fishery regarding its ecological impacts in terms of bycatch and Endangered, Threatened or Protected (ETP) species interactions. However, quantitative information on these impacts are not readily available and the activities of this fishery are known to warrant improvement.

An ETP species is defined by the MSC (Marine Stewardship Council) as any species recognised by national ETP legislation, species listed in binding international agreements (e.g. CITES, Convention on Migratory Species (CMS), ACAP, etc.), and any species classified as 'out-of scope' (amphibians, reptiles, birds and mammals) that are listed in the IUCN Red List as Vulnerable (VU), Endangered (EN) or Critically Endangered (CE).

Here, we present work on the development and implementation of an ETP management strategy for South Africa's albacore TPL sector, which, until now, has been lacking. The project builds on outcomes from a comprehensive literature review and stakeholder consultation, which underpin the development of potential mitigation measures aimed at improving the status-quo with regards to current ETP interactions of this albacore fishery

A desktop literature review was undertaken to assess and evaluate the current status of ETP interactions of the albacore pole and line fishery in South Africa. ETP species were assessed on their temporal and spatial interactions with the fishery, and an attempt to quantify these interactions was made. Operational practices of the pole and line and rod and reel fisheries were identified and further confirmed through stakeholder engagement. ETP interactions with the albacore pole and line fishery in South Africa were compared with similar interactions elsewhere globally, and the severity of interaction assessed in comparison to stock status, threats and the level of interaction for each ETP species. Successful mitigation measures from other parts of South Africa and the world are assessed and inform and support this current project and its outputs. A review of current national and international management of albacore and affected ETP species was also undertaken.

Stakeholders engaged included government and non-governmental organizations (NGOs), research institutions, individuals and companies, each with relevant experience of and/or interest in the albacore tuna fishery in South Africa. Building on the outcomes and outputs of both the literature review and from engagement with stakeholders, an ETP species Risk Assessment of the albacore tuna fishery was performed. This assessed the known and potential impacts (type, magnitude, frequency) on ETP species within this fishery, and key challenges (operational, environmental, financial) were reviewed. Based on these, initial mitigation measures were developed and a comprehensive Management Strategy has been developed. To assess success of the strategy, a monitoring and evaluation framework was developed. The framework is built into the ETP Management strategy in the form of a 'regular review'. This review ensures periodic assessment of each measure's efficacy by assessing the 'evidence' requirements for each measure.

We demonstrate how this strategy is working towards multiple wins for the sector. These wins include economic (e.g., eco-label accreditation, cost effective technology use), operational, and environmental (e.g., ETP interactions reduced) wins, while helping to satisfy national and international protection targets for at risk species. We argue this buy-in increases the likelihood of Permit Conditions being met in a fishery where enforcement is challenging. If nothing else, this strategy will improve data collection on ETP species caught in this fishery, many of which are currently under threat from overfishing.

Since its publication, a section of the albacore fishery has become MSC certified (August 2024), with the application of elements of the ETP strategy developed here being adopted and implemented, which fed into the MSC assessment. Moving forward, the efficacy of this strategy will be periodically reviewed and hopefully rolled out to the entire fleet around South Africa.

Slow somatic growth rates and intermittent recruitment of Namibian west coast steenbras analysed with novel bootstrapped length-at-age (otoliths), length-frequency, and tag-and-recapture approaches

Margit Wilhelm (UNAM), Arariky Shikongo (UNAM), Angelika Veii (UNAM), Ralf Schwamborn (FUP)

Background

West coast steenbras (*Lithognathus aureti*), a coastal Sparid in Namibia, is one of the most important linefish species caught in Namibia (Kirchner et al., 2000; Holtzhausen et al., 2001). They are believed to consist of two genetically distinct, highly resident stocks, one in the north (17-24 °S) and one in the south (24-26 °S) (van der Bank and Holtzhausen, 1999) and are protandric (Holtzhausen and Kirchner 2001a). The northern stock, which is open to fishing, is severely overfished with catch rates having declined to about 1/3 of those in the 1990s (Wilhelm et al., this issue). This decline also reflects the general perception of anglers (Gusha et al. 2024). The southern stock is protected and therefore essentially pristine.

Age determination and growth rates are important data for understanding the life history strategy of an exploited stock, as well as crucial input data into stock assessment models. However, despite the stock declines since the 1990s, growth rate data and stock assessments for west coast steenbras have not been updated since the 1990s (Holtzhausen and Kirchner 2001a; 2001b). In addition, given recent critique on previous restrictions on estimating Von Benrtalanffy growth (VBG) rate parameters (Schwamborn, 2018), previous estimated on west coast steenbras growth may have been biased by the restrictions to parameter estimation used at the time. Considering this, and also given recent climate-change driven environmental changes in the northern Benguela (e.g. Brandt et al. 2024) that may have contributed to changed growth rates of west coast steenbras, this study aimed to address these gaps in knowledge. The study had following aims: To calculate body growth rates with 95% confidence intervals (CI) of the northern and southern stocks of west coast steenbras from three methods: 1. Length-frequency analysis (LFA), 2. Tag-and-recapture (T&R) and 3. Otolith-based length-at-age (LAA), to compare the results between stocks (otolith data only) and sexes (otolith data only), and to compare the results across methods (LFA, T&R and LAA, the last two with different analysis parameter settings) for possible cross-validation with novel, standardized methods.

Methods

We used the following three data sources: length-at-age (LAA) data derived from otoliths (2019-2023), northern (N) and southern (S) (based on n = 104 otoliths N stock and n = 155 S stock), length-frequency-analysis, LFA (n = 29 monthly length-frequency-distributions of 20,090 measured individuals) and tag-and-recapture (n = 80 growth increments). From each data source, we obtained von Bertalanffy growth function (VBGF) parameter estimates (K and $L\infty$) and their bootstrap confidence intervals (CI) of 1000 resamples with the following functions in the “fishboot” package Schwamborn et al. 2021) in R: “grolenage_boot” for the LAA data, “ELEFAN_GA_boot” for LFA, and “grotag_boot” for T&R data.

We compared medians of posterior distributions between methods (length-frequency analysis, LFA, T&R, LAA), between stocks (LAA only) and between sexes (males, females and hermaphrodites, LAA only) using the bootstrapped two-sample (BTT) median test “boot.medians.test” for medians. We compared CIs of posterior distributions with violin plots.

Results

No significant differences were found between medians of parameters K and $L\infty$ by stock (N and S), sex (males, females or hermaphrodites) or data source / method ($p > 0.05$, BTT). In contrast, differences were found in precision (CI widths) between methods. LAA was by far the most precise method for estimating K, explained by the low uncertainty regarding the age of each individual, leading to an overall low uncertainty in instantaneous growth rates. However, LAA from the southern stock was the least precise method, and LAA from the northern stock was the most precise method for estimating L∞.

Finally, we used the results of parameter estimates for the southern stock (median estimated of posterior distributions) from combined models that best explained the data, with the following median values: K = 0.066 y^{-1} (from otoliths, 95% CI: 0.0067 – 0.12 y^{-1}), L∞ = 77.29 cm (from otoliths, 95% CI: 55.48 – 400.26 cm), t_{anchor} = 0.50 (from LFA, 95% CI: 0.18 – 0.87), C = 0.53 (from LFA, 95%CI: 0.19 – 0.87), and ts = 0.47 (from LFA, 95% CI: 0.14 – 0.88) to show that southern west coast steenbras had extremely slow growth with intermittent recruitment peaks occurring every four to five years (in 2000, 2004, and 2008), with near-zero recruitment in between.

Conclusions

In this study, for the first time, a robust bootstrapped approach was used to compare three methods of growth estimation, namely length-frequency analysis (LFA), otolith-based length-at age analysis (LAA) and tag-and-recapture (T&R) analysis. No differences in medians of growth rate parameter estimates between methods were detected. This cross-validates the age determination method currently used on west coast steenbras. It also confirms the robustness of bootstrapped LFA, and validates its results with two independent methods (bootstrapped T&R and LAA).

The differences in precision estimates of L∞ between northern and southern stocks may be explained by the much larger sample sizes of large-sized fish (> 50 cm fork length) for LAA from the northern stock than for the southern stock. The northern stock's maximum age from otolith readings was 38 years (84.8 cm fork length) and the minimum age was 1 year (11.6 cm), while for the southern stock, the maximum age was 18 years (63.7 cm) and minimum age was 2 years (26.3 cm). It is therefore essential to increase sample sizes for otolith data from the southern stock at the entire length range of the stock. Although LAA with the whole length range covered was more precise than LFA, LFA is still useful for seasonal growth, recruitment and mortality estimates (and more precise L∞) estimates in the case of west coast steenbras southern stock. We recommend that LFA should thus still be used to validate and complement LAA data as demonstrated with our approach.

West coast steenbras of the southern stock, even though underexploited, showed intermittent recruitment with peaks every four to five years. This phenomenon of intermittent recruitment is also seen in other hermaphrodites (Attwood, this issue), and may be a life-history strategy, i.e. an adaptation to compensate for costly reproductive investment. However, at its overexploited status (northern stock), this makes west coast steenbras even more vulnerable to fishing pressure and climate change, as it has few chances to recover in the "intermittent recruitment failure" years.

We showed no differences between growth rates of the northern and southern stocks, in contrast with results from the mid-1990s by Holtzhausen and Kirchner (2001a). The southern stock's growth rate thus appeared to have increased to faster growth and higher variability in individual measurements of length at age from the 1990s to the 2020s. Since west coast steenbras annual growth appears to be positively correlated with water temperature (Veii et al., this issue), the reason could be related to climate change and warming in southern Namibia. However, this does not explain the constant growth rates from 1990s to 2020s for the northern stock of west coast steenbras. Another, very plausible explanation for this phenomenon could be an increased stock mixing between the northern and southern stocks from the 1990s to the 2020s due to warming waters in the northern part of the northern Benguela, and thus a resulting overall apparent increase in growth rates of the southern stock.

We demonstrate cross-validation of age estimates, a robust bootstrapped approach as well as updates of age and growth estimates for west coast steenbras in Namibia. Considering its irregular reproduction, recruitment, and extremely slow growth, there is an urgent need for the development and application of new management strategies for this endangered, longevous species.

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6. ANGLER ENGAGEMENT

The ORI Cooperative Fish Tagging Project – Celebrating 40 Years Down the Line

Gareth Jordaan (ORI), Bruce Mann (RU, ORI)

Background

Fish tagging has a history dating back to the mid-1800s. In South Africa, numerous tagging projects have been initiated, yet many have failed to produce substantial results, often leaving data unpublished or unused. The Oceanographic Research Institute's Cooperative Fish Tagging Project (ORI-CFTP), however, stands out as a notable exception. Past ORI Director Rudy van der Elst initiated the ORI-CFTP in 1984 with the main aim being "A collaborative citizen science project between scientists and anglers to collect information on fish movement patterns, growth rates and population dynamics to help ensure their wise and sustainable use and to create awareness amongst anglers." Celebrating its 40th anniversary in 2024, the ORI-CFTP has evolved from what started off as a simple idea of tagging elf/shad *Pomatomus saltatrix* to try and better understand their movements, into one of the longest ongoing operational and most successful marine citizen science projects of its kind in Africa, ranking with many other top volunteer tagging projects from around the world.

The ORI-CFTP has improved greatly over the years from how data are captured and stored, to how the management team are able to communicate with anglers and members of the public. Important advances and improvements in tagging equipment and techniques have been made, with one of the most important improvements being how fish are captured and handled in order to ensure their greatest chance of survival.

Results and Achievements

During the past 40-years, there have been over 387000 fish tagged with an average of 20 fish tagged per member and an average of 9685 fish tagged per year. From these tag releases there have been over 24600 fish recaptured (6.3% recapture rate) with an average of 616 fish recaptured per year. This recapture rate is similar to many other volunteer tagging projects globally.

There have been over 7300 anglers that have joined the project over the past 40 years with an average of 483 active members tagging fish each year and an average of 184 new members joining the project each year. Since 2018 onwards there has been an increase in the number of anglers joining the ORI-CFTP. This is mainly because of a greater presence on social media leading to more anglers finding out about the project and wanting to contribute to research and make a difference to fish conservation. There have also been a lot of "fish-influencers" that have promoted tagging on their YouTube channels resulting in more anglers wanting to join the project.

Overall, there have been 376 different fish species tagged with an average of 166 species tagged per year. The galjoen *Dichistius capensis* is the top tagged species for the project followed by the dusky kob *Argyrosomus japonicus*. The majority of the tag releases and recaptures have occurred in the Western Cape, followed by the Eastern Cape and KwaZulu-Natal, with relatively few fish tagged in neighbouring Mozambique and Namibia (note that since the late 1990s the Namibian authorities have requested that members of the ORI-CFTP do not tag fish in Namibian waters as they have their own tagging project being conducted through the Namibian Ministry of Fisheries).

With the veritable goldmine of data collected, the ORI-CFTP has contributed greatly towards science and conservation. This has been achieved through: (1) Academic achievements –over 200 peer-reviewed scientific publications and book chapters have been published; more than 24 post-graduate degrees have used data from the ORI-CFTP; and many talks and posters have been given at scientific conferences and workshops; (2) Resource management –over 150 reports have been prepared for management agencies responsible for fisheries management in southern Africa, and direct inputs into fisheries policy and regulations based on some of the results from the tagging work; and most importantly (3) the ORI-CFTP has had a big impact on changing the attitudes and behaviour of marine anglers in South Africa through interactive tagging demonstrations, published articles in newspapers and fishing magazines and social media posts.

Over the years there has been a big improvement in angler attitudes towards fish handling and conservation. Mann-Lang et al. (2022) found that the ORI-CFTP has made a considerable contribution towards improving the conservation ethics and behaviour of marine recreational anglers in South Africa. This paper also identified that improved communication with anglers— both taggers and non-taggers—through the ORI-CFTP, has the potential to amplify much-needed conservation information to the broader angling community and thereby enhance greater environmental awareness.

