POSITIONING PAPER

Thematic track 5
Building resilient systems: Resilience as a set of capacities to respond to change

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Contents

1. Sustainable Development Goals in an African context

The United Nations Agenda 2030 identified 17 Sustainable Development Goals (SDGs) that address development in an integrated manner, such that it balances social, economic, and environmental sustainability, among other critical global imperatives. Current global progress on the implementation of the SDGs varies across countries, goals and targets. According to the Africa SDG Index and Dashboard 2019, the African continent is on average less than 50% on track towards meeting the best possible outcome scenario on all the SDGs (SDGCA, 2020). On the other hand, European countries range between 60-79% on track to meeting their SDG targets, with best results relating to socio-economic goals (SDGs 1, 3 and 6) (SDSN & IEEP, 2020). The need to meet the SDGs is most urgent on the African continent, and yet the challenges to address them are far more acute. The region has more people to bring out of hunger, and provide decent work for, on top of the challenge of dealing with colonial legacies that have in many instances left unstable political and economic contexts. The post-colonial context has often entrenched inequality for generations and continues to magnify the environmental (Omisore, 2018) and social stresses on already (in most cases) fragile states. The burden for African countries in meeting the 2030 Agenda SDGs is further compounded by other interlinked challenges that range from power and gender differentials (Struckmann, 2018), contrasting urban and rural contexts (e.g. water access (Chitonge et al., 2020) to weak governance structures which then manifest into poor planning, challenges in decision-making and slow implementation of development projects. Into the future, Africa is the continent with the greatest expected population growth – a projected increase from 1 to 2 billion people by 2050, and the biggest forthcoming rural to urban transition; the former means that resources to support SDGs will be spread thinner than today, while the latter means that urban systems will be at the forefront of success or failure in achieving SDGs. The synergistic relationship between SDGs (Adger et al., 2005; Jiménez-Aceituno et al., 2020) means that one cannot be attended to without addressing others, requiring financial investments for which many African countries do not have the budgets.

Despite the challenges, many bottom-up approaches, including local, small-scale initiatives have been addressing myriad issues related to SDGs for decades, but may not have necessarily described or explicitly aligned their efforts to SDGs per se (Jiménez-Aceituno et al., 2020). At the same time, the African continent has been facing overlapping and inter-linked shocks and stresses for generations (e.g. political unrest, poverty, colonialism, state fragility, climate-related shocks), suggesting that there are intrinsic capacities for resilience that emerge when faced with these concomitant shocks. In this context, while we recognise the many barriers to resilience, or even the deficit of a range of enablers for resilience, we focus on these emerging capacities to develop our understanding of resilience in an African context. Using resilience as a lens, or approach, we explore three case studies with the aim of highlighting how resilience leads to better navigation through ongoing shocks and stress, and how it contributes to the ultimate outcome of attaining the SDGs. Knowing that shocks and other challenges may derail efforts towards attaining the SDGs (and Agenda 2030), our work here also explores resilience as a process through these specific cases; attempting to draw out enabling conditions and characteristics of resilience that can help the attainment of the SDGs.

a. Resilience and the SDGs

There is an already large and expanding literature around resilience across many disciplines; in social, natural and interdisciplinary sciences, the humanities, as well as in development, disaster risk reduction (DRR) and management specialities. Rather than defining a unifying concept of resilience it is increasingly recognised that there is more value in embracing pluralistic associations to resilience (Ungar, 2021;

Quinlan et al., 2016; Olsson et al., 2015). For example, African creative literature is replete with invigorating – if not challenging – portraits of human resilience. The recent editorial in Nature Sustainability "Resilience of the resilience debate" highlights the significant variation in views relating to resilience within sustainability research (Nature Sustainability, 2019). We recognise and support the plural and diversifying "epistemic nature" of resilience and argue that such diversity is important in addressing the range of contexts and challenges in the SDGs. We specifically explore how resilience can be used in achieving SDGs in challenged contexts.

As a point of departure, we broadly frame resilience as a set of capacities of a system that allow it to respond to and navigate through change, both expected and unexpected. We argue that many of the challenges to achieving SDGs in Africa are founded in a deficit of such capabilities or capacities. Such capacities will look different across contexts, scale, discipline, and social-ecological system (SES) but can be broadly grouped into absorptive (also persistent), adaptive and transformative capacities. In development resilience for example, Barrett & Constas (2014) emphasise resilience as "*the capacity over time of a person, household or other aggregate unit to avoid poverty in the face of various stressors and in the wake of myriad shocks. If and only if that capacity is and remains high over time, then the unit is resilient*". In this context, well-being is considered a state variable which the authors argue is best represented by the concept of 'capabilities' (Sugden & Sen, 1986), defined by indicators such as income, expenditure, assets, health, security, nutritional status or life satisfaction. It is worth noting here that we consider wellbeing to extend beyond the individual or population scale, to encompass the natural systems and planetary dynamics (e.g. water and biogeochemical cycles) that support society. The notion of 'Planetary Health' (as used by the Rockefeller-Lancet Commission) is fitting in the context of SDGs as it explicitly encompasses the interdependence of human health, flourishing natural systems and wise stewardship of natural resources.

How to define the capacities that enable resilience in the African context is of course dependent upon place and scale. In resilience engineering for example, capacities that are commonly considered are flexibility, efficacy, efficiency, autonomy (Thomas et al., 2019), whereas, in psychology literature capacities represent the internal characteristics of a person known to be correlated with resilient outcomes amid adverse conditions, such as cognitive (e.g. self-esteem), affective (e.g. internal locus of control, optimism) and behavioural capacities (e.g. ability to engage support of others) (*ibid*). Finally, resilience from the disciplinary perspective of the Humanities (as alluded to previously) is best underlined by the moving portraits of the indomitable African spirit of survival in contexts and conditions that are often not just bewildering, but also dehumanising (see for example works by Alex La Guma; Peter Abrahams; Fugard, Ngugi; Imbuga; Sembene; Armah, and many more).

