BRIEFING NOTE

PROMOTING CLIMATE CHANGE RESILIENT ESTUARIES FOR FISHERY SPECIES AND THE LIVELIHOODS DEPENDENT ON THEM

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Objective – A briefing note aims to provide a concise outcome based synopsis of recent research or expert opinion that may inform decision making and activities by authorities, NGOs and NPOs. The briefing note series complements the academic peer reviewed literature published by SAIAB.

Background

Understanding the vulnerability and resilience of coastal ecosystems and associated species to climate change is important in planning for a future climate. South Africa's ±290 estuaries are dominated by juvenile marine fish, with 19 species entirely dependent on estuarine nurseries. Of these 19 species, seven (dusky kob *Argyrosomus japonicus*, spotted grunter *Pomadasys commersonnii*, white steenbras *Lithognathus lithognathus*, Cape stumpnose *Rhabdosargus holubi*, leervis/garrick *Lichia amia*, estuarine bream *Acanthopagrus vagus* and ladyfish *Elops machnata*) are important fishery species. These species spend their adult life at sea but use productive estuaries as nurseries for the first year or two of their lives. The diverse habitats (such as seagrass, mangroves and salt marsh) and food available in estuaries makes these ecosystems amongst the most productive on Earth.

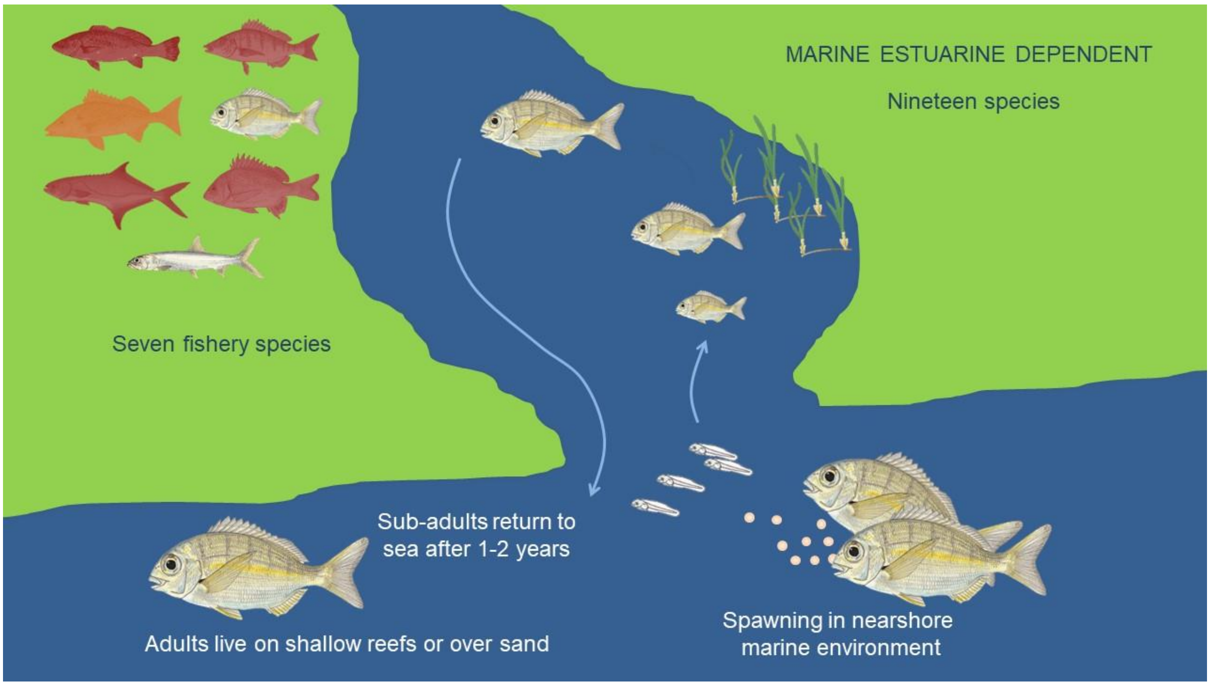


Figure 1. Life-cycle of marine estuarine-dependent fish species in South African estuaries. Species in red are severely overfished (collapsed) and species in orange are overexploited.