Perhaps one of the ORI-CFTP's greatest achievements is the fact that it has recently been recognised as one of the leading volunteer fish tagging projects globally. In August 2023, the first World Volunteer Fish Tagging Summit, now called the Global Fishtag Network (GFN), was held online. Led by Bill Sawynok from Suntag, Australia, the Summit aimed to bring together volunteer fish tagging programs from around the world to discuss their projects, the data collected, how the data has been used, and ways to collaborate in future to improve both fisheries management and fisher behaviour. An overview of the ORI-CFTP was presented, highlighting how the tagging data alongside other information has been used to enhance our understanding of South Africa's linefish resources and to promote better catch-and-release practices among recreational fishermen. It was heart-warming to see that the ORI-CFTP stands on a par with some of the most renowned and long-standing fish tagging projects globally, such as Suntag (Australia), Tag Louisiana (USA), and the DPI Gamefish Tagging Program (Australia).

A significant highlight was that ORI-CFTP has already implemented a variety of data validation techniques, training materials, and effective communication methods, both with our taggers and members of the angling public — areas where some other programs are still facing challenges. Additionally, although the ORI-CFTP is not quite as old nor has tagged quite as many fish as some of the other programs (some have been running for over 50 years with over one million fish tagged), our tag recapture rate (6.3%) compares favourably. This success is largely due to our dedicated tagging members and our ongoing efforts to improve fish handling and tagging skills, as well as promoting active use of the tagging data to inform better management. This summit also provided valuable insights into various aspects of fish tagging and data collection that the ORI-CFTP can implement to further improve and refine the project.

Conclusions

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 large number of anglers that have joined the project have not only learnt about tag and release, but they have also learnt about the importance of correct fish capture and handling procedures to ensure their greatest chance of survival. Through the ORI-CFTP, members have had the opportunity to gain a better understanding of fish movement patterns and growth rates, the value of sustainable fishing and ultimately contribute towards the improved conservation and management of these species.

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Understanding the impact of the ORI Cooperative Fish Tagging Project on angler attitudes and behaviour

Judy Mann-Lang (TOAF, RU), Bruce Mann (RU, ORI), Gareth Jordaan (ORI), Ryan Daly (ORI, SAIAB)

Background
The Oceanographic Research Institute's Cooperative Fish Tagging Project (ORI-CFTP) has provided valuable information for biological and fisheries research, with more than 150 scientific papers that have used data from the ORI-CFTP. But what about the effect of the programme on the taggers themselves – the anglers who make the programme possible. To investigate this question, we designed a study to review the ORI-CFTP from the perspective of the participating anglers. Understanding how angler attitudes and behaviours are influenced by conservation initiatives such as the Tagging Project is crucial for the long-term sustainability of the project.

Methods
We are very grateful to the 267 members of the ORI-CFTP who responded to our online survey. The survey gathered information on the profile of taggers, their preferred methods of communication, attitudes towards fish tagging and fish conservation in general, changes in angling behaviour since becoming a member of the Project and support for the continuation of the ORI-CFTP.

Results
A little about the taggers: Most respondents were shore anglers (89%), followed by offshore ski-boat anglers (40%) and light-tackle boat anglers (38%). Just over 29% participated in all three facets. Most taggers were experienced with 84% having fished for over 10 years. Just over half (55%) had been a member of the ORI-CFTP for more than five years and 71% had tagged at least one fish in the past 12 months.

Anglers like to chat: The most common way members had heard about the ORI-CFTP was from fellow anglers (68%), and most found out about fishing in general from other anglers (55%). About 17% learnt about the project from social media and 22% used social media to find out about fishing in general. Surprisingly, only 1% had heard about the project from a local fishing tackle shop and very few respondents considered their local bait and tackle shops to be a good source of information about fishing in general! Many respondents suggested that better use could be made of Tackle Shops to communicate with taggers and non-taggers. Given the amount of time anglers spend purchasing tackle and bait, this clearly presents an opportunity for the ORI-CFTP to communicate more directly with anglers, both active taggers and those anglers who may recapture a tagged fish.
The Tagging News is popular and widely read. Over 90% of the respondents had watched at least one of the tagging videos on YouTube, while 82% had used the Tagging website. Some useful comments on how to improve communication with taggers included hosting angling clinics and webinars at fishing competitions and through more direct involvement with fishing clubs.

For research: The main reason why taggers joined the ORI-CFTP was to contribute to marine research, to contribute to the conservation of fish and to learn more about fish. The following quotes help to illustrate some of the attitudes expressed towards the ORI-CFTP: *'This project is a win/win/win – great data, involved and informed recreational anglers, and more released fish.'; 'It has definitely changed the perceptions of the people I fish with regarding C&R.'; 'For the most part, the project does improve anglers' handling of the fish they catch and increases their survival rates.';* and *'It continues to yield valuable information and it is a very powerful tool for creating awareness amongst anglers.'*

Taggers are active**:** Over half (65%) of the respondents had caught a tagged fish and, of these, 92% had reported the tag number to ORI – and fortunately almost all had received interesting feedback on

the recapture! Almost half of the respondents had tagged between 1 and 50 fish (47%) and 39% reported that 1 to 10 of their fish had been recaptured.
Behaviour when tagging: Many respondents said that they now keep the fish in water before and after tagging, while about half regularly use circle hooks and a wet cloth to handle fish. Unfortunately, fewer anglers regularly crimp the barbs of their hooks or use a measuring stretcher. These simple behaviours should be encouraged to increase fish survival post tagging. A good example of one of the beneficial effects of the ORI-CFTP has been the incorporation of C&R into competitive shore angling and light tackle boat angling in South Africa. This change to fishing practise in a competitive environment has shifted angler behaviour and greatly improved fish handling. Not surprisingly, most taggers said that they go fishing for the fun of catching fish, to spend time outdoors and for the adventure and excitement associated with recreational fishing.

Support for continuation: All respondent felt that the ORI-CFTP should continue because of the project's excellent contribution to fish research (67%), its role in fish conservation (32%) and angler education (30%). These quotes illustrate some of the depth of commitment taggers feel about the project:
'The project plays an integral part in the conservation of our fish species by providing irreplaceable research and raising interest and awareness in the promotion of sustainable fishing.'
'1. It provides an opportunity for anglers to contribute data for research. 2. Tagging often generates discussions pertaining to fish amongst fellow anglers and members of the public. 3. Recaptures of tagged fish have often led to anglers who recaptured the fish joining the Tagging Project. 4. Recaptures provide fascinating information. 5. Taggers provide a connection and a conduit for research and information to reach fellow anglers.'
'Without any doubt, the concept of tag and release has encouraged the release of more fish.'
'The Tagging Project more than any other initiative has engendered a spirit of conservation in South Africa.'
'More and more people are starting to become aware of how depleted our fish stocks are because of ORI research.'

Conclusions
The Tagging Project has significantly contributed to enhancing the conservation ethics and behaviour of marine recreational anglers in South Africa. And better communication with anglers—both taggers and non-taggers—through the project has the potential to disseminate crucial conservation information to the broader angling community, thereby increasing awareness of the need for responsible angling behaviour.

Most importantly, the Tagging Project has become an important part of the fishing experience for many taggers as these quotes highlight:

'*Thank you for the amazing work that ORI does. It is of utmost importance that the longevity of the project is ensured. As a member of the angling public with a vested interest in the protection of our environment (including marine life) I cannot thank ORI enough for its service in this regard.*

'*I am encouraged that we still have an organization that tries to educate, assess and guide us for the future so that others can enjoy what we have now.'*

'*Thank you for putting in the time and effort to protect our fishery, I am sure it's an uphill battle and rather disheartening at times, just know there are many anglers out there who appreciate your efforts and acknowledge the absolute importance of the ORI Tagging Project.'*

This last quote sums it up for many respondents: *'I joined the Tagging Project during its year of inception, when I was 18 years old. I remain a proud member of the project and I hope to be a member of this project for many years to come.'*

This work has been published in the *African Journal of Marine Science*:

Mann-Lang JB, Mann BQ, Jordaan GL, Daly R. 2022. An assessment of the impact of participation in the Oceanographic Research Institute's – Cooperative Fish Tagging Project on angler attitudes and behaviour. *African Journal of Marine Science* 44(4): 299-309, DOI: 10.2989/1814232X.2022.2126525

Knowledge to power: understanding the impacts of marine protected areas (MPAs) on the commercial linefishing sector in KwaZulu-Natal as a first step towards sustainable MPA governance

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Marine protected areas (MPAs) in South Africa are typically gazetted with stated objectives. Recovery of linefish resources and fisheries sustainability is the third most stated objective countrywide and is gazetted for all KwaZulu-Natal's (KZN) MPAs. Another common objective among them is maintaining cultural heritage. My MSc looks at providing a baseline from which to measure the impacts of the MPAs in KZN on the commercial linefishing sector – one of the oldest fishing sectors in the country. I measured these impacts from an ecological and social perspective for a holistic understanding. To measure ecological effectiveness, I used Baited Remote Underwater Stereo-Video (stereo-BRUVs) footage to compare fish populations inside and outside five MPAs, focusing on species found on mesophotic reefs which are important to the commercial linefishing sector. However, indicators of ecological progress in conservation projects are no longer enough: in the Anthropocene, we must consider humans as part of the systems we manage. MPAs are a case in point: compliance plays a disproportionate role in determining their effectiveness, and the perceptions of communities living adjacent to MPAs are strongly linked to their willingness to support and abide by their rules. Therefore, the perceptions of commercial linefishers regarding the ecological and social impacts of MPAs and their management were gathered by means of open-ended, face-to-face interviews. Initial results indicate that most MPAs are ecologically effective, with no-take areas containing more and bigger linefish species than exploited areas. However, fishers´ expert knowledge indicates that the sustainability and overall effectiveness of the MPA network are compromised by insufficient and ineffective enforcement, as well as insufficiently diverse sources of information for decision-making processes. The future management of MPAs in KZN would benefit from greater stakeholder inclusion and better adaptive management planning.

Identifying key research areas, angler compliance and perspectives on current regulations that aim to promote co-management and sustainability of the marine recreational fishery in Namibia

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Recreational fishing is popular worldwide, but many low- and middle-income countries (LMICs) are experiencing increased participation and reduced catches. Like other LMICs, the recreational fishery in Namibia is facing concerns regarding its sustainability. Empirical evidence suggested limited knowledge of the fish and fishery as one plausible cause. Fisheries management using knowledge of stock status have been mostly applied through a traditional top-down approach. In isolation, this approach is unlikely to work for recreational fisheries, where there are various stakeholders at different levels. A combined bottom-up-ecosystems-based approach is therefore necessary. However, this is challenging as it requires a shift in social science understandings of fishing towards context and interrelationships between fishers, the environment, and legislative bodies. This however does not exist for most fisheries. In an effort to address this, we carried out an onsite survey of shore-based angling in Namibia to evaluate angler compliance, behaviour and perceptions towards the regulations, management, and opinions regarding catch. Approximately 40% of anglers are motivated to fish for livelihood support. From the 235 anglers interviewed, there was a high level of non-compliance, which appears to be largely attributable to poorly defined regulations, and a lack of enforcement and limited access to information. Many anglers had limited knowledge or were confused by the complexity of some regulations (e.g. bag limit of maximum size). In addition, most had little appreciation of good handling practices, possibly due to the information not being readily available. Respondents highlighted issues such as the need for stricter regulations for both recreational and commercial fisheries, inclusion of volunteer anglers in enforcement, and re-evaluation of bag and size limits. We therefore recommend use of fisher ecological knowledge as critical point of synergy among anglers, scientists, and government to support and improve future management of coastal angling and sustainability of Namibian recreational fisheries.

The use and abuse of social media in the management of the South African marine recreational fishery

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Background

Recreational fishing is an increasingly popular activity worldwide, with over 220 million participants globally and ~ 400 000 in South Africa. While recreational fishing can have positive ecological and economic impacts, it can also lead to overfishing and negative impacts on fish populations. Catch and release (C&R) is a common practice in recreational fisheries that is used to mitigate these negative impacts. However, the effectiveness of C&R depends on the survival of the released fish, which can be affected by a number of factors, including the type of fishing gear used, the handling practices of the angler, and the physiological stress experienced by the fish during the C&R event. Social media is a powerful tool that can be used to both promote pro-environmental behaviour among recreational anglers as well as perpetuate the use of new angling technologies and in some instances the use of illegal methods. For example, social media can potentially popularise C&R angling or be used to share information about best practices for C&R, to encourage anglers to adopt more sustainable fishing practices. Consequently, social media can also rapidly advertise new fishing technologies increasing angler efficiency as well as organise anglers on where fish are aggregating. Marine recreational drone fishing is a new and growing activity involving the use of unoccupied aerial vehicle (UAV or drones) to transport baited lines into otherwise inaccessible areas or to perform reconnaissance and identify optimal areas for fishing. While drone fishing has been hailed by many recreational anglers, there are also concerns about its ethical and ecological implications.

Methods

The first case study examined the potential of Facebook to encourage pro-environmental behaviour among recreational anglers. The study focused on a large South African Facebook group called Salt Fishing South Africa (SFSA), a conservation-conscious group with a mission to promote sustainable fishing practices and the ethical treatment of all marine life. The group was established in 2013 and had nearly 70,000 members at the time of the study. The accompanying comments on the posts and the first 25 comments in response to each post were analyzed. These comments were categorized as positive (pro-environment), neutral, or negative (anti-environment) from a conservation perspective. The fate of the catch (C&R or catch and keep (C&K)) was also recorded. For C&R posts, the handling practices of the angler were assessed using a score-based system.

The second study used unconventional data sources to investigate the global interest in marine recreational drone fishing. The study also examined the catch composition in countries with the most active drone fisheries and discussed some of the biological, ecological, and conservation challenges associated with drone fishing. A global legislative policy review was conducted to identify whether the new activity is actively governed by any existing legislation. Evidence from social media platforms was collated with the social-ecological perspectives of South African fisheries scientists who shared their understanding of the potential consequences of drone fishing in a country where this practice is growing rapidly.

Results

The first case study found a notable increase in positive environmental attitudes and pro-environmental behaviour among the SFSA community between 2013 and 2020. This improvement was not associated with any intervention by scientists or the management agency and could therefore be attributed to a dedicated group administration. The administrators promoted a strong group ethos, environmental awareness, and education through the moderation of user-generated content. There was a significant increase in the proportion of catch-and-release (C&R) photos over time. There was also a significant association between the handling practice scores and year, with an increasing trend in the proportion of photos depicting good handling practices. The negative binomial model indicated a significant positive effect of year on the number of likes for photos showing C&R and C&K, although fate (C&R and C&K) and the interaction between year and fate did not have a significant effect on the number of likes.