b. Resilience as an approach and process

Challenges to achieving the SDGs may arise from a failure to recognise and/or understand the interdependencies within social-ecological systems, the feedback mechanisms through which they function and the multi-scalar interaction between social, ecological, and technological system components. Constas et al. (2021) highlight the value of considering resilience as a paradigm when conceptualising and implementing programmes that aim to address particular or multiple SDGs. There is a growing recognition of the need to shift perspectives away from framing and managing contexts in terms of stability, equilibrium, linearity or optimality, toward a more dynamic view which accounts for complex, non-linear interaction between system entities under continuous change (including shocks and stresses) and uncertainty (Cooper, 1994; Ludwig et al., 2001; Mbembe, 2001; Folke et al., 2002; Folke, 2003). Using resilience as a lens or approach to sustainable development in different settings allows for a more

comprehensive understanding of system dynamics at large, as well as how the various SDGs are interlinked. This is an important advantage of using a resilience approach, especially when considering that the achievement of one particular SDG target is dependent upon achieving others. By using resilience as an approach to understand and map out context, actors, conditions and capacities of a system (singular or multiscalar), resilience as an outcome (i.e. the achievement of one, or rather, several SDGs) is achievable.

c. Resilience as a system property and outcome

Across the various scales, disciplines and definitions of resilience lies a broad set of capacities within the system. When viewed as an outcome or an intrinsic feature of a system, the three primary features of resilience are highlighted by Folke et al. (2009) as persistence, adaptability and transformability. Persistence is the capacity of a system to maintain structure and function in the face of shocks and change and to stay in a current state of regime. When a system is viewed in relation to its persistence, external factors and internal processes are identified and a greater understanding is developed of their role in the persistence of the current state and how close to a threshold a system is. Adaptation and adaptability involve understanding thresholds and how to move away from them. In social-ecological systems, adaptability is largely socially driven and can be considered as the capacity of actors within the system to manage resilience. Transformability is the capacity of a system for learning, reflection and self (re)-organisation when the system exceeds a threshold and/or is locked-in to an undesirable or unsustainable state. In the context of development resilience, the focus of transformation requires the recognition of human wellbeing and the capacity to avoid poverty-traps (Carter & Barrett, 2006; Barrett & Constas, 2014) as dependent upon the capacity of the biosphere to provide ecosystem services.

In seeking practical means to assess and measure resilience, Quinlan et al. (2016) suggest that resilience metrics can be used to move systems towards more desirable and sustainable states. This is based on the premise that as the complexity of a system is simplified into metrics that are important for decision making, learning is maximised and new insights into system dynamics or structure emerge (*vis.* Biggs et al., 2015). Importantly, as systems adapt, change and move towards particular goals, so should the metrics that are used to assess and measure these systems. The three features of resilience, i.e., persistence, adaptability and transformability determine the system's likelihood of shifting to an alternate state, desirable or not. Where resilience contributes greatly in a management and governance context is in learning how to avoid thresholds between alternate states, how to influence the positions of thresholds and how to transform to a different system or state when necessary.

2. Resilience in practice: Case Studies

The aim of our thematic group was to gather insights into what resilience means for sustainable development in diverse African contexts and this was achieved through the exploration of selected case studies to address the question, 'why does sustainable development need resilience?' In three groups, our team discussed and explored the context of the highlighted case studies, which, owing to geographic bias of participants, were all based in South Africa: 1) Cape Town Day Zero; 2) Resilient Youth in Stressed Environments and 3) Southern Cape Fishers. The groups then explored the narrative of the case studies to highlight capacities for resilience across various contexts by identifying the key features of each system, major shocks and stressors; evidence of capacities for, or barriers to, resilience; and critical points of intersection with the larger system(s) within which the case studies were embedded (*see Appendices*). We have not made explicit reference to any particular SDGs within each case study, as it is self-evident

that all SDGs are fundamentally interdependent. A brief overview of the case studies is highlighted below, followed by Table 1 summarising the key points we use to identify capacities for resilience.

a. Case study overview

i. Cape Town Day Zero

The region around Cape Town, South Africa was subject to a period of very low rainfall between 2015 and 2018, with the 2016/17 hydrological year recording the lowest rainfall in 100 years. The Cape Town Day Zero case study highlights resilience at multiple levels, whilst also demonstrating how resilience in one area can negatively influence resilience in another (*see Appendix I*). There was significant uncertainty about whether the water supply system was resilient enough to be able to withstand the period of very low rainfall (1:300 to 1:400 year event) that was experienced, with the associated threat of 'Day Zero'. Ultimately, Cape Town did navigate its way through the crisis, largely thanks to strict water conservation and demand management (WCWDM) measures, but there were significant associated costs to the economy, to the surrounding agricultural and tourism industries and severe impacts on some of the city's most marginalised. The city is now gearing itself (through its new Water Strategy and other policy instruments) to reduce the risk of water shortages by increasing assurance of supply in the system. New investments and an improved understanding of water risk have also resulted in improved resilience with respect to water, and these learnings are also being applied elsewhere (within the City itself as well as in other municipalities around the country). Resilience capabilities such as improved budgeting processes, strategy development, programme management, communications and reflective learning, as well as the introduction of more participatory processes and community-generated data are all 'assets' that can be repurposed for building resilience to other forms of shocks.

ii. Resilient Youth in Stressed Environment (RYSE)

The Resilient Youth in Stressed Environment (RYSE) case study (*see Appendix II*) presents findings from a study (in Canada and SA) of youth resilience in communities stressed by the oil and gas industry and related economic, psychosocial, and environmental risks. RYSE defines resilience as an adaptive, multisystemic process that supports positive outcomes (e.g. school/work engagement; positive contributions to household or community; wellbeing) for youth who are significantly stress-exposed. Theron et al. (2021) explored youth resilience as informed by a biopsychosocial-ecological system of interacting resources specific to situational and cultural dynamics. In this way, resilience is informed by contextually responsive, systemic approaches, rather than framed by use of individual resources (as is often the case in social science studies of adolescent resilience). The RYSE research compared two communities, Maple Hill (Alberta, Canada - small rural town in Drayton Valley reliant on oil extraction) and eMba (Mpumalanga, SA - a township in Secunda reliant on coal to oil company, Sasol), dependent on the oil and gas industry, both disrupted by the economic volatility of these industries. Around 500 adolescents (13 to 24-year olds) in each community were surveyed from 2018 to 2020. This case study draws on a sub-sample engaged in qualitative work - 31 Canadian and 21 South African youth - that explored positive health/wellbeing outcomes; asking "What are the biggest challenges for youth in [site]?"; "what helps you overcome challenges you face?"; "what resources currently support youth in the community to overcome challenges?" etc. Through one-on-one and additional follow up interviews, data was analysed to understand what contributes to resilience, particularly to the disruptions (economic) from this (extractive) industry. In short, youth capacity for wellbeing was enabled by layered biological, psychological, social and ecological resources that fit situational and cultural dynamics.

