1. **LINKING CLIMATE DRIVERS AND ARTISANAL FISHERIES OF THE WESTERN INDIAN OCEAN (WIO) COASTAL SYSTEMS**

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1. **Abstract**

This project seeks to investigate the impacts of climate drivers on **fish larval production and dispersal**, and link that to artisanal fisheries of the Western Indian Ocean coastal ecosystems (WIOCEs). As fish larval production and dispersal are critical bottlenecks for sustainable fish production of a system, the study is therefore looking to establish relationship between changing climate drivers within coastal habitats and fish larval production and dispersal, and how this link has affected artisanal fisheries and communities who depend on artisanal fisheries in the region. A great emphasis of this study will be placed on both **socio-ecological** and **socio-economic** impacts by looking on how land-based sources and activities may have enhanced vulnerability of coastal habitats to climate drivers and how this jeopardize economies, food security and wellbeing of people who depend on artisanal fisheries.

Healthy coastal habitats, including seagrass beds, coral reefs and mangroves, are a coupled social-ecological system providing critical spawning grounds and nursery areas for new generations of **commercially and societal** valuable fish species. However, these spawning grounds and nursery areas are threatened by climate change, which is predicted to profoundly affect conditions of the four key climate drivers (i.e., **pH, temperature, oxygen concentration and food availability)**. When settings of climate drivers in an ecosystem changes considerably, new conditions or a new combination of conditions, emerge and persist, which forces inhabiting organisms to adapt, migrate to more favorable areas, or face extinction. Moreover, such climate drivers are linked to fish larval production and dispersal, a main determinant of sustainable fish production of an ecosystem. Hence, a small change in conditionsof **pH, temperature, oxygen concentration and food availability** may limit fish larval production and dispersal and thereby, affecting fish production of coastal ecosystems.

Apparently, there is a big concern that fish catch is increasingly declining in the region mainly due to overexploitation, mismanagement, ecological degradation and climate change. However, the **key question is how changing climate drivers in essential coastal habitats limits fish larval production and dispersal, a critical bottleneck for sustainable fish stock.** Yet, the climate drivers and their relationship to fish larvae production and dispersal, and how this link is affecting artisanal fisheries, have not been assessed in the WIOCEs.

The effects of changing drivers on fish larval production and dispersal and how they are linked to artisanal fisheries of the WIOCEs will be examined through a combination of *i*) field surveys to relate fish larvae production in coastal habitats to climate drivers, *ii*) genetic tools to identify fish dispersal *iv)* remote sensing tools to determine primary production hot and cold spotsand *v)* modeling to estimate effects of changing climate drivers on health of coastal habits, on fish production and dispersal and thus, artisanal fisheries and economic impact on coastal society. The field samples to analyze essential parameters will be collected from identified primary production hotspots within coastal habitats off XXX (Tanzania) and XXXX (MOZAMBIQUE). To examine socio-economics and coastal governance and management, we will conduct socio-ecological surveys using a variety of tools such as Social Vulnerability Index. Our linked objectives are designed to provide knowledge-based management and protection strategies for sustainable fish recruitment, scientific guidance for the mariculture development and suggest mitigation measures to slow the pace at which coastal acidification and warming emerge, which allow time for additional conservation and planning of artisanal fisheries and mariculture development, in developing WIO countries.

***Linkages between climate drivers and artisanal fisheries***

**Specific objective # 1:** Determine hot and cold sports within coastal habitats critical for fish larval production **Specific objective # 2**: Determine how diversity and abundance of fish larvae are linked to climate drivers (i.e., pH, temperature and primary productivity) **Specific objective # 3:** Determine the dispersal distance of fish larvae from hot and cold sports to recipient habitats. **Specific objective # 4:** To assess the interaction between ecosystem changes and management responses towards improved management and protection strategies against local disturbances **Specific objective # 5:** Determine how limitation of fish larvae production and dispersal by changing climate drivers affects artisanal fisheries and economy of coastal societies that depend on such fisheries.