The second case study found that there has been a significant increase in online interest in drone fishing in recent years. Where a single drone fishing YouTube video went viral in 2016 promoting a 357% increase in Google searches. This interest seemed to be concentrated in New Zealand, South Africa, and Australia. It was also found that drone fishing is targeting a variety of fish species, including some that are vulnerable to overexploitation such as elasmobranchs.

Conclusions
The first study suggests that online platforms may have an important role to play in improving recreational angler environmental attitudes and behaviour. Social media can therefore play an important role in angler self-reform within a recreational angling community. Social media can be used to share information about best practices for C&R, to encourage anglers to adopt more sustainable fishing practices, and to monitor angler behaviour. Drone fishing is a new and emerging activity with the potential to have significant ecological and social impacts. Further research is needed to assess the full extent of these impacts. In the meantime, fisheries managers should consider developing regulations to manage drone fishing.

Catch-and-release norms, attitudes, and perceptions among anglers in the recreational marine shore-based fishery in the Eastern Cape, South Africa

Christopher Bova (RU), Matthew Farthing (RU), Kata Lehloenya (RU), Warren Potts (RU), Alexander Winkler (RU), Amber-Robyn Childs (RU)

Marine protected areas (MPAs) effectively enhance fish stocks but often face resistance from local communities and recreational anglers due to short-term economic losses and perceived restrictions. Catch and release (C&R) zones, which are designated areas where the release of captured fish is mandatory, offer a potential compromise. This study examines the perceptions and attitudes of South African recreational anglers toward C&R zones, focusing on the Eastern Cape Province's marine shore-based fishery.

Data were collected through on-site surveys targeting recreational anglers in the Eastern Cape Province, South Africa. The surveys emphasised capturing self-reported C&R behaviours, attitudes toward C&R practices and zones, satisfaction levels related to catch and non-catch-oriented drivers, and perceptions of social norms. Findings reveal several insights. First, demographic factors such as age, income, education, and fishing frequency had little to no significant influence on angler attitudes toward C&R or C&R zones.

Within the sample group, satisfaction with the angling experience was shaped predominantly by non-catch-oriented drivers. This finding suggests that angler satisfaction may be less dependent on demographic characteristics than intrinsic enjoyment derived from the angling experience. Notably, although self-reported C&R practices and attitudes were generally positive, with many anglers voluntarily practising C&R, there was significant opposition to mandatory C&R practises in the form of C&R zones. Despite agreeing with C&R's conservation goals, most respondents expressed a reluctance to support regulatory restrictions that would mandate C&R practices within specific zones, i.e. a C&R zone.

The study proposes several explanations for this discrepancy between voluntary C&R support and resistance to C&R zones. One interpretation suggests that anglers view C&R as a personal, value-driven choice. When practised voluntarily, C&R may provide a sense of moral satisfaction, identity expression, and environmental stewardship; however, making it mandatory may feel like an infringement on anglers' autonomy, leading to psychological reactance. Drawing on reactance theory, we argue that mandatory regulations may trigger a sense of loss of control or restriction, causing anglers to resist even conservation measures that align with their own beliefs. Additionally, perceived social norms, particularly the perception of whether other anglers practice C&R, showed an inverse relationship with support for C&R zones. This suggests that when anglers believe C&R is already widely practised by others, they may perceive formal regulations as unnecessary or burdensome.

These findings indicate that support for C&R zones may depend less on demographic variables and more on how regulations are perceived in relation to autonomy, social norms, and identity. The weak but significant inverse relationship between income and catch-oriented satisfaction drivers and a positive correlation between catch-oriented satisfaction and support for C&R zones suggests that economic and experiential factors play nuanced roles in shaping attitudes toward conservation practices. Higher-income anglers, who may prioritise the non-consumptive aspects of fishing, showed less interest in catch-based satisfaction, aligning with prior research indicating that the motivations of higher-income anglers may be less tied to harvest and more to experience. However, the positive correlation between catch-oriented satisfaction and C&R zone support implies that anglers who derive satisfaction from catching fish, even if they release them, may be more amenable to regulatory efforts that protect fish stocks.

In conclusion, this study contributes to understanding the dynamics of angler attitudes toward C&R and C&R zones, emphasising that demographic factors alone do not predict attitudes, norms, or satisfaction. The findings highlight the importance of considering perceived autonomy, psychological reactance, and the role of social norms in developing practical, conservation-focused management strategies. They also emphasize the need for stakeholder engagement strategies that respect angler autonomy and align conservation measures with the motivations and identity values that shape angler behaviour.

THIRD KEYNOTE ADDRESS

Fish, fishers and the future: a spotlight on small-scale fisheries

Philile Mbatha (UCT, OOH)

In underlining the need to promote sustainable fishing, conserving marine and coastal areas and reducing marine pollution, SDG 14 directs our focus to 'life below water' in order to conserve and sustainably use ocean and marine resources. However, what happens 'above water' (i.e., above oceans, rivers and seas), as well as in coastal areas is arguably just as important as this is where people and livelihoods that depend on fisheries exist. The are many misperceptions and misunderstandings about small-scale fishers and their livelihoods when small-scale fisher livelihoods are multi-faceted and complex. For instance, some argue that small-scale fishers fish because they are poor, while other argue that small-scale fishers are poor because they fish. However, for many, small-scale fishing is not a means to an end – it is rather a way of life. Small-scale fisher livelihoods are intertwined with complex histories, socioeconomics, political and other contextual factors that influence their identities, values, customs and norms that inform where, how and why they fish. Needless to say, in various global South and North contexts, the rights of small-scale fishers have been progressively undermined by various interventions and decision-making processes over the centuries and decades, and more recently, various fisheries, ocean and coastal governance tools, strategies and processes continue to undermine the customary tenure, human rights and access of small-scale fishers. These and other challenges facing small-scale fisheries at the global scale, including (but not limited to) climate change and blue economy expansion, have made it necessary to promote the implementation of global tools that spotlight the rights of small-scale fishers within the broader fisheries agenda. The FAO *Voluntary Guidelines* for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF Guidelines) are useful not just as a set of tools, but exemplary principles for comprehensive small-scale fisheries governance that should be embraced by actors including governments, private sector and civil society. Although significant strides remain to be made in promoting the implementation of SSF Guidelines in country and regional contexts, there is a significant role that academic communities and civil society can play in supporting small-scale fishers and the implementation of the SSF Guidelines at local levels.

7. FISHERIES

Project CAREZONE: A trans- and multi-disciplinary approach to assess spatial connectivity of South Africa's marine shore-based linefish species

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Marine shore-based fisheries provide considerable economic and livelihood benefits, yet their governance is poor, particularly in developing countries, with the overexploitation of most stocks attributed to excessive harvest. South Africa's inshore fishery resources are heavily exploited by a large marine shore-based recreational fishery which has reduced the abundance of these species and the opportunities for a growing small-scale fishery. Research on this fishery has focused on life history and stock assessment of some species, but critical knowledge gaps on the ecological, human dimensions and governance aspects of the fishery still exist. An improved understanding of how to conserve nearshore linefish species is necessary for the persistence of coastal fish populations and livelihoods dependent on them. While compliance is poor with most fisheries regulations (i.e. traditional output controls), closed areas appear to be relatively well respected by shore-based recreational anglers but come at a socio-economic cost. This research highlights the potential for other effective conservation measures, such as non-consumptive catch-and-release zones, which may yield considerable benefits for species targeted in this fishery. Given that knowledge on the spatial distribution and connectivity of fish is critical for spatial-based management and conservation strategies, this research highlights the valuable role that both traditional and innovative methods, such as fishery catch data, species distribution modelling, ecophysiology, population connectivity, acoustic telemetry and angler perceptions and attitudes can play in assessing marine protected area connectivity in our shore-based linefishery. It is hoped that this trans-and-multi-discipline approach will provide a framework for linefish research, management and conservation in our changing climate.

Linefish bycatch in the trawl fishery: trends, areas and species associations

Colin Attwood (UCT), Kim Greenwood (UCT)

The inshore trawl fishery of South African operates over the continental shelf between Cape Agulhas and East London. This fishery primarily targets shallow water hake (*Merluccius capensis)* and east coast sole *Austroglossus pectoralis* but given that trawling is a non-selective fishing method, more than one hundred species are caught. This wide range of species leads to overlap and competition with other fishing sectors. Most overlap is with the traditional line fishery. Among the species caught by both fishing sectors are the silver kob *Argyrosomus inodorus*, carpenter *Argyrozona argyrozona* and white stumpnose *Rhabdosargus globiceps*. Each species is caught by both fisheries in similar quantities, although in the case of the silver kob the mean length of the catch is smaller in the trawl fishery. These are economically important species for the linefishery, and damage to their stocks by overfishing is an environmental, social and economic concern. This research was conducted in support of a project to alert the South East Coast Industrial Fishing Association of over-catching of certain bycatch species throughout the year. It investigates the potential of using real-time monitoring to give skippers the opportunity to adjust targets to avoid certain bycatch species.

In order to mitigate the potential threat to these species and the linefishery posed by inshore trawl bycatch, we examined trends in areas of capture, abundance and species associations in the trawl fishery for silver kob, carpenter and white stumpnose. Silver kob occupy inshore coastal waters. The two sparid species are widespread across the Agulhas Bank. In the inshore trawl fishery, all three species are caught primarily in warmer waters to the east and west of the fishing range, but are rarely caught in the cold ridge that forms over the bank between 22 °E and 26 °E during the summer months. Silver kob and white stumpnose are trawled predominantly in winter, between Cape Infanta and Mossel Bay and off Algoa Bay. Carpenter are trawled in cooler water on the central Agulhas Bank. Because it occurs closer to shore, silver kob experiences higher fishing pressure from all sectors than the other two species.

There was a general decrease in the fishing effort in the inshore trawl fishery from 1990 to 2020. The number of hours trawled dropped from ~80000 to ~ 20000 hours per year over this period. In 1992, the Japanese trawl fleet was removed from South Africa's EEZ, resulting in further reduction in trawling on the Agulhas Bank. There were increases in the trawl catches of carpenter and white stumpnose over the same period with similar peaks. Carpenter catches peaked at 43944 kg per annum (p.a.) in 2003 and 55886 kg p.a. in 2012. White stumpnose catches peaked at 103019 kg p.a. in 2003 and 46774 kg p.a. in 2012. CPUE was calculated as the catch per trip divided by the number of trawls per trip. The CPUE data per species were standardized by year, season, vessel and catch composition, using the *Clustering Fishing Tactics* procedure. Multivariate analysis on catch composition per trip was used to identify targeting clusters, and these clusters were used as categorical explanatory variables in the standardisation models. The standardized catch per trawl of both species increased over the time series. This increase implies a recovery of these two species stocks that coincides with the general reduction in fishing effort. Improvements in gear and technology used in fishing may have contributed to the increase in CPUE. On the other hand, silver kob shows a general decrease in total catch across the period, with peaks at similarly timed peaks as the other two species. The heights of these peaks were 245 359 kg p.a. in 2002 and 151722 kg p.a. in 2011. The decline of silver kob in tandem with the decline in fishing effort indicates that reducing the effort of the inshore trawl fishery has not allowed the stock to recover. The failure of this species to recover when compared to the other two species suggests other causes, including an escalation of fishing mortality from commercial line fishing and recreational fishing.

Studying the associations between the presence of different species within the catch can provide insight into where and when bycatch species are vulnerable to fishing aimed at another target. The compositions of catches from a 20-year dataset (2000 - 2019) were used in a multivariate analysis to estimate the co-occurrence of species in the landings from each trawl. Dendrograms and MDS plots were used to cluster trawls according to their catch composition using a Bray-Curtis similarity cutoff value of 0.3. Each of the three species shared with the linefishery occurred in distinct species assemblages in the landings. Associations were found between silver kob, east coast sole and St Joseph's shark (*Callorhinchus capensis)*, which prefer mud grounds, panga *(Pterogymnus laniarus)*, carpenter and belman *(Umbrina canariensis)*, which like low-profile sandstone reefs, and white stumpnose, gurnard *(Chelidonichthys capensis)*, and cuttlefish *(Ommastrephidae)* which prefer sandy substrata.

The annual catch composition of trawls showed strong clustering by vessel, which suggests that skippers might influence bycatch composition by changing their fishing strategy. By acting on information derived from detailed multispecies monitoring, competition between sectors and threats to vulnerable species could be more effectively managed. Management options might include more nuanced use of zonation, time-area closures or co-operative management of catch composition within the trawl fleet.

A conservation strategy to halt the decline of kob (*Argyrosomus* spp.) populations in South Africa

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Background

Collectively, sciaenids in the genus *Argyrosomus* are known as "kob" in South Africa and are favoured by multiple fisheries for their large size and desirable food quality. The dusky kob *Argyrosomus japonicus*, silver kob*A. inodorus*) and squaretail kob *A. thorpei* are amongst the most sought-after species in South Africa's multi-sectoral linefishery, and are also caught by industrial inshore trawlers. Additionally, the west-coast dusky kob *A. coronus* has recently become increasingly prevalent in Namibia and along the West Coast of South Africa. The dusky, silver and squaretail kob were historically abundant in South Africa, but their populations have since collapsed and continue to be overexploited by many sectors. Sciaenids have a vulnerable life-history, with aggregative spawning and predictable seasonal behaviour making them susceptible to targeted fishing pressure. For both the dusky kob and the west-coast dusky kob, this is compounded by slow maturation and use of estuaries, which makes them especially vulnerable. Both growth- and recruitment-overfishing across all habitats places tremendous pressure on these populations. In addition, some of these kob inhabit and rely on river-dependent marine ecosystems in estuaries and the coastal zone. These habitats have undergone significant degradation (e.g. increased sedimentation from poor agricultural practices and sandmining), natural systems modification (e.g. fresh water abstraction), pollution (agrochemical run-off) and other anthropogenic disturbances One of the primary management challenges for this group is their similar physical appearance, leading to confusion in accurate species identification. As a result, management actions are typically not species-specific, but instead attempt to manage the *Argyrosomus* genus with a complex set of region- and sector-specific regulations. As of 2024, the current management regulations are inadequate to effectively protect the populations of these species, especially in the large, open-access recreational sector. This is coupled with growing concerns about their susceptibility to climate change, changes in critical ecological processes such as fluvial discharge, and the declining quality of essential fish habitats, such as estuaries. As such, the aim of this project was to develop a conservation strategy to halt the decline of kob (*Argyrosomus* spp.) populations in South Africa

Methods

A group of 18 members of various institutions participated in a workshop to support the development of an IUCN Species Conservation Strategy for four kob species in South Africa. The workshop took place on 4th August (2022) and aimed to provide the initial support needed for developing an action-oriented strategy for the conservation of these important fishery species in South Africa. By the end of this workshop, an extensive list of potential threats, objectives, actions and research gaps was developed. It was then decided that a follow-up, prioritisation meeting was required to focus the Kob Conservation Strategy document on the most pressing and strategic threats, in accordance with the IUCN guidelines. This took place on 23rd August (2022) and yielded a refined list of priority threats and actions.