Estuaries are shallow environments that are influenced by both tidal action and freshwater inflow, and as such are naturally highly variable environments with physico-chemical conditions oscillating on hourly, daily, seasonal, yearly and decadal scales. Climate change is expected to change the magnitude of these oscillations, as well as changing long-term average physico-chemical conditions (such as average temperature, salinity and dissolved oxygen levels). In addition to rising temperatures, climate change in coastal seascapes also incorporates changes in temperature variability (land and sea), winds and ocean currents, freshwater flow (rainfall), extreme weather events (droughts, floods and heat waves), sea level and ocean acidification.

Here we highlight work from NRF-SAIAB and NRF-SAEON on South Africa's estuaries and associated fish to show how healthy estuaries may not only promote climate resilience for associated fauna but also potentially provide refuge from climate change impacts, such as decreasing pH associated with ocean acidification and extreme temperature variability associated with marine heatwaves and upwelling in the nearby marine environment.

Climate change and South Africa's estuaries and associated fish

Estuarine water temperatures are influenced by sea and river temperatures, wind, solar radiation, air temperatures and estuarine geomorphology, with a recent study showing that globally estuaries in temperate regions where air temperatures are rising rapidly are warming the fastest. This is true of South African estuaries, where temperate estuaries are warming at a rate of 0.06°C per year (Prum, Harris and Gardner 2024).

Although estuarine water temperatures are rising, during the estuarine phase of their life cycle, both fish and invertebrates are able to tolerate both very high and very low temperatures and it is unlikely that warming will severely impact juvenile fish in estuaries. For example, in the warm-temperate Kariega Estuary, juvenile mullet and sparids (southern mullet *Chelon richardsonii*, grooved mullet *Chelon dumerili* and Cape stumpnose *Rhabdosargus holubi*) are able to tolerate temperatures up to 38°C, which is eight degrees above the maximum water temperature recorded in the estuary (van der Walt et al. 2021a). These species, are also tolerant of low temperatures in winter and can tolerate temperatures as low as 5°C, which is well below the 12°C minimum winter temperature recorded in the estuary (Figure 2).