iii. Southern Cape Fishers

The case study taken from the Southern Cape Interdisciplinary Fisheries (SCIFR) project focuses on the southern Cape linefishery (Jarre et al., 2018). This case exemplifies a multi-scalar system that spans a broad geographic range, including relatively static land-based communities, and fishing grounds which are characteristically highly variable across several spatial and temporal scales (*see Appendix III*). Situated along the 155km stretch of southern Cape coastline of South Africa, the southern Cape small-scale commercial linefishery encompasses coastal communities between Witsand and Mossel Bay who fish in the inshore area of the Agulhas Bank (Gammage and Jarre, 2020). In operation for over 100 years, this fishery predominantly targets the commercially viable silver kob (*Argyrosomus inodorus*) with an important human livelihood dimension (Duggan et al., 2014; Gammage et al., 2017a,b). This fishery is subject to multiple stressors, from policy and economic disadvantages to increasing resource scarcity and high variability in the natural physical system (Gammage & Jarre, 2020). South African fisheries policy has favoured industrial fisheries from the twentieth century that left a long history of marginalisation for these small-scale fishing communities (Visser, 2015), which is further compounded by current policy uncertainty linked to the staggered and troubled implementation of the Small-Scale Fisheries Policy (Act no 474 of 2012) (Gammage & Jarre, 2020).

Small-scale fisheries have also traditionally struggled to access markets due to competition from large-scale fisheries and other pressures (Duggan et al., 2020), where the financial viability of their livelihoods have been further impacted by diminishing silver kob catches in recent years (Gammage et al., 2017a,b). While changes in the natural system of the Agulhas Bank display decadal-scale variability (Ward et al., *in press*), the effects of climate change will add further complexity and challenges to resilience in these fishing communities (Gammage & Jarre, 2020). Effective decision-making for adaptation within these complex, multi-scalar social-ecological systems thus requires approaches that focus on increasing the capacity of stakeholders so they can make sustainable decisions within rapidly changing ecological, social, and political environments (Gammage & Jarre 2021).

Table 1: Overview of case studies and highlighted features

Feature	**Case study**		
	Cape Town Day Zero	**Resilient Youth in Stressed Environment (RYSE)**	**Southern Cape Fishers**
Shocks and stressors	*Major*: low rainfall (1:300 to 1:400 drought event) leading to threat of 'Day zero'; climate variation; over-reliance on rain-fed water supply system; cooperative governance issues across spheres of government *Mid-range (shock within a shock)*: multiple intersecting systems; economic impacts; job losses; impacts on agriculture and tourism; cumulative risks across different socio-economic contexts; increased settlement fire risk.	*Major:* Economic volatility (boom and bust cycles related to the Oil industry), ecological degradation (in SA) including mine closure, limited job access and lack of government support services (in SA). *Mid-range:* disruption to work promise	[1]*Major:* Policy and regulation, fish availability, climate variation, other fishing sectors *Mid-range:* enforcement and implementation of policy, economic, inter-sectoral political issues, socio-economic *Minor:* remoteness, inadequate infrastructure, social, lack of knowledge, fishing methods, other marine species

Current state of the system	Supply currently meeting demand but ongoing climate variability and increasing urbanisation. Water Strategy implemented; funding for new water schemes prioritised including groundwater abstraction, water re-use and desalination, prioritised up until 2026. Notable increase in investment into alien invasive management in the catchments from multiple partners. 'Drought legacies'; water consciousness; private household investment in alternative water, rainwater tanks and boreholes; ongoing Water Conservation and Water Demand Management; ave daily demand reduced by 200ML Governance of groundwater use problematic.	Contextually responsive, interacting resources (including physical health, psychological strengths, relational support and ecological assets) form a biopsychosocial-ecological system that enables youth resilience to their stressed environment.	Small-scale fisheries effectively operate in policy gap. Unsustainable management of the fishery, including overfishing. High variability and/or change of natural system at various temporal and spatial scales. Recent marine ecosystem regime shifts in southern Benguela affect species distribution. Conflict and competition between small scale fishers and commercial inshore trawl fisheries, where fishing grounds overlap.
Evidence of capacities for resilience	Strong data science and project management, good access to behavioural economics, enhanced communication capabilities and availability of high-level expertise; regulatory environment; strong resilience team Collaborative capabilities within neighbourhood organisations and public groups; high-functioning intermediary (aggregator) organisations such as GreenCape, EDP, Wesgro and new statutory bodies such as Section 80 Water Resilience Advisory committee	Youth-led accounts of multi-systemic and interacting supports that enable youth wellbeing (e.g., mental health; civic engagement) despite exposure to significant stress. De-emphasis of psychological resources; Multiple overlapping sources of support; spaces of safety/exercise; outdoors/natural environment access; elders/mentors with similar experiences; opportunities (or the perception thereof).	Established social capital in the form of strong networks among fishers. Sources of both traditional and scientific knowledge.
Barriers to resilience	Unequal access to resources; increasing informality and poverty levels. Misinformation; lack of societal trust.	In the SA context, the lack of availability of government and other formal services, poor quality education, the lack of outdoor unpolluted green spaces and the lack of job opportunities. In Canadian community, slow pace of diversifying the economy (e.g., reducing reliance on oil and gas industry).	Trapped in poverty cycles; policy does not provide an enabling environment; hierarchical gatekeepers; unfavourable market forces; knowledge disconnects and mismatches between scientific and traditional observations.
Measurable capacities for resilience observatory	Data capabilities. Communications capacity. Civil society organisations. Living laboratories for resilience-based research / demonstration cases. Robust habits of water conservation acquired by citizens in the drought, some of which will endure.	Biological indicators of wellbeing despite significant stress exposure (e.g., lower cortisol levels; allostatic load). Psychological indicators of wellbeing despite significant stress exposure (e.g., limited symptoms of mental illness; personal capacity for agency, problem-solving etc.).	Capacity for diverse information sources to reach all stakeholders across multiple scales from individual fishers to policy makers. Assets that can buffer no fish days or assets that enable diversification of activity (i.e., alternative livelihood strategies).