Results

Following a consolidation of all known threats to these species, threats were classified into broad categories using the Conservation Measures Partnership (CMP) Direct Threats Classification V2.0 (2016), and then assessed for impact using the IUCN Threat Impact Scoring System. The following five key threat categories are identified as the most impactful and pertinent in the following order: i) biological resource use (harvesting); ii) natural systems modification (including flow reduction, changes in sediment input and pollution); iii) human intrusion and disturbance; iv) invasive problematic species, pathogens and genes, which were considered less impactful, but were included strategically because they are suspected to be significant emerging pressures, and v) climate change. Although climate change is not immediately impactful, it has been included as a key threat because there is considerable evidence to suggest that this group of fish is likely vulnerable to the impacts of climate change, and it therefore must be considered in strategies of this nature regardless of a current low impact score.

Conclusions

This conservation strategy was developed using a collaborative workshopping approach with multiple stakeholders from government and non-government entities. The intention of the two workshops was to assemble a group of regional experts to support the development of an action-oriented strategic planning priorities to enable the recovery of these important linefish species back to/towards sustainable population levels in South Africa. Five key objectives for recovering kob populations in South Africa were developed, namely (1) Support the Linefish Scientific Working Group's proposed changes to the current kob regulations, and increase public awareness and acceptance of said regulations, (2) Promote stewardship of kob amongst user groups and management authorities, (3) Improve the spatial protection of kob in South Africa, especially within vulnerable aggregation sites, nursery areas and bycatch hotspots, (4) Ensure sufficient quality and quantity of freshwater flow into estuaries and the marine environment, and (5) Address critical knowledge and research gaps needed for effective management of kob in South Africa. Under each objective, key actions, sub-actions, lead actors, supporting actors, priority level and timeline are assigned. Researchers, advocates, fishers, conservationists, managers and decision-makers are invited to contribute additional information and support the conservation strategy and key actions required to achieve the long-term conservation vision of recovering these populations in South Africa.

Two decades of catch-per-unit effort and catch trends of five teleost species in the recreational shore-angling fishery in the northern Benguela

M. Wilhelm (UNAM), M. Gusha (UNAM), C. Bova (RU), M. Shipanga (UNAM), K. Hyder (CEFAS), W. Potts (RU)

Catch-and-effort (CPUE) data are important in assessing stock status to provide information for specific management regulations in each fishery. In this study, we used roving-creel survey data of recreational shore-angling collected by the Ministry of Fisheries and Marine Resources, Namibia between Terrace Bay and Walvis Bay from October 1995 to September 2017 (1995/1996-2016/2017 fishing season). Between 95 and 105 days were sampled over 22 sampling strata (five beaches with 4 strata each, plus two) per year/season. From 28 October 1995 to 24 September 2017, 2135 surveys were undertaken with 52030 angling groups, consisting of 155936 anglers, interviewed; 137415 fish counted and 54297 of them measured. CPUE and catch time series were calculated for five teleost species, silver kob *Argyrosomus inodorus*, west coast steenbras *Lithognathus aureti*, galjoen *Dichistius capensis*, blacktail *Diplodus capensis* and barbel/sea catfish *Galeichthys feliceps*. Long-term CPUE trends revealed that all stocks, expect for blacktail, had declined severely in CPUE, beginning in the early 2000s, with up to a 30% decline by the end of the time series. For west coast steenbras, the CPUE remained at 30% of the initial values in 2017. CPUE of silver kob recovered slightly but remained at 50% of the initial values by 2017. CPUEs of both barbel and galjoen recovered to initial values by 2017. Blacktail CPUE started increasing in 2010 and in 2017 was at 200% of the initial values. This indicates that silver kob and especially west coast steenbras are severely overfished and management actions need to be taken immediately. This dataset is unique in time series length of CPUE data in any recreational fishery in the world. It should be used as input into updated stock assessments for silver kob and west coast steenbras and for initial stock assessments of galjoen, blacktail and barbel.

Fishy business in Richards Bay

Sean Fennessy (ORI), Bernadine Everett (ORI)

Background
The South African national linefish survey conducted in the late 1990s produced seminal findings on participation in and socio-economic information on the linefishery. However, logistic challenges meant that the estuarine linefishery was excluded. Consequently, ORI conducted a survey of the linefishery in Richards Bay in the early 2000s, including the estuarine component, as the harbour is effectively a functional estuary. While undertaking the surveys of the different sectors, the question of assessing the consumer demand for linefish was raised – an aspect which has not hitherto been considered in South Africa.

Methods
Consumers were interviewed at a large shopping mall in Richards Bay on two weekend days. Respondents were approached at random, and asked about their fish and linefish consumption frequency, preferences, their sources of linefish, etc. Linefish examples were given to interviewees to ensure there was no confusion as to what the term meant. Local restaurants and wholesalers/retailers were also interviewed to determine other possible sources of linefish supply to consumers. Standard national linefish survey/interview methods were used monthly for the recreational and commercial linefish sectors to determine total catches from June 2002-July 2004.

Results
The demographics (race, gender) of interviewees was similar to that reflected in the Stas SA figures for Richards Bay at the time. Of the 170 mall interviewees, 27 (75%) said they ate linefish; ca. 40% of households ate linefish meals 1-5 times per month; 50% of households ate between 0.1-1 kg of linefish per meal, ca. 30% ate > 3 kg of linefish per meal. Given a total number of Richards Bay households of 12 200 (Stats SA) this translates to 27000 linefish meals/month and a demand of 24 t/month. Only four restaurants had linefish on their menus, because of franchise agreements, low demand and inconvenience, and they served limited quantities. Of the three wholesale or retail outlets, one (a supermarket) was retail only, the others were a mix. The supermarket sourced all its linefish (ca. 5 tonnes per annum [t p.a.]) from Durban; the one outlet only sourced linefish from Richards Bay and sold ca. 50 t p.a., but 95% of this went to Gauteng or Durban; the other outlet sourced most (75 t p.a.) of its linefish from Richards Bay, but 70% of it was sold in Gauteng and the rest was split equitably between Durban, Stanger and Richards Bay. Thus only 5-10% of linefish (ca. 10 t p.a.) caught in Richards Bay was retailed there. For the commercial skiboat sector (11 boats), 30% of the ca. 950 annual launches were inspected, with a mean catch per outing of 157 kg, translating to a total estimated monthly catch of ca. 12.5 t (compared to 17 t reported on the NMLS logbooks). For the recreational skiboat sector (ca. 500 boats), ca. 5% of 5 300 annual launches were inspected, with a mean catch per outing of 16 kg, translating to a total monthly catch of ca. 7 t.

Relative contributions to catch composition of the two skiboat sectors varied considerably, with recreationals catching a wider variety of species of which the more common species were more equitably distributed. Commercial percentage (%) composition by weight: slinger/soldier *Chrysoblephus puniceus* 76%, rockcod 7%, king mackerel *Scomberomorus commerson* 5%, kobs *Argyrosomus* spp. 3%, other 9%. Recreational % composition by weight: rockcod 30%, king mackerel 16%, slinger/soldier 14%, kobs 10%, cavebass *Dinoperca peteri* 4%, emperor snapper *Lutjanus sebae* 4%, tuna 4%, spotted grunter *Pomadasys commersonnii* 3%, Other 15%.

When asked where they obtained their linefish (they could choose > 1 option), 40-50% of consumers said they mostly or sometimes caught their own or bought it from shops; 80-90% said they never bought directly from fishers; and ca. 40% said they mostly or sometimes were given linefish.

Conclusions

The results produce a conundrum: the demand for linefish from consumers is 24 t per month, but the catch from commercial and recreational skiboats available to consumers amounts to only ca. 9 t per month. Either the consumers' estimates of the amount of linefish they consume is inflated, or there is far more use being made of recreationally caught linefish than deduced from the interviewees – either self-caught, or from being given it, or they are buying it from recreational fishers.

WWF-SASSI rating of the linefishery – is it theoretical scoring or practical improvements in the fishery?

Kolobe Mmonwa (WWF-SA), Pavitray Pillay (WWF-SA), Craig Smith (WWF-SA)

WWF's South African Sustainable Seafood Initiative (SASSI) undertakes regular annual assessment of local fishery resources to guide consumers and retailers on sustainable seafood choices and promoting implementation of sustainable fishery practices. In 2023, 14 linefish resources were reassessed using a newly revised marine common assessment methodology (MCAM) fishery standard. MCAM standard assesses sustainability of the fishery based on three main categories: stock status of the targeted species, ecosystem and habitat impact of the fishery, and management of the fishery. The current method is different to the previously applied standard in that it considers whether there is data available or not to make assumptions on stock status. Furthermore, multiple independent questions are asked on the environmental impact of the fishery including ecosystem and habitat impact, risk and management of ghost fishing gear. Of the 14 linefish resources assessed last year only two species showed improved SASSI rating, namely geelbek *Atractoscion aequidens* improved from red (2015) to orange rating, and catface rockcod *Mycteroperca andersoni* improved from orange (2014) to green rating. The remainder of the linefish species retained the same SASSI rating since their preceding assessment undertaken in 2014/2015. In this paper, we show that availability or lack of data and knowledge on the stock status of the linefish resources remains the key criteria in determining WWF-SASSI rating, not necessarily scoring criteria or technicality of the standard. Significant strides have been made in advancing our insights on environmental impact and management of the fishery, but limited knowledge on stock status of several species hinders improvement on WWF-SASSI rating.

8. GENETICS

On the importance of including molecular data in connectivity and forecasting studies of marine coastal fishes in South Africa

Romina Henriques (UP), George Brett (UP), Phindile Ntuli (UP), Kelvin Hull (UP)

Ongoing climate change is rapidly transforming marine ecosystems and communities throughout the world's oceans. Changes in sea surface temperatures and pH are considered two of the main drivers of latitudinal distribution shifts in marine fishes. Forecasting models that predict range shifts are thus essential to anticipate and mitigate potential conflicts and the subsequent socio-economic impacts of a moving resource. In order to distinguish among the multiple drivers behind range shifts it is necessary to understand the evolutionary dynamics that shaped current patterns of diversity, and, in particular, to identify the genomic basis of how fish are adapted to their local environmental niche. Understanding such local adaptations might aid forecasting models to predict which populations are likely to persist, expand or disappear under different climate scenarios and under which time frame. Furthermore, the contribution of fisheries to current levels of genomic diversity, as well as its adaptive significance, needs to be taken into consideration when establishing the vulnerability of a species to climate change, as decades of exploitation are likely to incur evolutionary consequences. In South Africa, genetic research of marine coastal species has generally relied on a handful of neutral markers, either mitochondrial DNA or nuclear introns and microsatellites, with majority of species studied showing extensive connectivity across the region. However, recent sequencing advances, which allow thousands of genome-wide markers to be obtained, have revealed evidence of local adaptation and cryptic population structure in regional marine species. Inclusion of genomic data into marine spatial planning and forecasting models also highlighted regions previously unrecognized as important for conservation of local marine biodiversity. Therefore, genomic data needs to routinely be included in species distribution models and marine spatial planning actions.

Insights from genetic and ecological knowledge for conservation management of rhino rays from the Western Indian Ocean

Mia Groeneveld (SU), Juliana Klein (SU), Rhett Bennett (WCS), Aletta Bester-van der Merwe (SU)

Rhino rays are highly threatened by overfishing (mostly as bycatch, but increasingly retained and targeted for their fins and meat), combined with climate change and low reproductive productivity. They were historically prevalent in soft-bottom habitats of shallow, warm waters, but catch and landing rates suggest drastic declines throughout most of their distributions. Yet, a lack of species-specific knowledge and taxonomic uncertainty persists, particularly for guitarfishes (*Acroteriobatus* spp.) and wedgefishes (*Rhynchobatus* spp) in the Western Indian Ocean region (WIO). When biological data from different species are pooled, species-specific fishery and demographic data can be overestimated or underestimated. Additionally, Sherman et al. (2023) found that the management shortfall for guitarfishes was greatest in Africa with the lowest scores for four endemic species, such as the Zanzibar guitarfish (*Acroteriobatus zanzibarensis*) found only in Tanzania. Although the families Rhinidae and Rhinobatidae are listed on Appendix II of the Convention on International Trade in Endangered Species of Flora and Fauna, enforcement of the management measures that are already in place remains challenging in the absence of species-level data.

Delineating species and understanding the population genetic connectivity of exploited species are important for their conservation management. This study (Groeneveld et al. 2024) investigated the population genetic structure of the whitespotted wedgefish *Rhynchobatus djiddensis* and the bottlenose wedgefish *R. australiae* from different locations across the WIO using a dual marker approach: (1) two concatenated mitochondrial gene regions (*COI* and the control region; $n = 117$), and (2) nine nuclear microsatellite markers ($n = 146$). Nuclear and mitochondrial DNA differ primarily in mode of inheritance and effective population sizes; thus their complementary use can enable more accurate quantification of genetic diversity parameters and investigation of population structure. The two species were delineated based on both marker types and their distribution patterns were refined by confirming that our samples from southern Mozambique and South Africa are *R. djiddensis*, whereas those from Australia, Réunion Island, Madagascar, Seychelles and Tanzania are *R. australiae*. For *R. djiddensis*, the sampling locations of South Africa and Mozambique were genetically homogeneous, thus they can be considered one management unit under this sampling regime. The frequency and extent of transboundary movements between South Africa and neighbouring Mozambique remains largely unknown, but *R. djiddensis* appears to move northwards as water temperatures cool with the onset of winter (Jordaan et al. 2021) and likely relies on nearshore habitats for pupping and mating in Mozambique (RH Bennett, pers. comm., Wildlife Conservation Society). Given that these sampling localities are mixing, the inshore marine protected areas on the east coast of South Africa could provide some protection for the species as a whole (Cliff & Daly 2022). However, the fishery-induced reduction in diversity and abundance of the species in Mozambique should be closely monitored; if it is confirmed that *R. djiddensis* uses these specific nearshore habitats for reproduction or as nursery areas, localised effects in Mozambique could have unfavourable consequences for the South African population too.