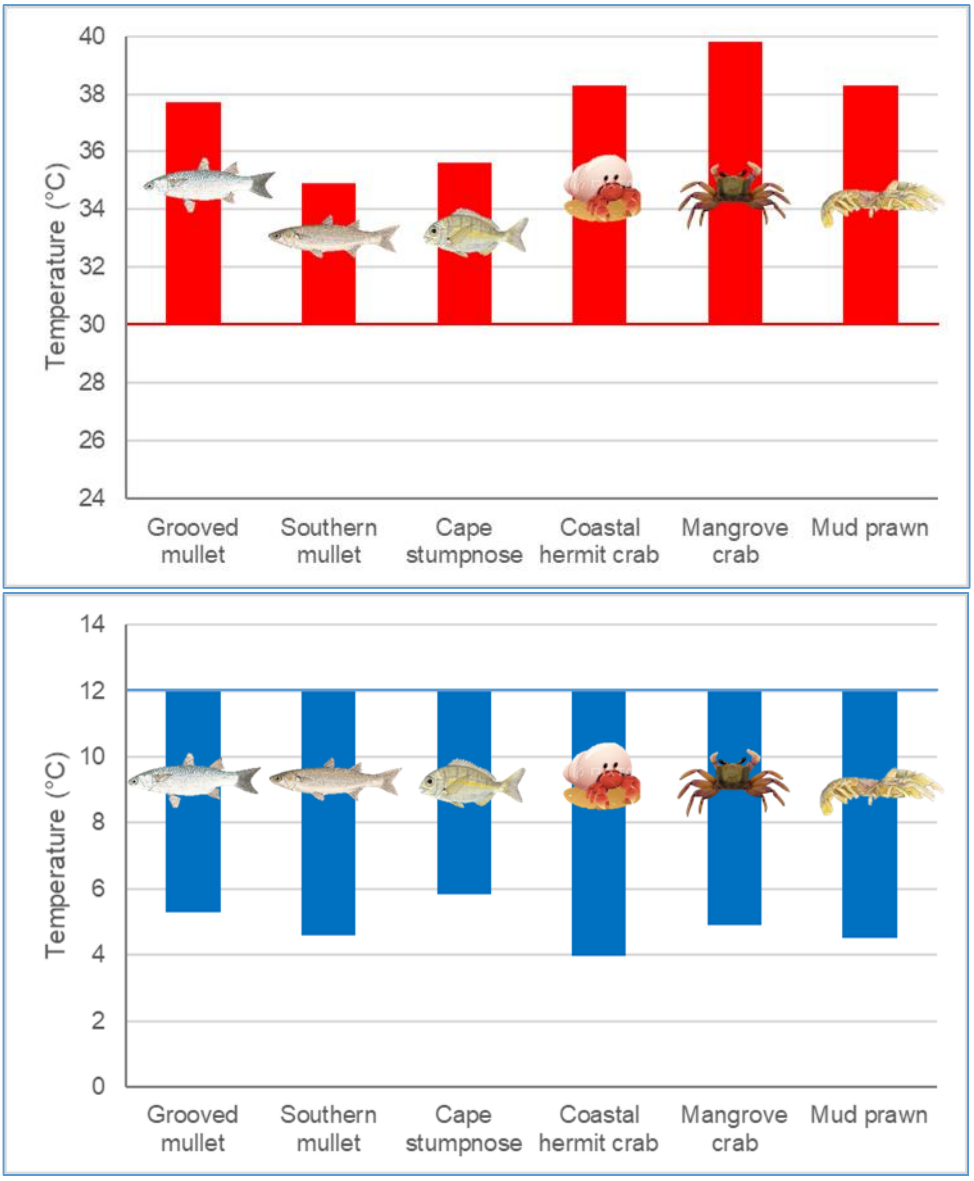


Figure 2. Critical thermal maximum (red bars) and minimum (blue bars) limits of fish and invertebrates and maximum (red line) and minimum (blue line) water temperatures recorded in the warm-temperate Kariega Estuary (after James, van Niekerk and Lamberth 2023; modified from van der Walt et al. 2021a)

Although juvenile fish in estuaries are tolerant of both extreme hot and cold temperatures, other climate change stressors, such as decreased average rainfall and droughts, floods and sea level rise have both direct and indirect effects on fish through habitat transformation. The frequency and intensity of extreme events (droughts, sea storms and river floods) is already increasing along the southern African coastline. Flooding can result in temporary loss of vegetated habitats in estuaries, such as seagrass. Seagrass is an important nursery habitat for many fish species (Whitfield 2017), with loss of seagrass in estuaries because of episodic floods (floods can physically remove seagrass) resulting in a decrease in the abundance of juvenile fish which use seagrass as nursery habitat, such as Cape stumpnose (e.g. Sheppard et al. 2011; James et al. 2018).

Extended droughts and lower average rainfall reduce freshwater inflow into estuaries. Salinity and turbidity gradients in estuaries, that are directly dependent on freshwater flow, are regarded as key determinants of estuarine species composition and the productivity of estuaries. Freshwater inflow also plays a critical role in the recruitment of estuarine-dependent marine species into estuaries, with settlement stage larval dusky kob using turbidity as a cue to recruit into estuaries (James et al. 2022) and Cape stumpnose using the smell of fresh and estuarine water (James et al. 2008). In the warm-temperate Kariega Estuary, freshwater abstraction and prolonged drought conditions means that freshwater inflow is negligible and the estuary is typically marine along its entire length. In this estuary the abundance of dusky kob is very low. Following a major 1 in 100 year flood in the estuary, a normal estuarine salinity and turbidity gradient was re-established, and zooplankton productivity increased substantially in response. Juvenile dusky kob responded to this increase in turbidity and productivity, particularly the early juveniles which prey on zooplankton. This led to a strong recovery in the populations of dusky kob within the Kariega Estuary (Figure 3, Nodo et al. 2018).