	Published articles; downscaled climate modelling; City Open Data Portal.	Healthy relationships to family, peers, community, elders, etc. Institutional supports (e.g., mental health services; quality schools; civil society organizations). Ecological resources (e.g., community safety; green/blue spaces; recreation facilities).	

[1] *Stressors identified by southern Cape fishers affecting local fishing communities (Gammage and Jarre 2020, Gammage et al. 2019, Gammage et al. 2017a)*

b. Initial cross-scale learnings

As highlighted in Table 1, resilience manifests in diverse ways across context and scale. However, across the three case studies highlighted in this paper, access to resources, or assets, along with meaningful and appropriate use of those resources, emerged as evidence for the capacity for resilience. Conversely, a lack of access indicated a barrier to resilience, with access to resources or assets taking diverse, multiple and overlapping forms. Among the case studies, capacities for resilience are observed to be:

- diverse information sources;
- capabilities to understand, process and respond to that information (e.g. data capabilities and appropriate expertise in Cape Town,);
- communication and trust of information (e.g. social networks among fishers in Southern Cape, or elders/mentors in RYSE);
- ecosystem services (e.g. water in Cape Town, green space in RYSE, fish stocks in Southern Cape);
- supportive/enabling 'external' conditions/actors (e.g policy in Southern Cape, youth organisations in RYSE);
- supportive cross-scale conditions/actors (e.g. collaborative partnerships such as GreenCape or Wesgro in Cape Town).

3. Resilience Observatories

We propose the notion of "Resilience Observatories", here defined as a 'longitudinal, long-term research platforms collecting core data in a regular manner, with a unique focus on observing the multiplicities of resilience in and of social-ecological systems'. There is increasing recognition of the need to provide place-based, long-term interdisciplinary observation of social-ecological systems with many observatory-type platforms and long-term interdisciplinary research agendas having been established around the world in the last few decades.

For example, critical zone observatories (CZO) (Anderson et al., 2008) aim to advance the understanding of the integration and coupling of Earth surface processes within what is termed the 'Critical Zone' (CZ). The CZ is the interface between the solid Earth and its outer fluid envelopes, extending from the outer vegetation canopy to the base of active groundwater within the system. Understanding the complexity of this interface and the interaction between components requires interdisciplinary approaches across multiple spatial and temporal scales. Initial CZOs have been funded by the U.S. National Science Foundation since 2007 with the overarching aim of answering questions surrounding coupled hydrological, geomorphological and biogeochemical interactions at the watershed scale.

In parallel, also in the U.S., long term ecological research (LTER) networks have been established throughout the US with notable sites being the Baltimore Ecosystem Study (BES) and Central Arizona Phoenix (CAP). These two sites are explicitly focused on social-ecological-systems (SES) research and much of the grounding interdisciplinary literature pertaining to urban sustainability, SES and urban ecology (e.g. Grimm & Redman 2004; Pickett et al., 2020) has emerged from the research carried out at these sites since their inception in the late 1990s. Urban observatories are also emerging around the world (Dickey et al., 2021) and are catalogued through activities such as the UN Habitat Global Urban Observatory. While there is a global north bias in where urban observatories are established, overall the global south is fairly well represented but on the African continent, only three appear to currently exist: the Gauteng City Region Observatory (GCRO), the Cape Urban Observatory (CUO) with the African Centre of Cities and the Sierra Leone Urban Research Centre in Freetown, Sierra Leone. There is also the imminent establishment of the Cape Metro Region long term social-ecological research site (CMR - LTSER) funded by the South African Earth Observation Network (SAEON) which aims to have a strong focus on the integration of ecological and social sciences in an African context.

These various platforms and networks indicate a growing acknowledgement of the value and urgent need for place-based, interdisciplinary research in understanding and facing global and local challenges. Comparisons across these research sites could help us to better understand resilience as both a universal and contextually responsive process. There is a need for critical understanding of the social-ecological-technological system (SETS) so that the adaptive capacity and thus resilience of SETS is enhanced. When resilience is used as an approach, or a lens through which the data coming out of these observatories and research sites are transformed and analysed, a resilience observatory may provide insight and support for decision-making and policy in line with achieving SDGs. In addition, when resilience is viewed as a property of the system, it should be quantifiable by metrics that are defined by the overarching scientific questions and programme/management objectives that support the achievement of the SDGs. We highlight the need to focus specifically on bringing in more diversity from less dominant and more marginal perspectives in the African context.

At the SDG summit, we propose dedicating a session to exploring the idea of establishing resilience observatories (ROs) across Africa / the wider world. The discussions could include: (i) the value proposition of ROs; (ii) scoping the types of “observations” that an RO should be recording, in terms of both process (resilience capabilities) and outcomes (which might map well onto existing SDG indicators); (iii) whether there are any existing sites where there has been long-term research data collection that could be adopted as resilience observatories; (iv) how they might be used for “living lab” or studio based teaching at senior undergraduate or graduate level.

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5. Appendices

Appendix I: City of Cape Town – resilience learnings from the 2015 to 2018 drought

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Context of the case study (the unit of analysis)

The region around the City of Cape Town (CoCT), South Africa was subject to a period of very low rainfall between 2015 and 2018, with the 2016/17 hydrological year recording the lowest rainfall in 100 years; collectively viewed as a 1:300 to 1:400 year event. Water resource managers had to operate on the extreme bounds of the planning model for the Western Cape Water Supply System (WCWSS), which supplies water to the CoCT and consists predominantly of 6 large rain-fed dams. There was significant uncertainty about whether the system was resilient enough to be able to withstand this event, and the looming threat of 'Day Zero' (when potable water supply to large parts of the city would have been suspended, and access to 20 litres per capita per day provided through designated 'Points of Distribution' located across the city). Ultimately, the CoCT did navigate its way through the crisis - largely thanks to very strict water conservation and demand management (WCWDM) measures - but there were significant associated costs to the economy and to the surrounding agricultural industry which resulted in a (mostly) temporary decrease in livelihoods across the region.