1. **Background and rationale of the proposed project**
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Human societies are entirely dependent on ecosystem services for the provision of natural resources including fish, and especially so in poorer developing countries ([Assessment, 2005](#_ENREF_2); [Costanza et al., 2016](#_ENREF_3)). In coastal WIO, a sustainable ecosystem production of fish, which is largely determined by fish larval production and dispersal, is essential for **food security and sustaining human livelihood and wellbeing** of coastal communities([de la Torre-Castro et al., 2008](#_ENREF_4); [Jiddawi and Öhman, 2002](#_ENREF_9); [Samoilys et al., 2017](#_ENREF_24); [van der Elst et al., 2009](#_ENREF_25)). Hence, a clear understanding of conditions and trends of climate drivers within coastal habitats and their relationship to fish larval production and dispersal, major components that contribute to sustainable fish stocks, is of high importance for predicting the future of artisanal fisheries of the WIOCEs. Moreover, such knowledge is helpful during planning and development of mariculture in WIO countries, where success will depend on exposure to coastal acidification and warming as well as on large variability that occurs in primary production and oxygen concentration (FAO, 2018).

* 1. **Coastal habitats and climate drivers**

Coastal habitats, including extensive seagrass beds, coral reefs and mangroves, are a coupled social-ecological system providing critical spawning grounds and nursery areas for new generations of **commercially and societal** valuable fish species ([Costanza et al., 2016](#_ENREF_3); [de la Torre-Castro et al., 2008](#_ENREF_4); [Mangora, 2011](#_ENREF_11); [Nordlund et al., 2017](#_ENREF_16)). However, these spawning grounds and nursery areas are threatened by climate change, which is predicted to profoundly affect conditions of the four principal climate drivers (i.e., **pH, temperature, oxygen concentration and food availability)** ([Henson et al., 2017](#_ENREF_6)). When settings of climate drivers in an ecosystem changes considerably, new conditions or a new combination of conditions, emerge and persist, which forces inhabiting organisms to adapt, migrate to more favourable areas, or face extinction ([Henson et al., 2017](#_ENREF_6)). Moreover, such climate drivers are linked to fish larval production and dispersal, a main determinant of sustainable fish production of an ecosystem. Hence, a small change in conditions of **pH, temperature, oxygen concentration and food availability** may limit fish larval production and dispersal and subsequently, can have long term impacts on artisanal fisheries and depending on how exposed and vulnerable the socio-ecological systems are as well as their capacity to respond ([Pörtner et al., 2014](#_ENREF_18)).

* 1. **Vulnerability of coastal habitats to changing climate drivers**

The vulnerability of the coastal ecosystems to changing climate is considered to be a function of exposure and sensitivity to drivers, combined with adaptive capacity ([Henson et al., 2017](#_ENREF_6)). The impacts of climate change are: 1) reduction of **pH** due to increasing atmospheric carbon dioxide (CO2) concentration ([Hoegh-Guldberg et al., 2007](#_ENREF_8); [Kroeker et al., 2013](#_ENREF_10)), 2) higher sea surface **temperature**, which are associated with increased ocean stratification ([Oschlies et al., 2018](#_ENREF_17)), and thus, prevents nutrient supply to photosynthetic organisms (**limiting primary production**) in surface waters, 3) decrease in solubility of **oxygen and exchange** of subsurface waters with the atmosphere, driving lower bottom oxygen concentrations with potentially negative effects on coastal organisms ([Oschlies et al., 2018](#_ENREF_17)). Although regionally and locally variable, the combined effect of these changes are predicted to be an overall global decrease in **primary production** (PP), which is the ultimate determinant of food availability to coastal organisms, including different stages (.e., larval, juvenile and adult) of fish species. **A key question is how changing climate drivers in essential coastal habitats limits fish larvae production and dispersal, a critical bottleneck for sustainable fish production** ([Henson et al., 2017](#_ENREF_6))**.  Yet, the climate drivers and their relation to fish larvae production and dispersal, and how this link is affecting artisanal fisheries, have not been assessed in the EACEs.**

* 1. **Effects of climate drivers on recruitment and production of fish**

Given that coastal habitats play a key role for the supply of fish larvae to replenish production in recipient habitats, a small change in conditions of **pH, temperature, oxygen concentration and food availability** in an ecosystem may limit fish larvae production and dispersal, a critical bottleneck for sustainable fish production ([Rodriguez-Dominguez et al., 2018](#_ENREF_22)). Moreover, larval dispersal capacity is also linked to water currents and circulation and determine how far larvae may travel ([Nagelkerken, 2009](#_ENREF_15)). These in turn could have huge impacts on fish production and thus, artisanal fisheries ([Allison et al., 2009](#_ENREF_1)). The impacts of changing drivers, however, are variable and more localized, depending on local disturbances of an ecosystem. For example, in productive coastal areas, conditions of pH and oxygen concentration are largely governed by respiration and/or remineralization processes that consume dissolved oxygen (DO) and release a great deal of CO2 into subsurface waters, leading to rapid seawater acidification and reduced oxygen concentration in coastal oceans, with huge impacts ([Hoegh-Guldberg and Bruno, 2010](#_ENREF_7); [Proum et al., 2017](#_ENREF_21)). The more rapidly the system is pushed out of its natural range of variability, the less time the fishes (and other organisms) will have to adapt or acclimate to the new conditions or migrate to more suitable areas ([Pörtner and Peck, 2010](#_ENREF_19)).