For *R. australiae*, significant differentiation was found between sampling locations, with Madagascar and Tanzania being genetically the most similar. A recent study (Simwanza & Rumisha 2023) found that *R. australiae* populations across the Indo-West Pacific should be managed as three different genetic stocks: WIO, Western Pacific and Australia, thus one distinct population such as Australia cannot replenish another such as WIO. Our study corroborates that populations from Australia and WIO populations are genetically different, but within the WIO, we found that there might be more fine-scale population structure, especially between locations that are geographically far apart. The detection of structure can imply that these species are susceptible to environmental changes, and the separation of these territories by deep oceanic waters and associated temperature changes likely constitutes physical barriers to gene flow. Management efforts should therefore be tailored to these isolated populations' needs. Overall, low diversity estimates of both species and some indications of recent population bottlenecks warrant careful management of all sampling locations. However, conservation priority should be given to the WIO region, especially the populations of *R. djiddensis*, and *R. australiae* from Seychelles. This information provides critical insights into the distribution range and stock structure of the whitespotted wedgefish species complex, highlighting priority populations and supporting the sustainable management of wedgefishes.

Detailed molecular attention is still necessary to fully resolve taxonomic issues and define appropriate spatial scales and stocks for rhino ray management. As such, further research will focus on expanding species-specific information for guitarfishes and wedgefishes within the WIO region using molecular taxonomy, population and seascape genomics, and community-based surveys. Delimitation and specimen assignment methods have been beneficial in addressing species identification challenges (Dellicour and Flot 2018, and references therein), offering insights into intra- and interspecific relationships and facilitating the inclusion of accurate entries into online sequence databases. Applying these techniques to *Acroteriobatus* spp. within the WIO region would aid in resolving the number of molecular operational taxonomic units (MOTUs) or evolutionary distinct lineages present, thereby contributing to the clarification of species distribution ranges.

Furthermore, vulnerability assessments provide a framework to evaluate the impacts of climate change on individual species. Recent evidence underscores the threat of climate change to coastal marine ecosystems, with many marine organisms already displaying shifts in distribution ranges (Diaz-Carballido et al. 2022). Both *R. djiddensis* and *R. australiae* are believed to be confined to the subtropical and tropical waters. Tropical coastal species are more vulnerable to rapid environmental changes, seeing that their members evolved in a relatively stable thermal state. Moreover, patterns of genetic population structure have been detected in *R. australiae* (Giles et al. 2016, Simwanza and Rumisha 2023, Tapilatu et al. 2023, Groeneveld et al. 2024). When species are not connected across spatial scales, populations can become fragmented with lower overall genetic diversity and decreased ability to respond to environmental pressures. Therefore, both species are likely vulnerable to rapid environmental changes, but their response to climate alterations on a genetic level is unclear. It is imperative to first understand the degree of population connectivity, as different populations of the same species may be subjected to varying regional selection pressures. Genomic studies provide a means to assess the latter and enable the identification of regions involved in genomic adaptation by comparing relative differentiation among genome-wide loci. Using a restriction site-associated DNA sequencing (RADseq) approach, neutral and putatively adaptive single nucleotide polymorphisms (SNPs) will be identified by correlating the SNPs with different environmental variables such as sea-surface temperature, salinity, dissolved oxygen content, pH and chlorophyll concentration. Here the goal is to have a better understanding of population connectivity and the impact of environmental changes on suitable habitats for vulnerable wedgefish populations (*R. djiddensis* and *R. australiae*) from the WIO.

Lastly, while there is nearly unanimous agreement within the scientific community regarding the significance of biodiversity conservation, the practical implementation of conservation measures often encounters obstacles due to insufficient integration with local communities. Therefore, we are conducting surveys, both online and in-person (when feasible), with water users such as divers and fishermen in local communities from South Africa and Mozambique to gather local ecological knowledge (LEK) about rhino rays. By combining insights derived from LEK (e.g., Gupta et al. 2023) with the aforementioned genetic analyses, a more realistic and equitable approach to conservation management of rhino rays can be taken.

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Reassessment of genomic diversity and connectivity of recreational linefish species in South Africa

Wilfred Olivier (UP), Romina Henriques (UP), Amber-Robyn Childs (RU)

Marine ecosystems are at risk due to human-mediated pressures such as overexploitation and climate change. For example, in South Africa, many of the fish species that are commonly targeted by the marine shore-based fishery (MSBF) are severely overexploited and have thus been listed on the IUCN Red List of threatened species with statuses that range from Least Concern to Critically Endangered. The species addressed in this project, blacktail *Diplodus capensis*, is an endemic species from southern Africa, with a range from southern Angola to Mozambique, and is predominantly targeted in the MSBF throughout their distribution range. Management of this species is not only important for maintaining the livelihoods of shore-based small-scale fishers but also for the conservation of endemic fish fauna. Research on the MSBF has focused primarily on the life history and stock assessment of some species, leaving gaps in the critical knowledge needed for management, including genetic diversity levels and population sub-structuring patterns. Therefore, determining genomic diversity levels, long-term population structure, and the likelihood of fisheries-induced evolution in priority MSBF species is a prerequisite to the vital regulation and ultimately conservation of South African marine biodiversity. This project will employ sequencing-based genotyping tools and multivariate statistical approaches to do so.

From the west side to the east side: Genetic diversity and population structure of two southern African endemic *Acroteriobatus* species

Michaela van Staden (SU), Juliana Klein (SU), Charlene da Silva (DFFE), Aletta Bester-van der Merwe (SU)

Guitarfishes (family Rhinobatidae) belong to the most evolutionarily distinct and threatened chondrichthyan lineages. Despite this, they remain poorly studied and undermanaged on a global scale. Along the southern African coastline, frequent misidentification has contributed to poorly defined distribution ranges and previous studies have highlighted the possibility of substantial population structure. In this study, a restriction site-associated DNA sequencing approach was used to generate single nucleotide polymorphisms (SNP) for specimens of lesser guitarfish *Acroteriobatus annulatus* and bluntnose guitarfish *A. blochii* sampled along the South African coastline. Given the frequent occurrence of misidentification, the morphological identifications of specimens were confirmed prior to investigating the distribution of inter- and intraspecific genetic diversity. Genetic clustering patterns were congruent with the morphological identifications of specimens, with a substantial divergence observed between sampling locations on the west coast and all other regions. The levels of intraspecific genetic diversity estimated were significantly different among the sampled regions, with *A. blochii* harbouring lower genetic diversity in comparison to *A. annulatus*. The population structure of *A. annulatus* was investigated through the use of putatively neutral SNP loci as well as loci putatively under selection to elucidate whether multiple evolutionary forces (adaptive and non-adaptive) are involved with the contemporary distribution of genetic variation within this species. While low levels of genetic differentiation were observed based on the neutral dataset, the presence of a genetic cline is evident across the continuous coastline from west to east for the outlier dataset. Although further analysis is necessary to test specific hypotheses about environmental factors driving selection, the contemporary distribution of genetic variation in *A. annulatus* has likely been shaped by more than geographical distance or non-adaptive evolutionary forces.

Unravelling two million years of evolution due to climate change: Genomic implications of hybridization in the southern African kobs (*Argyrosomus* spp.)

Phindile Ntuli (UP), Romina Henriques (UP), Warren Potts (RU), Pierre-Alexandre Gagnaire (UM)

The great biodiversity seen in the coastal seas of southern Africa includes the *Argyrosomus spp.* (kobs), which are seriously threatened by oceanographic alterations brought about by climate change. To develop successful conservation efforts, it is imperative that we comprehend the effects of these modifications on the genetic composition and distribution of the kob species. This study attempts to fill that knowledge gap. Ocean warming has led to a northward shift in the distribution of the southern west coast dusky kob *Argyrosomus coronus*, causing it to overlap and hybridize with the closely related Namibian species silver kob *A. inodorus*. Preliminary evidence suggests this hybridization may promote adaptation to warming conditions, though the cold Lüderitz Upwelling Cell appears to constrain both species, potentially subjecting *A. inodorus* to a "coastal squeeze". This research aims to evaluate the genomic patterns of hybridization between the southern African kob species including *A. inodorus*, *A. coronus,* dusky kob *A. japonicus* and squaretail kob *A. thorpei.* Further, genomics data will be used to evaluate genetic diversity, selection pressures, population sizes, and hybridization levels to provide crucial insights for the adaptive management of these threatened linefish species in the face of climate change.

Assessing the role of marine protected areas in maintaining evolutionary resilience in roman (*Chrysoblephus laticeps*) in South Africa

Mannda Ndou (UP), Warren Potts (RU), Amber-Robyn Childs (RU), Peter Teske (UJ), Jaco Greef (UP), Tuan Duong (UP), Romina Henriques (UP)

Roman *Chrysoblephus laticeps* is a South African endemic and exploited marine linefish, classified as Near Threatened by the IUCN. Previous research suggests that fishing pressures are altering its physiological response, with fish caught outside marine protected areas (MPAs) exhibiting lower resilience to increases in temperature when compared to fishes caught inside MPAs. Given the high residency of adults, the observed changes may have a genotypic component and may impact evolutionary resilience in roman, particularly in the context of changing oceanographic conditions. We generated an Oxford Nanopore reference genome data and Whole Genome Sequence data for 140 samples collected from two well-established MPAs (Tsitsikamma and Goukamma) and five non-MPA areas (Port Alfred, Gqeberha, St Francis, Struis Bay, False Bay), to characterize genome-wide diversity levels, differentiation, as well as to identify loci associated with physiological capacity between MPA and non-MPA areas along the South African coastline. This study connects ecological and genomic research to enhance conservation management of an iconic South African endemic fish, to arrest further declines.

Stock structure of west coast steenbras (*Lithognathus aureti*) along the Namibian coast using mitochondrial Cytochrome c Oxidase subunit I (COI) DNA sequencing and otolith shape analysis

Ndinehafo Nghipangelwa (UNAM), Margit Wilhelm (UNAM), Romina Henriques (UP)

West coast steenbras *Lithognathus aureti* is the second most important species caught by shore-anglers and the third most important species landed by the commercial line fishing boats along the Namibian coast. The last assessment of stock structure on west coast steenbras dates back to the 1990s, and no recent studies have been conducted. Furthermore, the degree of mixing and the exact border between the previously defined northern and southern stocks remains ambiguous. In this context, the overall objective of this study is to investigate the stock structure of west coast steenbras along the Namibian coast using both a molecular and a biological approach, by employing sequencing of the mitochondrial gene (COI), and otolith shape analysis. The study was confined to six sampling areas along the distributional range of the species in Namibia (from the far north, Kunene River Mouth 17.3°S, to south of Meob Bay, 24.7°S). A total of 120 fish were collected for this study, 20 fish from each site. For each fish sampled, both whole sagittal otoliths were removed for shape analysis, as well as fin clips for DNA extraction. Mitochondrial DNA (mtDNA) analysis and otolith shape analysis will be used to assess the stock structure of the species. In addition to offering an updated evaluation of west coast steenbras stock structure, key findings from this research are essential for assisting fisheries managers to develop updated management strategies based on the stock structure of the species. This information will guide decision-makers in fisheries management to avoid early exhaustion of vulnerable populations and therefore promote the sustainable use of the resource.

9. CLIMATE CHANGE

Promoting fish of the future – development of a strategy to mitigate the impact of climate change on our linefish populations

Warren Potts (RU), Cuen Muller (RU), Lauren Bailey (RU), Michael Skeeles (DU), Murray Duncan (US), Alexander Winkler (RU), Xolani Nabani (RU), Nonhle Mlotshwa (RU), Nicola James (SAIAB), Amber-Robyn Childs (RU)

With climate change rapidly influencing our linefish in several ways, it is essential for us to find ways to mitigate their likely responses and maintain resilient fisheries. Over the last eight years our research group has been trying to understand how exploitation selectively removes certain physiological phenotypes from fish populations. We were only able to do this research because of our large, old no-take MPAs and our findings have not only demonstrated how hook-and-line fishing reduced the potential of fish populations for physiological adaptation to the impacts of climate change, but also that no-take MPAs have the potential to retain “fish of the future” (FOF) that will promote adaptation. Using roman, *Chrysoblephus laticeps*, as a model species, this presentation aims to explain the mechanism driving selection by hook and line and its impact on the evolution of our linefish. We then look more closely at how a well-designed network of no-take MPAs or even “catch-and-release zones” can reduce these impacts by retaining and exporting FOF and facilitating the physiological adaptation of fish populations to a changing climate.

Growth rate extremes of a Sciaenid in an ocean-warming hotspot

Charmaine Jagger (UNAM), Warren Potts (RU), Brett Pringle (RU), M. Hadi Bordbar (IOW), Romina Henriques (UP), Niall McKeown (AU), Margit Wilhelm (UNAM)

In this study, we developed a 34-year otolith biochronology for silver kob *Argyrosomus inodorus*, a cool-water Sciaenid, found in the northern Benguela off Namibia, making up the highest catches in the recreational shore-based fishery. The linear mixed-effects models fitted to the *A. inodorus* otolith biochronology indicated that the best linear unbiased predictor of growth was significantly positively affected by mean sea surface temperatures (SSTs) in September of the year of formation and significantly negatively affected by mean summer SSTs (in November each year) in the central Namibian area (20-24 °S, 12-14 °E). Thus, faster annual growth was observed during warmer spring temperatures (increasing up to 15 °C), but slower growth was noted when exposed to warmer summer temperatures above 16 °C. This indicates a low thermal tolerance plasticity of *A. inodorus* and highlights the vulnerability of this species to future enhanced ocean warming predicted for this hotspot at the northern boundary of the northern Benguela. Thus, our findings suggest future narrowed distribution ranges and consequently temporary higher catch rates, and potentially recruitment failures. Our findings further suggest that fisheries selectivity likely influenced *A. inodorus* growth rates, which implies that fisheries-induced evolutionary changes had occurred in this heavily exploited Sciaenid found along the Namibian coast.