Key features of the system

Social and ecological constituents of the system and system-boundaries - what is being considered as part of the system

The CoCT water supply system and the larger WCWSS on which it relies, include the political boundaries of the city itself as well as the surrounding environment – meaning that multiple intersecting systems responded to the drought, and a number of different users across all scales (local to regional); i.e. agriculture, nearby smaller municipalities, businesses, and households. The collective sharing of responsibility as people assessed the cumulative risk and its impacts also affected people differently across socio-economic contexts; with the unavailability of sufficient water at times creating new risks (e.g. fire-fighting and sewer blockages). These challenges were more apparent in poorer communities; different levels of access to resources and an extremely unequal society still persist in the CoCT. Informal settlements continually exist under 'Day Zero' conditions with an average per capita demand of around 45 litres water per day irrespective of climatic conditions. (Any relevant historical factors affecting the system, e.g. apartheid; political economy)

Governance arrangements; the processes and rules of interaction and decision-making among the actors involved

The delivery and management of water in the CoCT is governed through all three spheres of government (local, provincial, national); although there are good systems in place, problems with these leading up to the drought resulted in over withdrawal of water from the WCWSS in 2015/2016 by agricultural users,

insufficient attention paid to clearing alien vegetation in mountain catchment areas, and a slow response from the National Department of Water & Sanitation to the crisis. The drought also highlighted that decentralised groundwater use is largely an ungoverned space within the City and is considered as a common resource.

Resilience in action

What shock(s), stress(es) or event(s) have been experienced?

In order to understand the resilience responses it is important to acknowledge that the drought that was experienced in the CoCT manifested as a shock within a shock – both financially for the City as well as a shock to certain economic sectors, most notably tourism and agriculture. The direct impacts of this were thus not only the limited availability of water for a variety of uses over a considerable period of time, but also job losses, decreases in agricultural production and exports, psychological stress, etc. Once the extremity of the drought began to be widely acknowledged (May 2017) some critical considerations emerged, and the responses to these varied widely, down to household and individual level: 'do we stay on the same path?'; 'do we have enough resources?'; 'do we do things differently?'; 'what happens if this event continues?'; 'what happens if it doesn't rain?'. From a City perspective, communications were strengthened (including the adoption of controversial narratives like 'Day Zero'), tariffs were increased, pressure management initiatives were ramped up, and small-scale augmentation efforts were put in place. From the perspective of households and businesses, the emphasis was on moral collectives, increased pressure to change habits, and individual resilience-based decision-making (such as people in mainly affluent areas accessing alternative water sources). This resulted in drought 'legacies' that continue to contribute to the ongoing resilience of the system; for example, large building complexes like Old Mutual office park and Cape Town International Convention Centre (CTICC) are now almost totally off the potable water grid. From a financial perspective, although the increased levels of private investment in water supply may present a sustainability issue for the water utility in terms of decreased water sales (average daily reduction of 200ML since the drought), increasing numbers of new water users and the gradual bounceback in water use have been sufficient to ensure continuous investment. Additionally, the planning of new water schemes has been prioritised post the crisis with a R6 billion capital investment programme now in place, including groundwater abstraction / Managed Aquifer Recharge in the Cape Flats Aquifer, water re-use and permanent desalination projects.

How (if at all) was the system resilient to the shock(s)/stress(es)/event(s), what impacts were lessened, and what might have happened without this resilience?

Prior to the drought, the resilience of the CoCT system in respect of water resources management was not richly understood, but reflecting on the lessons learned from the crisis, it became clear that Cape Town is a city with high resilience capability. In particular, some of the more generic learnings can be used in any shock events, e.g. the need for excellent data science and project management, good access to behavioural economics, enhanced communication capabilities and the availability of high-level expertise on the issue at hand – and can also help in turning attention to any needed response or respond to other disasters.

What characteristics of the system enabled resilience?

Further, the existing regulatory environment, capabilities of service providers and engineering expertise (such as implemented in the strict pressure management programmes) all enabled resilience in the system – as did the collaborative capabilities within neighbourhood organisations and public groups.

What characteristics reduced or acted as barriers to its resilience?

The most significant vulnerability in CoCT continues to be its growing informality, with over 300 informal settlements plagued with poverty, unemployment, trauma, crime and violence. Another barrier to resilience is the spread of misinformation, and difficulties in ensuring clear communication channels with easily-interrogated and digestible data shared in a transparent way. It took time for societal stakeholders to agree on the severity of the water crisis, and to build trust within the larger system and across communities. Another emerging reality is that social media, and traditional media with a political agenda, can derail communication efforts and need to be balanced with the good that social media provides.

Were there any external factors (multi-scale) that affected resilience?

Intermediary, high-functioning organisations such as Green Cape, Economic Development Partnership (EDP), Wesgro and Cape Town Tourism contributed to mass outreach in the city, acted as aggregators of practical instruction and provided useful data to Province and CoCT. One way of building resilience behaviour is to support these types of organisations and see them as examples of the city's 'assets', thus inviting identification, assessment and strengthening in readiness for future shocks.

Has resilience changed over time [e.g. through learning and adaptation to previous experience, or through a reduction of capabilities, or as a result of multiple shock(s)/stress(es)/event(s)]?

The CoCT is currently gearing itself (through its new Water Strategy and other policy instruments) to reducing the risk of water shortages to an estimated one year in every 200 years by increasing assurance of supply in the system. New investments and an improved understanding of water risk have also resulted in improved resilience with respect to water, and these learnings are being applied elsewhere (for example, through a commitment to the implementation of a water sensitive city). The core team in the city that worked on the drought have been redirected onto dealing with the Covid-19 pandemic shock, using the same methodological approach in the context of a large metropole, e.g. budgeting processes, strategic work, programme management, communications, and reflective learning. A number (20 of the 75) named actions in the Resilience Strategy, that is aimed at decreasing risk so that the City has the ability to respond to a multitude of shocks, can be used to respond to the pandemic also - this has resulted in data capabilities being increased significantly, and also better decision making.

Any other aspects of the case study that should be considered?