Fishes have developed physiologically to survive within a specific range of environmental variation, and living outside of that range can be stressful or fatal ([Pörtner and Peck, 2010](#_ENREF_19); [Pörtner and Knust, 2007](#_ENREF_20)). It has been shown that fish respond differently across their alternate life stages to climate drivers ([Rodriguez-Dominguez et al., 2018](#_ENREF_22); [Russell et al., 2013](#_ENREF_23)) as physiological, phenological (seasonal timing), and behavioural alterations are often life-stage specific and leave a legacy on adult stages ([Rodriguez-Dominguez et al., 2018](#_ENREF_22)). Furthermore, differential sensitivity to climate drivers across early life stages can create bottlenecks for population growth and persistence ([Pörtner and Peck, 2010](#_ENREF_19); [Rodriguez-Dominguez et al., 2018](#_ENREF_22)). As a result, the capacity of each life stage to acclimate or adapt represents a critical component of how a given fisheries might respond to future changes ([Munday et al., 2010](#_ENREF_13); [Munday et al., 2012](#_ENREF_14)). It is possible that the negative effects observed during early life stages (e.g. production of fish larva and dispersal) are linked to the decrease of fish catch ([Rodriguez-Dominguez et al., 2018](#_ENREF_22)). The spatial scale over which marine populations are connected by larval dispersal is largely not known in general, and particularly so in the **East African coastal region** due to a lack of empirical data on how far larvae can travel. This has profound consequences for distributions, genetic connectivity and management of a given fisheries. Therefore, understanding **how marine fish populations are connected and replenished by larvae from seagrass, mangrove and coral reef habitats** will be instrumental for resilient fisheries planning in the coastalEast African region.

* 1. **Socio-economic importance of artisanal fisheries in developing WIO countries**

Human societies are totally dependent on ecosystem services for the provision of natural resources, and especially so in poorer developing areas ([Costanza et al., 2016](#_ENREF_3)). Artisanal fisheries supplies over 90% of the marine catch and are principal for income generating activity and employment for a large number of coastal communities in developing countries of Western Indian Ocean (WIO) ([van der Elst et al., 2009](#_ENREF_25)). The contribution of artisanal fishing to national landings varies between countries: Tanzania – 90 - 95%, Mozambique at least 75%, Comoros - 100%, and Madagascar - 73% ([van der Elst et al., 2009](#_ENREF_25)). Artisanal fisheries make significant economic contributions to the livelihoods and wellbeing of the coastal communities in the region ([Samoilys et al., 2017](#_ENREF_24)). However, there is a big concern that fish catch is increasingly declining in the region mainly due to overexploitation, mismanagement, ecological degradation and climate change ([McClanahan et al., 2015](#_ENREF_12); [Samoilys et al., 2017](#_ENREF_24)). Fish production of given system depends on both fish larval production and dispersal, which are major components that contribute to sustainable fish stocks and can minimize the risk of fish collapse even under heavy fisheries exploitation. However, existing fisheries management programs in the region does not consider fish recruitment within its coastal habitats, where success will depend on fish larval production and dispersal capacity.

* 1. **Relationship to regional programs**

The objective of this project is consistent with the objective of the Contracting Parties to the Nairobi Convention, which is“…to address the accelerating degradations of the world oceans and coastal areas through sustainable management and use of marine and coastal environment.” This project has a similar objective, which is: “*to* *provide knowledge-based management and protection strategies of vulnerable areas and reorganized fish larvae production ‘hotspots’ for sustainable fish recruitment, scientific guidance for the mariculture development and suggest mitigation measures to slow the pace at which coastal acidification and warming emerge, which allow time for additional conservation and planning of artisanal fisheries and mariculture development, in developing WIO countries’’*. Moreover, the project objective above is in parallel to objectives of United Nations Framework Convention on Climate Change (UNFCCC) the Nairobi work programme on impacts, vulnerability and adaptation to climate change which are: ‘‘1) *to assist all Parties, in particular developing countries, including the least developed countries and small island developing States, to improve their understanding and assessment of impacts, vulnerability and adaptation* *and* 2) *to assist all Parties to make informed decisions on practical adaptation actions and measures to respond to climate change on a sound scientific, technical and socio-economic basis, taking into account current and future climate change and variability’’*.