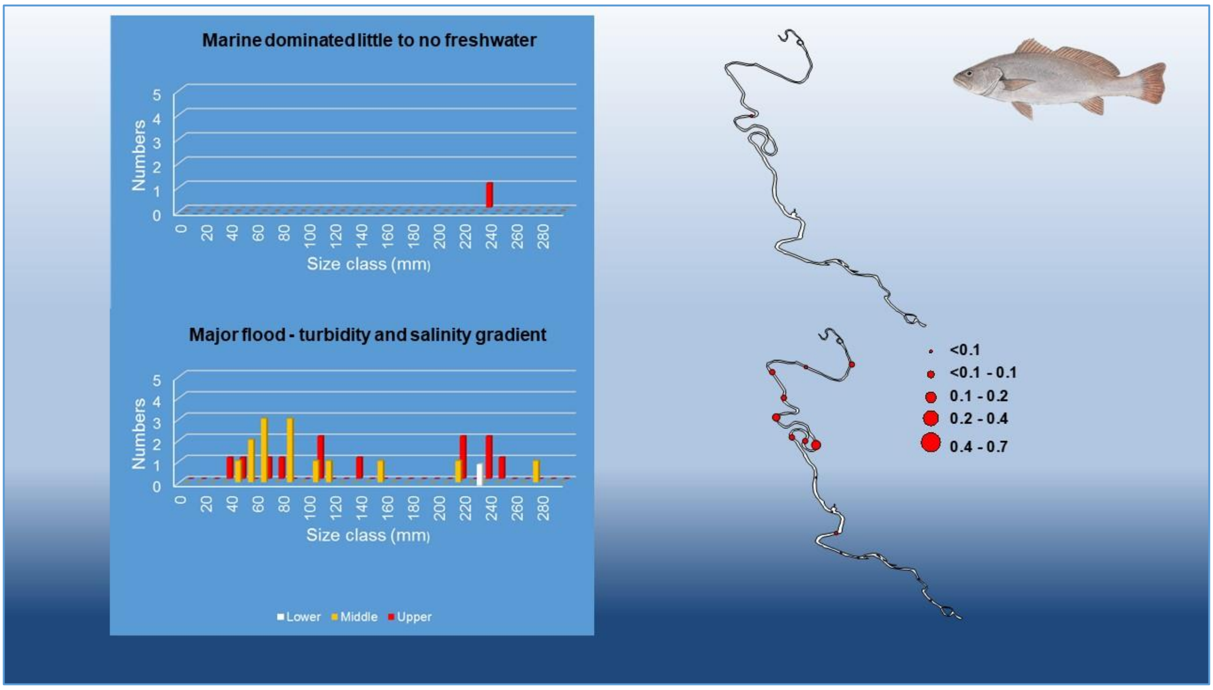


Figure 3. The distribution and abundance of dusky kob *Argyrosomus japnicus* in the Kariega Estuary (adapted from Nodo et al. 2018).

Climate change resilience and adaptation

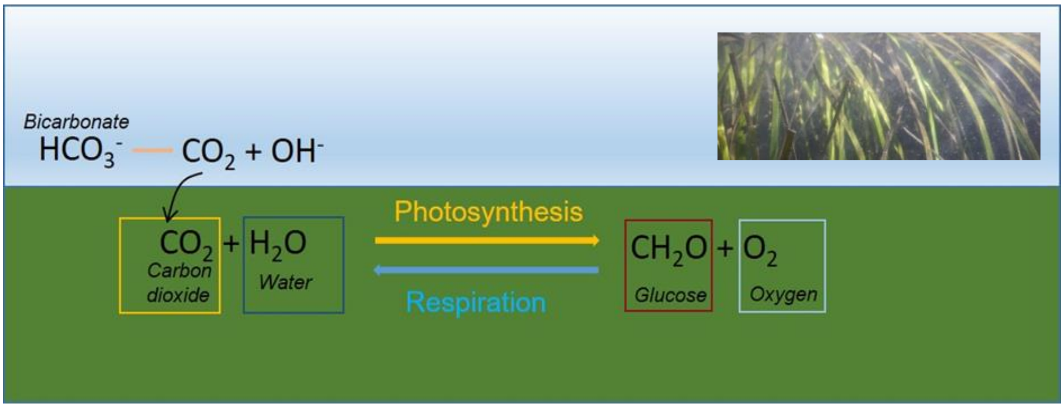
Estuaries are focal areas for human activity and development, with climate change exacerbating other anthropogenic impacts to these systems, such as freshwater abstraction, habitat transformation and loss, overfishing and pollution. By reducing some of these non-climate change impacts on estuaries and associated species and conserving and rehabilitating important estuarine habitat we can to some extent promote resilience to the effects of climate change.

Overall the biggest threat to estuarine-dependent marine fish is not climate change but growth overfishing (removal of juveniles before they are able to recruit to adult fish stocks) and because of this the stocks of four of the seven estuarine-dependent marine fishery species have collapsed and one is overexploited (Figure 1). Studies from marine protected areas and fished areas show that overfishing also makes fish less tolerant of extreme temperatures (by removing the fittest individuals) (Duncan et al. 2020), and as such, reducing growth overfishing in estuaries and establishing estuarine protected areas may also promote climate change resilience.