This case tells the story of resilience at all levels, whilst also highlighting that resilience in one area can negatively influence resilience of another. There are general 'capabilities' that have been identified within water resilience in the CoCT and it is proposed that many of these 'assets' can be repurposed for building resilience to other forms of shocks facing cities around the world.

If this system became a "resilience observatory" what would it look like?

One way of showcasing and sharing these learnings can be through the establishment of a 'resilience observatory/ies' that include, *inter alia*:

- Ongoing ‘theatres’ of information and collaboration, e.g. Section 80 Water Resilience Advisory Committee;
- Undergraduate and postgraduate water and resilience related courses at all regional universities;
- Publicly accessible data repositories – City open data portal, City water dashboard, climate models, etc.;
- High number of civil society organisations – Friends of the Liesbeek, Cape Town Water Caucus, Informal Settlement Network (ISN), Federation of the Urban Poor (FEDUP), etc.;
- Living Laboratories for resilience-based research;
- Experimentation with, and expansion of, engagement of officials with experts and community representatives and organisations.

Appendix II: Resilient Youth in Stressed Environment (RYSE) – resilience learnings

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Description

This case study presents findings and considers resilience while drawing on research from Resilient Youth in stressed Environment (RYSE) study (Canada and SA) – a study of youth resilience in communities stressed by oil and gas industry and related economic, psychosocial, and environmental risks. Theron et al. (2021) explored youth resilience as informed by a biopsychosocial-ecological system of interacting resources specific to situational and cultural dynamics. In this way, resilience is informed by contextually responsive, systemic approaches, rather than framed by use of individual resources, to best facilitate resistance to stress. In this way, resilience is processual.

Context of the case study (the unit of analysis)

The RYSE research compared two communities, Maple Hill (Alberta, Canada - small rural town in Drayton Valley reliant on oil extraction) and eMba (Mpumalanga, SA - a township in Secunda reliant on Sasol - coal to oil), dependent on the oil and gas industry, and both disrupted by the economic volatility of these industries. While there are other commonalities, these are the most salient. At the same time, both places share (very different) colonial histories, however it is worth noting that South Africa's apartheid regime impacts heavily on legacies of service delivery and inequality.

METHODS AND PARTICIPANTS

Around 500 adolescents (13-24-year-olds) in each community were surveyed in 2018, 2019, 2020. This case study draws on a sub-sample engaged in qualitative work; 31 Canadian youth (average age: 20.77; 19 young women; 12 young men) and 21 SA youth (average age: 20.28; 8 young women; 13 young men). The sub-study explored positive health/wellbeing outcomes; asking "What are the biggest challenges for youth in [site]?"; "what helps you overcome challenges you face?"; "what resources currently support youth in the community to overcome challenges?" etc. Through one-on-one interviews and additional follow up interviews, data was analysed to understand what contributes to resilience, particularly to the disruptions (economic) from this (extractive) industry.

Key features of the 'system'

Social and ecological constituents of the system and system-boundaries

The biopsychosocial-ecological system is a composite of interacting biological resources, psychological resources, social (informal relational supports; formal supports; services) and ecological resources in the built and/or natural environment. The specific resource examples reported in the case study are those that youth reported most often.

Relevant historical factors affecting the system [e.g. apartheid; political economy]

Boom and bust cycles linked to reliance on extractive processes (oil); in SA, Apartheid legacy and related defunct service sector.

Governance arrangements *[the processes and rules of interaction and decision-making among the actors involved]*

Overlapping layers - parents, schools, State.

Critical points of intersection/interaction with the larger, multi-scalar system

Youth as the future of the systems themselves – their agency and other psychological resources matter, as do the relational/social and ecological system resources that they are connected to. Youth resilience (i.e., the capacity to function well/normatively despite the ongoing risks associated with the oil and gas industry) is dependent on multiple resources, distributed across multiple systems, working together to support functional outcomes like mental health or civic engagement.

Other key features

RYSE defines resilience as an adaptive, multisystemic process that supports positive outcomes (e.g. school/work engagement; positive contributions to household or community; wellbeing) for youth who are significantly stress-exposed. In the qualitative work, those with positive outcomes were not eligible, as the researchers did not aim to confirm resilience of participants, rather their goal was to learn from youth in stressed environments (Theron et al., 2021). “Maple Hill and eMba are environments associated with atypically high exposures to adversity, and so youth ability to function normatively in these environments implies resilience (Ungar, 2019a). All participating youth spontaneously referred to normative functional behaviours (e.g. engagement in education and/or employment; contributions to family/community), and/or spontaneously referred to themselves as ‘resilient’” (Theron et al., 2021).

FINDINGS

Youth capacity to adjust is informed by different systems (or scales); their capacity to do well despite very challenging contexts was impacted by resources available across scales and systems (built environment, natural resources, social, psych). Resources that enable resilience were variable, but always about the interaction between the resources youth reach out to - the capacity to co-facilitate, rather than resources acting individually. Youth rely on layers of resources, interacting and overlapping; their coping mechanisms were based on using multiple resources towards resilience where resources work together to facilitate adaptive responses. This highlights the importance of embedded systems - composite - relational/capacity oriented. In RSA the context of being male, where male work opportunities were more available, meant that young people identified their sex as making a difference in their capacity to cope; future orientated perspectives also aided in coping. In RSA there was no mention of formal services at all (links to SA apartheid history and certain areas experiences of infrastructural violence).

Resilience in action (or not)

What shock(s), stress(es) or event(s) have been experienced?

Economic volatility, ecological degradation (in SA) including mine closure, or disruption to work promise and job access.

What were the direct impacts of the shock(s)/stress(es)/event(s)?

Poverty, economic tensions, resultant social tensions, strife, expectations to leave (during boom periods), violence/violent crime; protests

In what ways were different environmental and social dimensions of the SDGs affected?

- Access to water (including mine pollution impacts)
- Hunger/malnutrition
- Poverty (SDG 1)
- Health and wellbeing (SDG 3)
- Gender equality (SDG 5)

How (if at all) was the system resilient to the shock(s)/stress(es)/event(s), what impacts were lessened, and what might have happened without this resilience?