1. **Goals and Objectives**

**Project goal:** To determine the effects of climate drivers– **pH, temperature, oxygen concentration and food availability**- on fish larval production and dispersal and link that to artisanal fisheries of the WIO coastal areas of Tanzania and Mozambique. Below are specific objectives of the project:

***WP1: Linkages between climate drivers and fish larval production and dispersal***

**Specific objective 1:** To determine hot and cold sports within coastal habitats critical for fish larval production.

**Specific objective 2:** To determine how diversity and abundance of fish larvae are linked to climate drivers (i.e., pH, temperature and primary productivity).

**Specific objective 3:** Determine fish larval dispersal distance from hot and cold sports to recipient habitats.

***WP2: Governance and management of critical habitats (socio-ecological relationships)***

**Specific objective 4:** To assess the interaction between ecosystem changes and management responses towards improved management and protection strategies of vulnerable areas and reorganized fish larvae production ‘hotspots’.

***WP3: Socio-economic implication of climate drivers***

**Specific objective 5:** Todetermine how limitation of fish larvae production and dispersal by changing climate drivers affects artisanal fisheries and economy of coastal societies that depend on such fisheries.

A transdisciplinary research team consisting of researchers WIO countries will complete these tasks. Together, the team has a unique combination of experience in fisheries, climate change, coastal ecosystem functioning, management and socio-ecological interactions, which will enable to effectively carry out, implement and communicate the proposed research.

1. **Methodologies**

**Specific objective 1:** **To determine hot and cold sports within coastal habitats critical for fish larval production.**

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1. Fifteen seagrass, mangrove and coral reef study sites will be selected in the coastal zone with known differences in levels of disturbance (1.e., nutrient enrichment, sedimentation effects and forest exploitation). This will allow us to separate direct and indirect effects from eutrophication and habitat degradation on fish larvae production.
2. Fish larvae will be sampled using an ichthyoplankton net and light traps, preserved and later sorted into taxa using available identification literature (18). Larval standard length, wet weight, growth and age structure, and RNA/DNA ratio will be measured as indicators for larval body conditions.

**Specific objective 2:** **To determine how diversity and abundance of fish larvae are linked to climate drivers (i.e., pH, temperature and primary productivity).**

1. An oceanographic buoy will be deployed at one site close to xxxxx in waters of 100 m depth. A thermistor chain with self-recording temperature sensors (MX TidbiT loggers) and dissolved oxygen loggers (HOBO) will be attached at every 10 m. These will allow the collection of high frequency temperature and DO data which will be used to calculate thermal stability, metabolic rates, and deoxygenation trends.
2. An automatic weather station will be attached on top of the buoy to record high frequency data of wind speed, air temperature, atmospheric pressure, and other parameters. This information is required because the fluxes of CO2 between air and water is a function of the gas transfer coefficient (k), which is also a function of wind speed, temperature dependent solubility, and the difference in partial pressure (pCO2) between the ocean water and the atmosphere.
3. DO, temperature, salinity, and pH data will be collected using a CTD. CTD casts will be conduced monthly in XXX (Site 1), Site2, and Site3 in Tanzania and xxxx sites in Mozambique.
4. Water samples will be collected using Hydrobios sampling bottles for nutrients (phosphorus and nitrogen) analysis in the laboratory at TAFIRI. Sampling will be conducted according to standard operating procedures (SOPs)([Dickson et al., 2007](#_ENREF_5))
5. Sampling will be conducted such that it captures day and night cycling, seasons and the effect of tidal regimes. However, the day and night sampling will be conducted at the buoy site and only three times a year to capture the monsoon and inter-monsoon periods