A new physiological model to forecast the climate response of linefish

Murray Duncan (US)

Background

Climate change is driving warming and deoxygenation of the world's oceans, directly affecting physiological rates of organisms and the fitness related processes they regulate. When conditions become sub-optimal, species may shift their distributions to maintain physiological functioning, but the direction and magnitude of these shifts in relation to environmental change is variable, complicating proactive management. Forecasts grounded in focal species' physiological responses to environmental change can better predict the realized responses. A popular physiological model is aerobic scope – the difference between basal and maximum metabolic rates, which is theorized to represent the metabolic capacity to fuel fitness related processes. When aerobic scope is quantified across a temperature range it is often bell shaped, allowing one to infer how temperature change may compromise/enhance metabolic capacity in a particular region for a particular species. A major drawback of aerobic scope is that despite measuring oxygen consumption as a proxy for metabolic rate the model does not explicitly incorporate environmental oxygen availability, limiting its usefulness to conditions where oxygen saturation is 100% in the ocean. Temperature and oxygen dynamics are particularly variable along South Africa's coastal zone driven by upwelling dynamics and relatively low oxygen conditions below 20 m depth which may make aerobic scope predictions of optimal temperatures for demersal linefish invalid.

Methods

In this talk I first present a new physiological model – the absolute metabolic index (Φ_A) (Duncan et al. 2023), that incorporates both environmental temperature and oxygen availability to quantify excess metabolic capacity (akin to aerobic scope), permitting predictions across the entire oxygen-temperature space in the ocean. Using an existing experimental metabolic dataset for the south African linefish; roman seabream (*Chrysoblehus laticeps*) (Duncan et al. 2019), I then compare the accuracy of thermal optima predictions for both aerobic scope (temperature only) and absolute metabolic index (Φ_A, temperature and oxygen) models.

Results

The absolute metabolic index (Φ_A) differs from absolute aerobic scope (maximum minus basal metabolic rates) by incorporating oxygen availability constraints on maximum metabolic rates. The oxygen level where basal metabolic demand can no longer be maintained is termed the critical oxygen partial pressure (PO_{2crit}) which also represents the point where maximum metabolic supply exactly matches basal metabolic demand. The rate of decline in maximum metabolic rate with oxygen (α) can be calculated as (α = basal metabolic rate/PO_{2crit}) and used to predict Φ_A across environmental oxygen and temperature, if the thermal dependence of both physiological metrics is known. See Duncan et al. (2023) for more details on this model.

The thermal optimum estimate for *C. laticeps* based on aerobic scope (i.e., temperature where aerobic scope is highest) is ~ 20 °C. Noticeably, 20 °C is far warmer than the cool-temperate south coast core-distribution of the species (average temperature ~ 14 °C) indicating an inability of aerobic scope to discern a realized thermal optimum for *C. laticeps*. Oxygen conditions throughout the south coast and below 20 m depth (the preferable depth of *C. laticeps*) often average below 50% saturation. Thermal optimum predictions using the absolute metabolic index (Φ_A) when oxygen saturation is 100% match those of aerobic scope at ~ 20 °C. This Φ_A based thermal optimum shifts cooler to ~ 14 °C, mirroring the temperature in *C. laticeps'* core-distribution, when oxygen availability drops to around 60% saturation, representative of the prevailing oxygen conditions throughout this distribution.

Conclusions

Overall, I find that predictions of a thermal optimum for *C. laticeps* appear more accurate (in terms of realized thermal conditions) when the effect of oxygen availability is incorporated using Φ_A, than temperature only aerobic scope models. This is because the temperature where metabolic capacity is maximized decreases as environmental oxygen declines. Linefish may thus exhibit a temperature shift in the absence of temperature change if oxygen levels decrease.

These results highlight the important non-linear interaction environmental temperature and oxygen availability have on rendering a habitat patch metabolically viable. Any forecasted climate responses of linefish through a metabolic physiology lens must therefore consider both temperature and oxygen effects to be more ecologically realistic – particularly important for the South African coastal zone given the prevailing temperature and oxygen dynamics.

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Can thermal metabolic physiology information predict fish behaviour observed on Baited Remote Underwater Video? – A case study on fransmadam, *Boopsoidea inornata*

Bradley van Heerden (RU), Amber-Robyn Childs (RU), Warren Potts (RU), Bontle Mateboge (UCT)

Background

Globally, climate change is placing fish populations under pressure through multiple environmental stressors including ocean warming. Fish may respond to these stressors through physiological acclimation, altering their behaviour or shifting their distributions. However, recent evidence has suggested that there is a clear link between physiology and behaviour in fishes. Understanding this link is critical for better predicting the likely response of fishes to a rapidly changing climate. While information on the physiology and predictions on their distribution is growing, there is limited information on the link between fish physiology and wild behaviour. The use of Baited Remote Underwater Videos (BRUVs) allows us to observe fish behaviour in the wild and with the increase and advancement of BRUV use in recent years, may augment our understanding of wild fish behaviour and when combined with appropriate physiological experiments, provide information on the link between physiology and wild behaviour.

This study aimed to improve our understanding of the link between metabolic physiology and the wild behaviour of a linefish species, the fransmadam *Boopsiodea inornata* by combining thermal metabolic information with wild behaviour observed using BRUVs.

Methods

A total of 45 live adult and subadult fransmadam were collected from an exploited (Cape St Francis) area using hook and line fishing. Fish were transported to the Aquatic Ecophysiology Research Platform laboratory at Rhodes University and acclimated for at least two months at 16°C. Standard metabolic rate (SMR), maximum metabolic rate (MMR) and aerobic scope (AS) of fransmadam was quantified using flow-through respirometry techniques at 8°C, 12°C, 16°C, 20°C, or 24°C. The relationship between the metabolic rates and temperature were modelled using a second order polynomial relationship and a population-level aerobic scope curve was developed for the species.

Behavioural information was collected from existing stereo-BRUV videos collected by SAIAB's Marine Remote Imagery Platform (MARIP) in Algoa Bay and Cape St Francis. These videos were taken at temperatures between 10°C and 18°C. The videos were analysed using EventMeasure software and the MaxN, 'Time to appear' and 'time to feed' was recorded.

Results

The SMR of *B. inornata* ranged from 0.69 to 3.75 O2.min^{-1}.kg^{-1} across test temperatures, with increased variability at the higher temperatures. Temperature had no significant effect on SMR (p-value = 0.155, R^2 = 0.54). Mean MMR ranged from 2.32 O2.min^{-1}.kg^{-1} (SD = ±0.65) at 8 °C to 6.995 O2.min^{-1}.kg^{-1} (SD = ±2.91) at 21°C across test temperatures with increased variability at the higher temperatures. Temperature had a significant effect on MMR (p-value < 0.01, R^2 = 0.39). The resultant mean AS ranged from 1.17 O2.min^{-1}.kg^{-1} (SD = ±0.62) at 8 °C to 4.19 O2.min^{-1}.kg^{-1} (SD = ±3.03) at 21 °C and temperature had a significant effect on AS (p-value < 0.01, R^2 = 0.197).

MaxN ranged from 3 to 110 individuals. Highest variability in MaxN was observed between 16 °C and 18 °C. Temperature did not have a significant effect on MaxN (p = 0.218). 'Time to appear' ranged from 1.58 minutes (13.59°C) to 50.92 minutes (11.74°C). Temperature (p < 0.01) and MaxN (p < 0.01) both had a significant negative effect. The interaction effect between MaxN and temperature revealed a significant positive effect on 'Time to appear' (p < 0.01). 'Time to feed' ranged from 2.25 minutes (17.53 °C) to 38.69 minutes (11.4 °C). Temperature (p < 0.01) and MaxN (p < 0.01) both had a significant effect. In addition, there was a significant positive relationship between ‘time to feed’ and the interaction between MaxN and temperature ($p < 0.01$). The peak physiological performance (AS) at 17 °C corresponded to the peak in MaxN and fastest ‘time to appear’ and ‘time to feed’. Similarly, the low AS at 8 °C corresponded to the lowest mean MaxN (no significant differences between temperature categories though), and the highest times for the ‘time to appear’ and ‘time to feed’.

Conclusions
The findings of this study indicate that there is a link between the metabolic physiology and wild behaviour of fishes at average and cold temperatures and confirm that AS could be a useful metric for understanding the likely response of fishes to the impacts of climate change in the wild. It also highlights the potential of archived BRUVs for understanding the wild response of fishes to environmental change. However, this study was limited by the availability of BRUVs at warmer temperatures and by a lack of information on the dissolved oxygen concentration in the wild. Therefore, future research should endeavour to collect this information. Ideally, the development of behavioural thermal performance curves (using the behavioural metrics identified in this study) may be the most cost-effective method to develop an understanding of the likely behavioural response of fishes to a changing thermal environment.

Living on the edge: Climate change induced intensification of upwelling impacts threatened and endemic species at their range limit

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The impacts of climate change on marine ecosystems by secular warming are well established. Recently, the lasting effects of extreme heatwaves have emerged as an additional threat to marine communities. In contrast, the impacts of extreme cold events are poorly understood. Using a multi-method approach we present the first evidence of climate-change induced intensification of upwelling on the coast of South Africa and its impacts on threatened migratory marine species, using the bull shark as a model species. We document intense upwelling events with substantial temperature declines that killed 81 species on the South African coast. Large and mobile marine species occurring near their thermal limits showed behavioural changes, likely to enhance survival of cold events when transiting through upwelling zones. Increases in frequency and intensity of upwelling could result in “bait-and-switch-systems”, where secular climate change expands species distributions, while simultaneously exposing climate-migrants to cold-stun events at distributional limits. This might increase mass mortalities, have severe impacts on range restricted species and potentially reverse range expansions. Our results highlight the complexities and context-dependence of climate change effects on marine ecosystems. We forecast that intense upwelling events will become more frequent on the South African coast and discuss the implications for threatened and endemic fish species.

Thermal tolerance of wild caught dusky kob *Argyrosomus japonicus* individuals

Josh Frachet (RU), Amber-Robyn Childs (RU), Warren Potts (RU), Matthew Farthing (RU), Alexander Winkler (RU)

Globally fish are facing the increasing pressures of various anthropogenic activities which influence fish directly and indirectly. One of the direct activities influencing fish populations and communities is fishing pressure. In South Africa, the marine shore-based recreational fishery places a significant direct pressure on fish stocks. Stock declines are exacerbated indirectly by climate change pressures such as ocean acidification, increasing sea surface temperatures, thermal variability, and intensifying upwelling cells. Coastal fisheries in South Africa are crucially important economically, socially, and ecologically, and their sustainability is crucial for livelihoods. Fishing is known to remove the fittest individuals able to tolerate greater temperature extremes. Understanding how the remaining fish will respond to changing temperature, (behaviourally and physiologically) is crucial to knowing the possible adaptative capacity of these exploited populations. Ectothermic fish have been shown to develop behavioural adaptations as a first response to changing environmental conditions. These behaviours however are driven by physiological processes. Therefore, an individual's physiological and behavioural phenotype will determine adaptability to rapidly changing environments. Populations with a large phenotypic diversity will likely have increased resilience to climate change. This study examines the link between physiology and behaviour of dusky kob to understand their adaptive capacity. We will capture 20 dusky kob *Argyrosomus japonicus* individuals from the Kowie Estuary in Port Alfred, assess their thermal tolerance to classify individuals into physiological phenotypes. They will then be tagged using acoustic transmitters and released at their capture site, and their movement will be monitored in relation to their physiological phenotype and in-situ temperature. This will contribute to the existing knowledge on fish physiology and improve our understanding of the adaptive capacity and resilience of important coastal species to the ever-increasing impacts of human-induced global change.

Development of ecological niche models to predict the future distribution of *Diplodus capensis* in South Africa

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Background

Changes in sea temperatures, resulting from anthropogenic climate change, is one of the leading causes of changes in the distributional range limits of several fish populations globally, which can result in distributional shifts. Many subtropical and temperate fish species are seeing poleward shifts in response to warming and cooling seas (through marine heat waves and upwelling). Shifts in the distribution of marine fishes can have major consequences for the fish themselves (by not being able to cope with the new environmental conditions) and also for the fishers that depend on these resources for their livelihood. Studies have shown that fishes in the South African linefishery may be vulnerable to these shifts and that the fishery at large may be threatened.

Understanding the response of an important fisheries species, such as blacktail, *Diplodus capensis* to climate change is an important step in effective and adaptive management of South Africa's shore-based fishery species. Distributional shifts of fishes are often studied retrospectively using occurrence data and are often at a low spatial resolution. Using the fish's physiological responses to temperature changes can help create a clearer image of its distribution and allow for the prediction of future patterns in response to climate change.

This project aimed to model the current spatial distribution of *D. capensis* along the South African coast and use physiological thresholds to predict future distributional shifts in their population in response to anthropogenic climate change. To do this the spatial distribution of *D. capensis* was modelled using occurrence data, adapted from existing catch data of the Rock and Surf Super Pro League (RASSPL), the Oceanographic Research Institute's Cooperative Fish Tagging Project (ORI-CFTP) and the Global Biodiversity Information Facility (GBIF), correlated with existing environmental data (including in situ temperature data from the South African Environmental Observation Network [SAEON], Acoustic Tracking Array Platform [ATAP]) and available sea surface temperature data (e.g. Copernicus and BIO-oracle) for the South African coastline to develop a contemporary species distribution model for this species. Respirometry trials on adult caught *D. capensis* were conducted to determine the species thermal performance and thermal thresholds to predict future distributional shifts under climate change.

Methods

Twenty-five adult blacktail (*Diplodus capensis*) were collected in Port Alfred, Eastern Cape (33°36'50.17"S, 26°53'24.50"E) by shore angling. Specimens were caught and kept in an onsite holding tank filled with sea water after which they were transported to the Aquatic Ecophysiology Research Platform (AERP), at the DIFS at Rhodes University. Once at DIFS, the fish were acclimated for two weeks in two cylindrical 3500l holding tanks. The filtrations system was fitted with a protein skimmer, bubble-bead filter, UV sterilizers, a heat pump and a biological filter to maintain optimal water quality. Water temperature was maintained at 18°C, mirroring the capture site conditions, with a 12-hour light/dark cycle. Daily monitoring ensured optimal water quality (35 PSU salinity, 7.9–8.4 pH, >100% oxygen saturation, and low ammonia/nitrate/nitrite levels). Fish were fed squid every second day to standardize intake, reducing metabolic rate variation.