Prolonged droughts and lower average rainfall associated with climate change have a much greater impact on estuaries where freshwater abstraction has already reduced the amount of freshwater flow reaching the estuary, as illustrated in the Kariega Estuary example above. This highlights the importance of maintaining adequate river flow into estuaries as a means to promote climate change resilience.

Conserving and rehabilitating important estuarine habitat can also to some extent promote resilience to the effects of climate change. For example, seagrass is threatened by eutrophication, coastal development, habitat destruction, bait digging and boating (Adams 2016). The endemic seagrass *Zostera capensis* is also more impacted by climate change threats (such as increased temperatures and floods) in degraded estuaries, where increased nutrients cause blooms of micro and macro-algae in warmer water that may smother seagrass beds and decrease growth (James, van Niekerk and Lamberth 2023). Where estuaries are healthy (i.e. catchment degradation, pollution and development is minimal), seagrass which is lost during flooding can return to pre-flood levels within one to three years (Adams 2016).

Extensive and healthy seagrass beds may have the added ecosystem service of providing ocean acidification refugia for associated animals (including fish) by raising mean pH on a local scale (elevation in pH occurs when photosynthesis dominates over respiration) (e.g. Ricart et al. 2020). For example, in the Kromme Estuary we deployed pH loggers over a 24 hour period and found that mean pH is higher in seagrass beds than nearby non-vegetated areas (Figure 4).



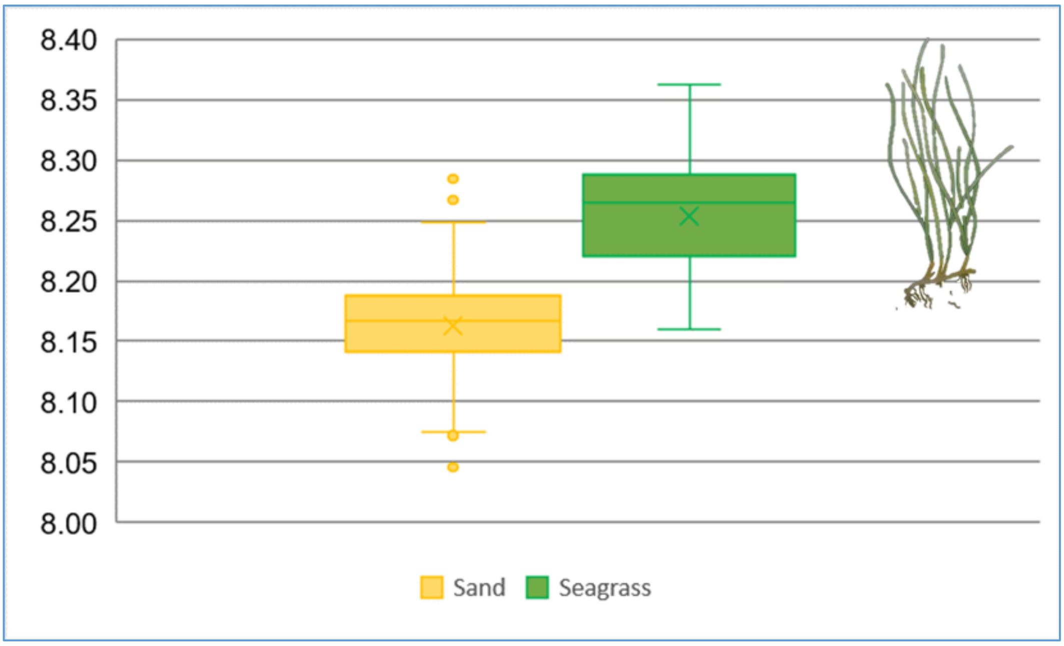


Figure 4. Average pH measured over a 24 hour period within seagrass beds (green) and non-vegetated areas in the Kromme Estuary.