**Specific objective 3:** Determine fish larval dispersal distance from hot and cold sports to recipient habitats.

1. We will focus on two fish species (….,,,) that utilize seagrass, mangrove and coral reef habitats as their nursery ground.
2. A genetic approach provides a valuable and widely accepted indirect means to examine connectivity across regions because fish larvae cannot be tracked by conventional tagging methods due to their small size.
3. We will use genetic parentage analysis using nuclear DNA sampled from juveniles and probable parents, which has been used successfully to measure the exact dispersal distances for individual larvae (21).
4. Adults of the two …… species will be collected within three seagrass beds, three mangroves and coral reef areas, fin-clipped and collected tissue will be preserved in 90% ethanol.
5. Another collection after 6 months will target juveniles of the respective species at scattered locations up to 30 km from the focal point.
6. Adult and juvenile specimens will be genotyped with microsatellite markers. All collected juveniles will be screened against the total pool of adult samples to identify parent offspring relationships (22).
7. By recording the sampling locations of all adult and juvenile fishes and assigning offspring to one or both parents, the dispersal distance and direction of juveniles sourced from the focal reserves will be determined.
8. Categorical allocation of parent-offspring relationships will be assessed based on a maximum likelihood approach as described in ref. (22).
9. Adult ontogenetic and feeding migration patterns of these species have been previously studied in this region using stable isotopes (23).

**Specific objective 4:** To assess the interaction between ecosystem changes and management responses towards improved management and protection strategies against local disturbances

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**Specific objective 5:** Todetermine how limitation of fish larvae production and dispersal by changing climate drivers affects artisanal fisheries and economy of coastal societies that depend on such fisheries.

1. We will apply structural equation models (SEM) to field data to identify major pathways and interactions between fish larvae biota and environmental drivers. Models will be constructed under multiple combinations of drivers affecting conditions in coastal habitats, including future climate change (precipitation, change in river runoff, temperature) and human activities (eutrophication, increasing fish food demand, and human population growth) based on low-to high Representative Concentration Pathways (RCP) scenarios.
2. We will also consider synergistic effects of increasing fish demand and thus reduced adult fish stocks. We will qualitatively describe temporal (coming decades and end of this century) and spatial impacts of drivers. The model prediction will be used to identify vulnerable areas and fish larval production hotspots based on present encountered and future stressors and evaluate how the spatial distribution of these hotspots and associated services from fish larvae production are likely to change.
3. We will also assess how different existing coastal habitats management and conservation efforts under projected environmental and human population development change affect fish recruitment. Different management strategies will be considered, including continues degradation based on a global decline rate of 7% yr-1 for seagrass and 2-8% yr-1 for mangroves (5, 26), implementation of coastal habitat reserves, and different habitat fragmentation scenarios.
4. The economic impact will be projected based on the estimate of fish production per square meter seagrass and hectare mangrove and coral reef.
5. **Project activity plan**

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1. **Outputs and Outcomes**

**Objective 1:**

1. Improved understanding on the functioning of coastal habitats to support local fish recruitment, and how this function is affected by eutrophication and habitat degradation. This will include theidentification of core spawning sites and prove a model to predict changes in habitathealth status in relation to future degradation.
2. It will also generate valuablebackground information on which to build on studies for WP4.

**Objective 2:**

1. Establish conditions and trends of climate drivers within coastal habitats and their relationship to fish larval production and dispersal is of high importance for predicting the future of artisanal fisheries of the WIOCEs.
2. Such improved knowledge is helpful during planning and development of mariculture in WIO countries, where success will depend on exposure to coastal acidification and warming as well as on large variability that occurs in primary production and oxygen concentration.

**Objective 3:**

1. Enhance understanding of habitat connectivity that is important for understanding the functions of coastal vegetated habitat connectivity to support artisanal fisheries and for setting appropriate spatial scales of coral reefs, seagrass and mangrove habitat reserves.

**Objective 4:**

**Objective 5:**

1. Improved information which will help to effectively manage potential coastal habitat risks from climate change and development over the coming decades, and how they are related to fish larvae production to benefit food-provisioning services.
2. Develop models which will to identify critical threshold levels of coastal habitat health for successful fishrecruitment and identify important coastal seascapes for fish production.
3. Developed models in 2) above are useful tools for fisheries and conservation management as they provide adirect measure of how coastal habitat health and management strategies are related tofish larvae production and ultimately fishery stocks.
4. **Applicability of the results in practice, and potential impacts**

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| --- | --- | --- | --- | --- |
| Outcome | Research Results/Outputs | Potential users/beneficiaries of the research | How will the research benefit users | What will be done to link research results to users |
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**Allison, E. H., Perry, A. L., Badjeck, M. C., Neil Adger, W., Brown, K., Conway, D., Halls, A. S., Pilling, G. M., Reynolds, J. D. and Andrew, N. L.** (2009). Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries* **10**, 173-196.