Static respirometry trials used four custom-built 13.046l respirometers, each housed in a 200l water bath to measure metabolic rates. Each unit had a primary recirculation loop driven by a submersible pump and a secondary loop with a peristaltic pump, directing water through a FireStingO2 fibre optic oxygen meter for real-time oxygen monitoring. Oxygen measurements were recorded via Pro Oxygen Logger Software. An overflow nozzle with one-way valves controlled water flow during flushing and measurement phases. The experimental procedure was approved by the Rhodes University Animal Ethics Committee (approval number: 2024-7395-8327).

The metabolic responses of *D. capensis* were assessed across five test temperatures (10°C, 15°C, 18°C, 22°C, and 24°C), with four fish tested per temperature to establish aerobic scope at the population level. The lowest temperature was based on prior research indicating a critical thermal minimum (CTmin) of approximately 9°C, while the maximum was selected based on the collection site's average monthly sea surface temperature, which does not exceed 20°C.

Each fish underwent a single trial, was then marked, and returned to the holding tanks post-experimentation to monitor survival, enhancing understanding of temperature effects on this species. Each trial spanned approximately 36 hours, comprising acclimatization (4-5 hours), temperature adjustments (2°C per hour), standard metabolic rate (SMR) measurements (12 hours), maximum metabolic rate (MMR) assessments (6 hours), and critical oxygen saturation (O2 crit) measurements (2 hours). Background respiration was measured for an additional 2-3 hours following O2 crit assessments. Trials commenced with respirometers receiving fully oxygenated water at 18°C. The experimental setup included pre-trial calibration of the oxygen sensors for each trial to ensure accurate readings.

Fish were isolated within the respirometers using opaque shields to minimize behavioural influences, while photoperiod conditions mirrored those in the holding tanks. During SMR and MMR measurements, a flush-and-measure cycle was implemented to maintain oxygen saturation above 80%. MMR involved inducing exhaustion in fish by chasing them in an external tank, simulating a catch event. Following a brief air exposure, the fish were returned to the respirometer, where oxygen consumption was monitored to capture MMR. Following metabolic rate measurements, fish were allowed a rest period of 4-5 hours before respirometers were sealed to evaluate critical oxygen saturation (O2 crit). Oxygen levels were gradually reduced while fish were monitored for respiratory distress indicators. O2 crit was recorded as the concentration at which equilibrium was lost, signalling respiratory failure.

Data from static respirometry included oxygen readings during flush and measurement phases. Standard metabolic rate (SMR) was determined by filtering readings to the lowest consumption rates, typically occurring between 2:00 and 5:00 am, with a quality threshold of $R^2 > 0.9$. The rate of oxygen consumption (RO_2) was calculated using the following equation (Svendsen et al. 2016)

$$RO_2 = \left(\left(\frac{V_{re}-M}{W}\right)\left(\frac{\Delta[O_{2a}]}{\Delta t}\right)\right) - \left(\left(\frac{V_{re}-M}{W}\right)\left(\frac{\Delta[O_{2b}}{\Delta t} \times 60\right)\left(\frac{V_{re}}{(V_{re}-M)}\right)\right)$$

Where V_{re} is the total volume of the respirometer, M is the mass (kg) of the fish expressed in liters, W is the mass of the specimen expressed in liters, Δ[O_2a]/Δt is the linear decline in oxygen during the SMR trials, (Δ[O_2b)/Δt is the linear decline in oxygen when there is no fish in the respirometer (background respiration). SMR was calculated as the arithmetic mean of the lowest 20th percentile of the data, while maximum metabolic rate (MMR) was based on the greatest decline in oxygen post-exercise. Both rates were temperature-corrected using the Boltzmann factor to account for thermal effects, and mass-corrected metabolic rates (MO_2) were computed through allometric scaling for MMR and linear scaling for SMR. A generalized least squares (GLS) model assessed the relationship between metabolic rate and temperature, implemented in the nlme package (Heisterkamp et al. 2017) in R (version 4.4.1). for $O_{2\,crit}$ a linear modelling approach was employed.

Results

Results indicated that mass-corrected metabolic rates (SMR and MMR) increased with temperature, with the lowest rates at 10°C and the highest at 22°C and 24°C. Variance in metabolic rates also rose with temperature, suggesting an allometric relationship. Both SMR and MMR exhibited significant positive correlations with temperature, although the polynomial relationship for MMR was not significant due to increased heteroscedasticity. Modelled aerobic scope (AS) demonstrated a significant negative polynomial relationship with temperature, peaking around 17°C before declining at higher temperatures, while the linear relationship was not significant, indicating complex metabolic responses to thermal changes in *D. capensis*.

The spatial distribution of *D. capensis* was modelled using occurrence data from the RASSPL competitive database and the ORI-CFTP. These occurrence data were correlated with existing environmental data (including in situ temperature data from the SAEON, ATAP and available sea surface temperature data (e.g. Copernicus and BIO-oracle) along the South African coastline to develop a contemporary species distribution model for this species. Preliminary assessment of the species distribution models showed that the species will experience range loss along its northeastern distribution by 2050. While this will continue to 2100, the model predicted a range expansion along the Agulhas Bank. Future analyses will include the incorporation of depth and the physiological thresholds into the models for more robust predictions of the future distribution of this important fishery species.

Conclusions

This study shows that publicly available data such catch and occurrence date and remotely sensed sea surface temperature date can be utilised alongside metabolic indices such as metabolic rates and $O_{2\ crit}$ to create a clearer picture of how important fisheries species with the South African shore-based marine line fishery will respond to on-going and future climate change patterns

Assessing the impact of exploitation on the activity of a coastal reef fish, *Chrysoblephus laticeps* in a thermally variable environment

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Background

The marine environment comprises a diversity of habitats and a wide array of organisms that are critical for sustaining life on planet earth as we know it. However, climate-induced pressures are leading to alterations in many marine ecosystems (Stuart-Smith et al. 2015), which are reducing the integrity of the marine ecosystem and negatively impacting marine biodiversity (Wabnitz et al. 2017). Climate change alters ocean conditions such as biogeochemistry and water temperature, which directly affects the growth, physiology, and reproduction of marine organisms (Pörtner and Knust 2007) as temperature patterns and photoperiod serve as reproductive cues for fishes. In addition to climate-driven pressures, fishing also plays a role altering the marine ecosystem and fish communities, by selectively removing more active, bolder, physiologically fitter, faster growing, larger, highly fecund individuals. This alters the behaviour of fish, their ability to adapt to change, and the productivity, and reproductive potential of fish populations. Understanding the synergistic impacts of a changing climate and exploitation are critical to better predict the responses of fish populations to climate change and how these may impact fisheries. One approach to do this is to compare the responses of exploited and unexploited populations of fish to extreme conditions.

Unlike many parts of the world, where ocean temperatures are warming rapidly, the coastal waters off the southern coast of South Africa is increasingly subjected to extreme thermal events through a warming Agulhas Current and increasing frequency and intensity of upwelling events. Comparing the response of exploited and unexploited populations of resident fishes in this area will improve our understanding of the likely response of fishes to these changes and provides an opportunity to uncouple the responses of impacts of exploitation and a changing climate on fishes.

The aim of this study is to examine the activity of individuals in an exploited and unexploited population to get a better understanding of how each population responds to the effects of climate change. This was achieved by assessing the acceleration (proxy for activity) of an exploited and unexploited population of the highly resident sparid, *Chrysoblephus laticeps* in the wild using acoustic telemetry. The findings were then compared to the findings of Skeeles (2019), for the purpose of developing our knowledge and understanding of the role played by exploitation on the resilience of fishes against climate change and the role played by MPAs in conserving the species resilience.

Chrysoblephus laticeps, is a reef associated sparid that is endemic to the South African warm temperate coast (Kerwath et al. 2007), with a core distribution along the Western and Eastern Cape provinces, South Africa. It is a highly exploited species targeted by commercial and recreational fisheries throughout its distribution (Brouwer and Buxton 2002, Duncan et al. 2019). This species is an excellent candidate for experiments on the synergistic impacts of exploitation and climate change due to its resident nature and the observed impacts of fishing on its demographic traits such as, growth, fecundity and reproduction (Buxton 1993).

Methods

A total of 13 *C. laticeps* were tagged with acoustic accelerometry tags in Cape St. Francis - CSF (exploited site) and Goukamma MPA – GKM (protected site). The activity of each fish was examined against the impacts of exploitation in a temperature variable environment using acoustic accelerometry. It was hypothesized that exploitation would have no effect on the acceleration in both populations. The results obtained from this study were compared to those of Skeeles (2019), who tracked wild-caught individuals tagged with accelerometer transmitters in the exploited site in Port Elizabeth (PE) and an unexploited site in the Tsitsikamma National Park (TNP), and found that fish from the exploited PE population were less resilient to climate change, as their activity was found to be significantly lower at thermal extremes when compared with fish from the unexploited population. Duncan et al. (2019) also compared the aerobic scope of *C. laticeps* from the exploited PE and unexploited TNP site and found that the aerobic scope of the exploited population was reduced, thus impacting their performance against a temperature variable environment.

While these studies have made a significant global contribution to our understanding of the impact of exploitation and climate change on fish behaviour and physiology, confounding factors related to the lack of study site replication cannot be discounted. It was thus critical to increase the replicates and comparisons of acceleration of unexploited and exploited populations to ensure that the data collected is relevant, robust and reliable if we are to use this data to inform fisheries managers and policy makers in establishing a sustainable marine environment and in the case of this research, the promulgation of additional MPAs.

To assess the relationship between acceleration and temperature in the exploited and unexploited populations, two acoustic telemetry arrays were deployed in both sites from February to August 2022. Thirteen receivers were deployed in a square-shaped array. Two transmitters were placed on two mornings to assess environmental noise. At the centre of each array, a temperature logger was attached to the mooring to record the water temperature every 30 minutes. Thirteen fish were captured within each array using standardized rod and line baited hook fishing methods in each site. Fish were measured to confirm their size range and thereafter anesthetized using clove oil. Using a sterilized hypodermic needle, the fish's gas-bladders were deflated, and an acoustic accelerometer pressure transmitter was surgically implanted into their coelomic cavity. Fish were allowed to recover in an aerated tank and thereafter released into the centre of the array.

Data for each fish was processed individually and the acceleration values were averaged every 30 minutes for the purpose of linking the values by date and time to the corresponding water temperature recorded in the array. Because it is a diurnal species data collected during daytime was used to estimate the activity of fish during the study period.

Results

The modelled daytime activity showed that the exploited CSF population displayed reduced activity below their environmental mean of 15.6°C, and thereafter slightly increased in activity and maintained a steady activity rate across all temperatures. The unexploited GKM population exhibited a general increase its activity as temperatures increased, with the lowest rates of activity observed when the temperature was around the GKM environmental mean of between 11 and 12°C. A higher level of activity was observed in the unexploited GKM population when compared to the exploited CSF population across the thermal gradient. This was attributed to fewer individuals that were active across all temperatures. The results from the generalized additive mixed model showed that temperature had a significant positive effect on activity (p-value < 0.01), and that the rate at which acceleration increased with temperature was significantly different between the populations (exploited and unexploited) of *C. laticeps* (Site, p-value < 0.001).

Conclusions

The findings of this study supported those of Skeeles (2019) and demonstrated that there were less individuals that were active across all temperatures in the exploited population when compared with the unexploited populations and this resulted in significantly higher activity at the population level. This finding suggests that exploitation plays a significant role in the response of fishes to changing thermal conditions and to the variable temperatures associated with a changing climate. These findings also highlight that by protecting high performance individuals, that are capable of activity across a broad thermal range, MPAs can play an important role in promoting population resilience of coastal fishes. Since Muller (2022) found that these high performing genes of *C. laticeps* were passed on to the next generation, it appears that MPAs play a role in preserving phenotypic diversity within fish populations and may be an effective climate management tool, as they harbour populations with high-performance aerobic scope phenotypes and greater physiological phenotypic diversity (Duncan et al. 2019). In addition, MPAs will play an important role in maintaining resilient passive fisheries, such as hook and line fisheries, that rely on active fish for maximizing capture success due to the spillover effect (movement of organisms near MPA borders into exploited areas) of adults (Kerwath et al. 2013, Gell and Roberts 2003) and larvae. Therefore, well-designed MPA networks can buffer the selective removal of HTPs in adjacent commercial line fisheries, leading to an increase in the physiological resilience of the population in a thermally variable environment (Duncan et al. 2019).

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Investigating the thermal tolerance of two estuary-dependent mugilids

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The rapid increase in global sea surface temperatures accelerated by anthropogenic climate change has prompted the proliferation of studies investigating the effect of climate change on biodiversity (Vinagre et al. 2015). Understanding the thermal tolerance of species is a crucial initial step that not only enhances our understanding of thermal biology, but also sheds light on the potential for aquatic species to adapt to the changing climate (Desforges et al. 2023). As a result, physiological adaptation is therefore crucial for organisms that inhabit unstable environments such as coastal ecosystems and estuaries where abrupt changes occur over a short period of time (Whitfield 2021). Although most estuarine fishes are capable of tolerating a wide range of physio-chemical conditions (van der Walt et al. 2021), an increase in the frequency and intensity of variables such as marine heat waves or wind-driven cold-water upwelling which infiltrate estuaries, may see these species adapting differently (Duncan et al. 2019; Whitfield 2021). Although the impacts of climate change on South African estuaries are well understood (James et al. 2016), our understanding of the thermal niche of several estuary-associated species is still very limited. As such, it is critical to understand how organisms within these systems will respond to climate change, and how this may impact the livelihoods of the people relying on these resources.