Where the productive middle and upper reaches of predominantly open estuaries are thermally stable they may potentially provide a thermal refuge to animals against extreme temperature changes associated with marine heatwaves and upwelling in lower reaches and the nearby marine environment. It is extreme temperature variability (rather than gradually increasing average temperatures) that animals and plants do not cope well with. A recent regionally extensive marine heatwave event was recorded along the South African east coast at the end of summer 2021 (February). In this event, temperatures as high as 24.0 – 26.0°C occurred for several days, followed by an upwelling event, with temperatures rapidly decreasing to as low as 10°C (early March). Thermal shock from the temperature difference, stunned fish and invertebrates, resulting in extensive fish and invertebrate washouts and kills (van der Walt et al. 2021b; Lubitz et al. 2024). There were also reports of aggregations of fish, sharks and rays finding refuge from both warm and cold water in estuaries and the nearshore (James, van Niekerk and Lamberth 2023). The potential thermal refuge provided by the middle and upper reaches of predominantly open estuaries, is illustrated from SAEON's long-term monitoring of temperature in the Kariega Estuary and adjacent coastline (Figure 5). Although temperatures recorded during the 2021 marine heatwave (February) were highest in the middle and upper reaches of the estuary, in contrast to the coast and lower reaches of the estuary, there was no rapid decline in temperature in the middle and upper reaches during the upwelling event (March) providing animals with a refuge against extreme thermal variability. The middle and upper reaches of estuaries are also the most productive section of estuaries highlighting the importance of maintaining the ecological integrity of these reaches.

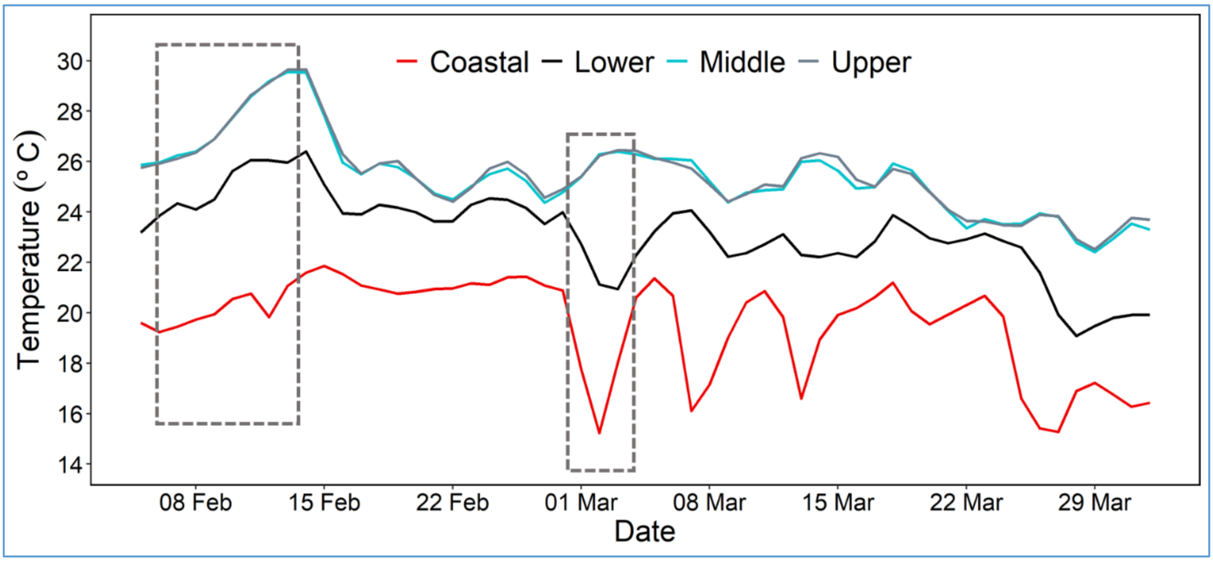


Figure 5. Daily water temperature from the Kenton coastal rocky shore (red) and the Kariega Estuary lower (black), middle (blue) and upper reaches (grey). SAEON unpublished data.

IMPLICATIONS FOR MANAGAMENT

- ❖ Juvenile fish in estuaries are tolerant of both extreme hot and cold temperatures, with climate change stressors (e.g. droughts, floods and decreasing rainfall) having both direct and indirect effects on fish through habitat transformation.
- ❖ By reducing some of the non-climate change impacts on fish, such as overfishing (through adequate resource management and estuarine protected areas), pollution (through estuarine management plans, agricultural best practices and storm and waste water management), freshwater abstraction (through DWS environmental flow requirements of estuaries) and habitat loss (through environmental management plans) and conserving and rehabilitating important estuarine habitat (blue and teal carbon) we can to some extent promote resilience to the effects of climate change.
- ❖ Maintaining the physical, hydrological and ecological integrity of estuaries through sustained and appropriate management interventions, will ensure the refuge potential for physiologically stressed species (from stressors such as temperature and acidification) is conserved in this time of growing implications linked to changing climates and systems.

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