Young people were understood to be resilient when they felt they were succeeding or 'doing well' in life. The impacts of stresses were lessened by access to multiple overlapping resources, including safe spaces to exercise, socialise, be outdoors, learn from others (elders) in how to do things that might bring in funds, positive outlooks (future focused). Without these tools to assist in being resilient to multiple stressors and challenges, these young people might not have succeeded (or some would argue, even survive? I.e., without tools to cope).

What characteristics of the system enabled resilience?

Multiple overlapping sources of support; spaces of safety/exercise; outdoors/natural environment access; elders/mentors with similar experiences; opportunities (or the perception thereof).

What characteristics reduced or acted as barriers to its resilience?

In te SA context, the lack of availability of government and other formal services, poor quality education, the lack of outdoor unpolluted green spaces and the lack of job opportunities were barriers to young people feeling that they are doing well.

Were there any external factors (multi-scale) that affected resilience?

Yes, multiple. In fact, across scales the factors that even allow the extractive practices to be (ongoing and) so close to someone's lived reality.

Has resilience changed over time [e.g. through learning and adaptation to previous experience, or through a reduction of capabilities, or as a result of multiple shock(s)/stress(es)/event(s)]

From the current case study, which draws on cross-sectional data, change cannot be identified. There is a suggestion of intergenerational replication (young people follow the example of elders) rather than change. [We are currently in the process of writing up the over-time analyses and they suggest that the same resources matter over time]

What are the opportunities for increasing resilience?

Listening to the young people in each setting, acknowledging that each settings' resilience is dependent on context and time specific concerns; this includes understanding/exploring "how situational and cultural contexts nuance the dynamics of multisystemic resilience in young peoples' lives" and providing absent supports (like services in the SA context).

Any other aspects of the case study that should be considered?

Gendered differences in the two samples across the two contexts.
Cultural aspects are context specific and time dependent (i.e., traditions change).

If this system became a "resilience observatory" what would it look like?

Diverse examples of young people's thoughts on what has made them successful combined with ways to show how such resources and things they use to cope (or their process of being resilient) overlap and interact. De-emphasis of psychological resources; youth resilience requires multiple resources distributed across multiple systems (including but not limited to psychological system), highlighting the importance of the biopsychosocial-ecological composite.

Appendix III: Southern Cape Fisher Communities

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Context of the case study (the unit of analysis)

The handline fishery has been active in the southern Cape for over a century, operating in the inshore area of the Agulhas Bank and traditionally targeting silver kob (Argyrosomus inodorus) (Duggan, Green and Jarre, 2014; Visser, 2015). This particular case study on the southern Cape small-scale commercial line fishery focuses on seven coastal communities - Mossel Bay, Gouritsmond, Melkhoutfontein, Still Bay, Vermaaklikheid, Witsand and Slangrivier.

Key features of the system

Social and ecological constituents of the system and system-boundaries - what is being considered as part of the system

The geographic extent of this system spans across the southern cape coast and the inshore area extending approximately 117 km (63 nautical miles) off Cape Agulhas, known as the Agulhas Bank subsystem. The Agulhas Bank is a very productive region for commercially exploited fisheries and forms one of the four shelf subsystems that make up the Benguela Current Large Marine Ecosystem (Jarre et al., 2018). The southern Cape small-scale commercial linefishery is a boat-based, multi-user, multi-area and multi-species fishery that mainly undertakes day trips that range from six to eight hours (Gammage & Jarre, 2021). The focus of this work is on fishing communities residing in Mossel Bay (a large urban centre situated on the coast), Gouritsmond (including Bitouville) (located on the coast), Melkhoutfontein (situated approximately 8 km from the coast), Still Bay (located on the coast), Vermaaklikheid (7 km from the coast as the crow flies, but fishers often travel 47 km by road to launch in Still Bay), Slangrivier (fishers travel 38 km by road to the coast), and Witsand (located on the coast).

Any relevant historical factors affecting the system [e.g. apartheid; political economy]

The makeup of community placement is defined by apartheid spatial planning, where largely crew (with a few skippers) reside in former “non-white” settlements and predominately skippers (or boat owners) reside in former “white” areas. Economic and socio-economic stressors across the different fishing communities are largely determined from past inequalities of apartheid (Gammage et al., 2017a, 2019). Historically, the South African fisheries policy has favoured industrial fisheries since the twentieth century, resulting in the marginalisation of small-scale fishers across the country, including communities living in the southern Cape (Visser, 2015).

Governance arrangements [the processes and rules of interaction and decision-making among the actors involved]

The Marine Living Resources Act of 1998 (MLRA) provides the regulatory framework to address inequalities due to South Africa’s past through regulating the use of marine resources via a rights allocation system. This is done according to a total applied effort, limiting the amount of total fishing effort that may be expended. The initial post-apartheid policy framework did not acknowledge and cater for

traditional small-scale fishers, despite the important role played by this sector in contributing to food security, poverty alleviation and rural development. After legal action was launched by civil society groups, the Small-Scale Fisheries Policy (Act No 474 of 2012)(SSFP) was gazetted and amendments to the MLRA were made accordingly. The SSFP is underpinned by an Ecosystem Approach to Fisheries (EAF) management that aims to address typical top-down decision-making and management within the fishery. Despite being promulgated in 2012, the implementation of the SSFP remains challenging due to the lack of structures or mechanisms for comprehensive stakeholder input or capacity building at the finer scales of operation within marginalised, and often isolated, small-scale fishers (Gammage et al., 2019).

Critical points of intersection/interaction with the larger, multi-scalar system

Prominent areas of intersection of the southern Cape fisher communities with the larger system include fisheries policy and regulation; biophysical elements such as climate variability (with its cascading effects on marine ecosystem health including fishery recruitment and distribution) and diminishing silver kob stocks; the inshore commercial trawl fisheries (with the subsequent issues around market access/competition and overfishing); and the availability of alternative livelihoods (or lack thereof).

Significant knowledge gaps remain in the marine system, particularly at the local scale of the southern Cape, and there are large discrepancies between scientific datasets and local knowledge. These disconnects arise from a lack of long-term, high quality monitoring environmental data, coupled with a naturally variable and complex climate system of the area (Ward et al., *in press*). For example, mismatches between fishers' knowledge and data analyses occurred when examining extreme wind days in the near-shore environment. Fishers observed that sea days had decreased over time partly due to unfavourable wind conditions, however these trends were not reflected in the available scientific data. Gammage et al. (2017a) discuss how the fishery operated in an unfavourable economic environment at the time, making it possible that weather was blamed for a decision largely based on resource scarcity and high input costs. However, these knowledge disconnects could also arise from scale mismatches, as changes in the off-shore environment showed a tendency of increased extreme wind days over time – corroborating fishers' observations at shelf scale but not necessarily in the inshore environments where they mostly operated (Ward et al., in press).