Mugilids (mullet) dominate most estuaries globally and contribute significantly to species composition and biomass in both permanently open estuaries temporarily open/closed estuaries in South Africa. The occurrence and distribution of mullet along the South African coast and estuaries are strongly linked to regional coastal water temperatures. Thus, it was suggested that they may be some of the first fish species to respond to a change in environmental variables linked to climate change (James et al. 2016). As such, the aim of this study was to evaluate the critical thermal limits; Critical thermal minima (CT_{min}) and Critical thermal maxima (CT_{max}) for two mullet species: flathead mullet *Mugil cephalus* and grooved mullet *Chelon dumerili* collected from a permanently open warm temperate South African estuary. In addition, the study also examined the effects of temperature on the opercula beat frequency of these fishes as a proxy for their ventilation rate.

Fish were collected from the Kowie Estuary, Port Alfred, South Africa. The Port Alfred coastal area has been reported to have frequent wind-driven coastal upwelling events, and due to global climate change, these events are predicted to increase in frequency and intensity (Lutjeharms et al. 2000; Duncan et al. 2019). Fish were caught using a seine net and cast nets and were transported from the estuary to the AquaLab Laboratory at Rhodes University, Makhanda. The fish were acclimated for four weeks at a temperature of 19.3 ± 0.2 °C and salinity of 35ppt before thermal tolerance trials were conducted. Water temperature and water quality measurements were taken every day for dissolved oxygen (DO), pH, salinity, ammonia, nitrites and nitrates.

Prior to the experiments, fish were tagged with Passive Integrated Transponder (PIT) and Visible Implant Elastomer (VIE) tags to uniquely identify each individual fish during the trials. Thereafter, repeated measures for CT_{max} and CT_{min} trials on each individual were performed. During CT_{max} trials, fish were transferred from the holding tank to one of five 1000-L experimental tanks with three fish of different coloured VIE tags in each tank. Using a heat pump (Aquaheat, SF040P G/EVAP) and heating rods (Eheim, 3619, Deizisau, Germany), the water temperature in the experimental tanks was increased at a rate of 1 °C/33.85 min (± 0.0004 min SD). The non-lethal endpoint was recorded when there was a loss of equilibrium, an onset of muscular spasms or when fish showed erratic behaviour (jumping or rapid up and down movements). Fish were allowed to recover for 2 days before CT_{min} trials were conducted. During the CT_{min} trials, the water temperature was decreased at a rate of approximately 1 °C/48.62 min (± 0.03 min SD). In addition to the heat pump, a chiller (Hailea, HS-90A) was connected to the inlet pipe draining into the sump tank. After reaching the end point, the fish were immediately and carefully removed from the experimental tanks with hand nets and placed in a 100-L recovery water bath. At every 2 °C change during CT_{min} and CT_{max} trials, two 7-minute videos (GoPro Hero8, California, USA) were recorded in each of the five tanks to assess the rate of ventilation by counting opercula beats and to observe fish behaviour.

The CT_{min} for the grooved mullet was 6.3 °C (range: 5.4 °C–7.6 °C), while the CT_{max} was 36.4 °C (range: 35.7 °C–37.9 °C). The rate of opercula gill opening ranged from 48 beats/min at 10 °C to 337 beats/min at 36 °C. The flathead mullet had a CT_{min} of 3.7 °C ranging from 2.6–3.8 °C and a CT_{max} of 37.7 °C (range: 37.2–38.3 °C). The rate of opercula gill opening in the flathead mullet ranged from 36 beats/min at 8 °C to 312 beats/min at 36 °C. Temperature was positively correlated with opercula beats in both species. At higher temperatures, near the CT_{max}, fish were observed rapidly swimming and starting to show signs of erratic movements. At low temperatures, fish were showing very minimal movements; however, due to suspected increased stress levels at low temperatures, some fish showed increased rate of opercula beats. Our results indicate that although both mullet species are tolerant to a broad range of temperature challenges, the flathead mullet had a considerably lower CT_{min} when compared to the grooved mullet. In addition, our results indicate that extreme temperatures may cause a decrease in aerobic performance, especially swimming ability, which may limit an individual's ability to escape unfavorable temperatures. This study provides essential information on the potential effect of climate change on estuarine fishes.

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The influence of habitat association on the tolerance of coastal fish to future coastal acidification

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Background

Although the nursery function of vegetated coastal habitats (such as seagrass and macroalgae) for economically important coastal fish species is well documented, other ecosystem services provided by these important habitats have received less research attention. The influence of global carbon dioxide emissions on seawater chemistry resulting in ocean acidification (OA) and its consequences on marine organisms has been broadly documented. Acidification in coastal habitats is far more complex and several other biophysical coastal processes influence local pH variability in addition to atmospherically driven OA, resulting in inherently variable conditions. One of these factors is autotrophic biological activity, which can influence local pH conditions over various scales of space and time. Recently, it has been acknowledged that marine vegetation, such as macroalgae and seagrass, can modulate local pH conditions through biotic processes and thereby serve as ocean acidification refugia for marine organisms by raising the average pH of surrounding seawater as well as through exposing organisms to more variability (reviewed by Falkenberg et al. 2021; Edworthy et al., 2023). This is supported by research that has shown that organisms associated with vegetation have a higher tolerance to low pH. The majority of research on this has focused on marine invertebrates like bryozoans, foraminifera and coralline algae, and much less has been done on fish. Our study aimed to assess the tolerance of an early-stage coastal species (blacktail *Diplodus capensis*) that is associated with marine vegetation to low pH treatments predicted with future coastal acidification.

Methods

Monitoring

Continuous monitoring of pH and temperature variability is being conducted at vegetated and adjacent unvegetated habitats across the temperate south coast of South Africa, with a focus on macroalgal reefs and seagrass habitats within Algoa Bay and St Francis Bay. HOBO pH and temperature loggers are deployed for 24 hours at a time.

Experimental study

Late post-flexion stage *D. capensis* were exposed to a range of pH conditions that covered the current variability that they are naturally exposed to (8.0 – 7.8 pH) as well as projected scenarios under coastal acidification (7.8 – 7.2 pH). After four days of exposure to experimental treatment conditions, their metabolic and behavioral response was quantified using intermittent flow respirometry, swimming activity trials and feeding trials.

Results

Monitoring

Variability in pH of up to 0.57 pH units has been recorded, as well as a consistent diurnal signal in pH variability. Peaks in pH are reached during the daytime (up to ~8.30 pH) and reach lows at night (~7.80 pH). This variability appears consistent in both seagrass and macroalgal habitats. Sporadic events, such as upwelling, have also been recorded and appear to have a substantial impact on pH minimums which can exceed 7.8 pH units.

Experimental study

Our study species showed physiological tolerance to even the extremely low pH conditions that exceed the natural variability they are exposed to after acute exposure. This was evidenced by no metabolic response (routine and active metabolic rates as well as relative aerobic scope). There was a slight increase in swimming activity (swimming distance and swimming speed) with a decrease in pH, however this did not have any influence on feeding rate which was unaffected by pH treatment.

Conclusions

Our research has shown much greater 24-hour variability in pH in vegetated macroalgal and seagrass habitats than in sandy habitats in Algoa Bay and St Francis Bay. Although *D. capensis* is found in a range of coastal habitats, vegetated habitats (seagrass and macroalgal reef) provide high quality nursery habitats for this species (shelter and food). Our results suggest that late-stage larvae collected from a vegetated reef are physiologically and behaviourally tolerant of extreme pH variability (8.2 – 7.2 pH) that far exceeds what is expected from coastal acidification alone. This may be a result of the exposure of this species to high variability in pH in its vegetated nursery habitats, and/or the physiological plasticity of this species which enables it to tolerate this variability in the absence of other stressors. However, there is a need to investigate the physiological link between habitat association, most likely related to food availability and energetic trade-offs, and individual fitness. Expanding this understanding to individuals from other juvenile habitats as well as to other coastal species is essential information for the conservation of coastal fisheries species and the habitats they depend on.

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Thermal tolerance experiments on late-stage larvae of a coastal fish demonstrate acclimation potential to warming but increased susceptibility to upwelling events

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Background
Marine and estuarine environments experience natural variation in water temperature and quality over various time scales (daily, seasonal, annual), specifically in temperate regions. These abiotic factors determine the presence of species, including various other factors relating to population dynamics and interactions. Subsequently, increased thermal variability because of global climate change, can affect fish populations variously. Thermal tolerance is the cells' ability to survive heat stress and is the favourable range of temperatures or performance breadth where some measure of performance exists, including an optimal and suboptimal zone. An animal's performance exceeding this range will be negatively affected with prolonged exposure, likely to prove fatal. Temperature has substantial effects on fish behaviour, metabolic activity, cellular processes and physiological functionality. The degree of thermal tolerance and resilience in fish is species-specific and is life stage specific in most species. Understanding thermal tolerance of a species at each life stage relies on understanding abiotic stressors affecting individuals naturally. This knowledge can improve our understanding of existing and historic species distributions. In addition, this information can be used in ecological niche to predict the future distribution and recruitment dynamics of a species.

The critical thermal maximum (CTmax) and critical thermal minimum (CTmin) limits are commonly used metrics to describe thermal tolerance. However, even small changes in acclimation temperatures have shown to affect the thermal breadth of fish. The potential of a fish to acclimate to thermal change can hinder or promote its survival. An acclimation potential to shifting temperature changes can support or hinder the survival of a species. Shifting temperatures can alter the distributional range limits survivable by individual larvae into adulthood, which can redefine the distributional range limits for future generations. The three major marine biogeographic regions in South Africa are the subtropical east coast, the temperate southeast coast and the western coastline. The subtropical east coast very gradually warms over time, experiencing minor thermal variation. The temperate southeast coast and the western coastline experiences high thermal variability with upwelling and marine heat wave events present. The temperate southeast coast experiences the most thermal variability.

The blacktail seabream, *Diplodus capensis*, is a temperate fish species important for South African recreational, small-scale and subsistence fisheries. *Diplodus capensis* is a marine estuarine opportunist, occurring along the southern African coastline. Adults occupy offshore and nearshore reefs up to 30m in depth. Late-stage larvae recruit into estuary mouths intertidal rock pools. Understanding thermal tolerance of marine fishes is crucial for predicting their response to increasingly changing ocean temperatures. Coastal species are particularly expected to experience dramatic changes in thermal regimes over the coming years, where the larval stages are anticipated to be most negatively impacted.

This study investigated the critical thermal maxima (CTmax) and minima (CTmin) of late-stage larval *Diplodus capensis* acclimated at 18°C and 22°C, simulating average contemporary temperatures during the time of collection and moderately elevated temperatures, respectively.

Methods
A total of 100 larvae were collected from the Kariega Estuary mouth. Larvae were allowed to acclimate to holding conditions and temperatures for one week prior to experimentation (170h) and were starved 24 hours prior to the commencement of experiments. An ammonia build up was avoided with the use of constant water changes (40% every second day) together with large acclimation tank sizes. CTmin and CTmax was determined using the dynamic approach and was assessed by either decreasing or increasing water temperatures by 3 °C/hour with the use of a chiller and heating rods.

The mean fish length (mm standard length, SL) for the CTmax and CTmin trial at 18 °C acclimation was 12.34 ([±1.70], range :10.70 to 14.50 mm) and 14.13 ([± 3.01], range :11.20 to 16.30 mm) respectively. Mean fish length (mm standard length, SL) for the CTmax and CTmin trial at 22°C was 13.98 ([±2.92], range: 10.60 to 13.80 mm) and 13.32 ([±1.63], range: 11.20 to 16.70 mm), respectively. There was no significant difference in fish lengths between acclimation tanks for the fish used to test for both CTmax ($t = 0.67$, $p = 0.50$) and CTmin ($t = 1.46$, $p = 0.15$). Over the 170h acclimation period dissolved oxygen, pH, salinity and temperature were measured daily. There was no significant difference between salinity ($z = 0.33$, $p = 0.74$) and DO ($z = 1.96$, $p = 0.06$) between the 18 °C and 22 °C acclimation tanks.

Results

The mean CTmax thermal endpoint for larvae in the 18 °C acclimation tank was significantly ($t = -5.43$, $p < 0.01$) lower (34.1 °C ±0.38, range: 33.1 °C to 34.7 °C) than in the 22 °C acclimation tank (34.9 °C ±0.45, range: 34.1 °C to 35.8 °C). Similarly, the mean CTmin thermal endpoint for larvae used in the 18 °C acclimation tank was significantly ($z = -5.17$, $p<0.01$) lower (7.1 °C, ±0.51, range: 6.3 °C to 8.0 °C) than the larvae in the 22 °C acclimation tank (9.1 °C ±1.07, range: 7.7 °C to 10.9 °C). The relationship between fish length and thermal endpoints produced was also investigated. For the fish larvae used for the CTmax trial from the 22 °C acclimation tank, larger individuals tended to produce higher CTmax endpoints. For the fish larvae used to test the CTmin trial from the 18 °C acclimation tank and the 22 °C acclimation tank, the larger individuals tended to produce the lowest CTmin endpoints.

Conclusions

The findings of this study indicated that the mean thermal scope of larval *Diplodus capensis* was broad (26.5 °C). This is expected because the nearshore environments where this life stage is found are highly dynamic. The significantly impact of the upper and lower thermal endpoints by the acclimation temperature ay suggest that *D. capensis* ay be resilient to shifting environmental temperatures through its acclimation potential. For example, the species may be able to acclimate in areas that experiencing constant warming, such as the sub-tropical east coast of South Africa (e.g., KwaZulu-Natal coastline). However, the acclimation potential may have negative consequences for the species in other parts of its distribution. For example, the warm-temperate coastline of the Southern Cape region in South Africa is increasingly subjected to increasing marine heat waves and cold spells, and acclimation to the warm conditions during a heat wave may reduce the resilience to an intense upwelling event that may follow. In this instance it is likely that the recruitment stage of this species may be exposed to conditions that are beyond their thermal tolerance.

While this study focused on the recruitment phase of this species, the thermal scope of this life stage was not dissimilar to the juvenile (27°C, CTmin of 8 °C, CTmax of 35 °C) life stage of this species (Van der Walt et al., 2021). In contrast, the thermal scope of adult *D. capensis* was lower (23.6 °C) (CTmin of 8.4 °C and CTmax of 32 °C). This ontogenetic shift is not surprising given the more stable sub tidal habitat where adults of this species are found.

Ultimately, understanding the thermal scope of all life stages is necessary for predicting how climate-induced temperature changes impact the survival and distribution of coastal fish populations. This information will be increasingly important for fisheries managers and conservation planners as the rate of climate change intensifies.

References

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