Due to a lack of historical data, together with high environmental and climatic variability, it is challenging to examine the extent to which fish stocks have changed over time, or the primary drivers of this change. The substantial depletion of economically important silver kob stocks over the last century on the Agulhas Bank is due to drivers ranging from fishing pressure to climate and environmental change dynamics (Currie et al., 2020). Shifting baselines are also important to consider when examining knowledge disconnects, as interpreting present variability observed in natural resources (such as water availability or fish abundance) by natural resource users depends on historical knowledge (Ward et al., *in press*).

What shock(s), stress(es) or event(s) have been experienced?

Increasing resource scarcity, poor socio-economic conditions, variability in natural physical systems and policy uncertainty has plagued this fishery in recent years. Policy regulation, fish availability, climate variation and other fishing sectors (such as inshore trawlers) were identified as major stressors by southern Cape fishers. Mid-range stressors were the enforcement and implementation of policy, capital (or lack thereof), political issues (within fishers and sectors) and socio-economic factors. Minor stressors included geography of the area, inadequate infrastructure, social factors, lack of knowledge (financial planning, literacy levels), fishing methods and other marine species (e.g. seals) (Gammage et al., 2017a; Gammage et al., 2019; Gammage & Jarre, 2021).

What were the direct impacts of the shock(s)/stress(es)/event(s)?

Policy and regulation: It has been shown that the small-scale commercial linefishery in the area is effectively operating within a policy gap or vacuum as none of the current policies promulgated caters for their specific sectoral needs.

Variability in the natural system: Recognising that observed changes in the natural system occur at various temporal scales, reported daily impacts show a link between the ability of fishers to proceed to sea (climate variation and its effects on weather) and the abundance and behaviour of target species in areas of operation.

Physical variability: Fishers indicated a general warming trend (air and/or sea surface temperature) with unseasonable prevailing wind conditions, attributing this to a deterioration of sea state and fewer available sea days. However, scientific data are not available to characterise ocean temperature variability and/or trends at the bay scale, making it problematic for scientists to relate to changes in temperature observed by fishers.

Biological variability: The observed change in catches and distribution of kob by fishers could be attributed to a recent ecosystem regime shift that has taken place in the southern Benguela. The southward and eastward shift of small pelagic fish in the late 1990s to early 2000s is thought to have been brought about by changes in environmental conditions and subsequently intensified by fishing activities.

Interactions with the inshore trawl sector: The inshore trawl fishery reportedly has a severe impact on the linefishery, ranging from impacts on kob stocks to modification of the benthic habitat, with specific reference to reef health and the impact that discards have on the marine environment.

In what ways were different environmental and social dimensions of the SDGs affected?

Direct contributions: SDGs 1 (Poverty), 2 (Food security), 11 (Sustainable communities), 14 (Life below water), 13 (Climate)

Indirect contributions: SDGs 3 (Good health and Wellbeing), 8 (Decent work and economic growth), 10 (Reduced inequality), 17 (Partnerships for the goals)

How (if at all) was the system resilient to the shock(s)/stress(es)/event(s), what impacts were lessened, and what might have happened without this resilience?

Gammage et al. (2017b) found that southern Cape handline fishers responded to stressors either through adapting in the long term or waiting for the poor fishing conditions to improve by turning to reacting or coping strategies. In this way, this fishery can be seen as very resilient in that fishers always seem to employ strategies that ultimately allow them to return to their starting state once the stressor or shock has abated. Unfortunately, this resilience could be hindering fishing communities from effecting the change they need to face the future.

What characteristics of the system enabled resilience?

Understanding the social interactions and networks that constitute social capital is key to understanding resilience in the face of change. Thus, the accumulation of social capital represents both a process and goal by which southern Cape linefishers reduce their vulnerability and bolster their resilience in the face of multiple intersecting challenges in a shifting social-ecological system (Duggan, 2018).

What characteristics reduced or acted as barriers to its resilience?

Poverty cycles in more impoverished communities, particularly for crew working in the fishery; limited enabling policy environment; custodians of fisheries management act as gatekeepers; and unfavourable market forces.

Were there any external factors (multi-scale) that affected resilience?

There are persisting knowledge gaps and poor understanding around environmental and climate variability in the southern Cape region and Agulhas Bank system, from local-scale drivers such as localised marine upwelling, to large-scale processes linked to the interaction between the South Atlantic and South Indian Anticyclone (Ward et al., *in press*). This poses challenges when dealing with high uncertainty in these complex social-ecological systems.

Has resilience changed over time [e.g. through learning and adaptation to previous experience, or through a reduction of capabilities, or as a result of multiple shock(s)/stress(es)/event(s)

Alternative seafood marketing strategies have been explored with these fishing communities, showcasing opportunities and constraints when operating under unfavourable market forces. Collective action was shown to have potential value to the linefishers, which could enhance livelihoods (Duggan et al., 2020). Strengthening of social capital by linefishers in response to market stressors indicates how their resilience has changed over time as they adapt to economic pressures within the fishery.

What are the opportunities for increasing resilience?

Scenario planning processes can provide opportunities for natural resource users to consider pathways for future responses to change, while simultaneously enhancing personal and local adaptive capacity, as demonstrated by Gammage & Jarre (2021). In addition, these tools integrate different knowledge streams, identifying ways to better address challenges across different scales in these complex systems, and provide an opportunity to build off the improved knowledge on climate variability and change from research undertaken by the SCIFR project.

Any other aspects of the case study that should be considered?

While fishers focus on policy and regulation stressors, a failure to recognise climate changes by local communities could push these natural resource users into vulnerable states should the natural system experience sudden changes or regime shifts (Ward et al., in press).

If this system became a "resilience observatory" what would it look like

Resilience would be seen more as a changing process rather than an outcome, moving into transformative spaces.