**Assessment, M. E.** (2005). Millennium ecosystem assessment. *Ecosystems and human wellbeing: a framework for assessment Washington, DC: Island Press*.

**Costanza, R., d’Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O’Neill, R. V. and Paruelo, J.** (2016). The Value of the World’s Ecosystem Services and Natural Capital (1997). *The Globalization and Environment Reader*, 117.

**de la Torre-Castro, M., Björk, M., Eklöf, J. and Rönnbäck, P.** (2008). Seagrass importance in food provisioning services: fish stomach content as a link between seagrass meadows and local fisheries. *Western Indian Ocean Journal of Marine Science* **7**.

**Dickson, A. G., Sabine, C. L. and Christian, J. R.** (2007). Guide to Best Practices for Ocean CO2 Measurements. In *PICES SPECIAL PUBLICATION No. 3. IOCCP REPORT No. 8*: PICES, IOCCP.

**Henson, S. A., Beaulieu, C., Ilyina, T., John, J. G., Long, M., Séférian, R., Tjiputra, J. and Sarmiento, J. L.** (2017). Rapid emergence of climate change in environmental drivers of marine ecosystems. *Nature Communications*.

**Hoegh-Guldberg, O. and Bruno, J. F.** (2010). The impact of climate change on the world’s marine ecosystems. *science* **328**, 1523-1528.

**Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell, C. D., Sale, P. F., Edwards, A. J. and Caldeira, K.** (2007). Coral reefs under rapid climate change and ocean acidification. *science* **318**, 1737-1742.

**Jiddawi, N. S. and Öhman, M. C.** (2002). Marine fisheries in Tanzania. *AMBIO: A Journal of the Human Environment* **31**, 518-527.

**Kroeker, K. J., Kordas, R. L., Crim, R., Hendriks, I. E., Ramajo, L., Singh, G. S., Duarte, C. M. and Gattuso, J. P.** (2013). Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. *Global Change Biology* **19**, 1884-1896.

**Mangora, M. M.** (2011). Poverty and institutional management stand-off: a restoration and conservation dilemma for mangrove forests of Tanzania. *Wetlands Ecology and Management* **19**, 533-543.

**McClanahan, T., Allison, E. H. and Cinner, J. E.** (2015). Managing fisheries for human and food security. *Fish and Fisheries* **16**, 78-103.

**Munday, P. L., Dixson, D. L., McCormick, M. I., Meekan, M., Ferrari, M. C. and Chivers, D. P.** (2010). Replenishment of fish populations is threatened by ocean acidification. *Proceedings of the National Academy of Sciences* **107**, 12930-12934.

**Munday, P. L., McCormick, M. I., Meekan, M., Dixson, D. L., Watson, S.-A., Chivers, D. P. and Ferrari, M. C.** (2012). Selective mortality associated with variation in CO2 tolerance in a marine fish. *Ocean acidification* **1**, 1-5.

**Nagelkerken, I.** (2009). Evaluation of nursery function of mangroves and seagrass beds for tropical decapods and reef fishes: patterns and underlying mechanisms. In *Ecological connectivity among tropical coastal ecosystems*, pp. 357-399: Springer.

**Nordlund, L. M., Unsworth, R. K., Gullström, M. and Cullen‐Unsworth, L. C.** (2017). Global significance of seagrass fishery activity. *Fish and Fisheries*.

**Oschlies, A., Brandt, P., Stramma, L. and Schmidtko, S.** (2018). Drivers and mechanisms of ocean deoxygenation. *Nature Geoscience*, 1.

**Pörtner, H.-O., Karl, D. M., Boyd, P. W., Cheung, W., Lluch-Cota, S. E., Nojiri, Y., Schmidt, D. N., Zavialov, P. O., Alheit, J. and Aristegui, J.** (2014). Ocean systems. In *Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change*, pp. 411-484: Cambridge University Press.

**Pörtner, H.-O. and Peck, M.** (2010). Climate change effects on fishes and fisheries: towards a cause‐and‐effect understanding. *Journal of fish biology* **77**, 1745-1779.

**Pörtner, H. O. and Knust, R.** (2007). Climate change affects marine fishes through the oxygen limitation of thermal tolerance. *science* **315**, 95-97.

**Proum, S., Santos, J. H., Lim, L. H. and Marshall, D. J.** (2017). Tidal and seasonal variation in carbonate chemistry, pH and salinity, for a mineral-acidified tropical estuarine system. *Regional Studies in Marine Science*.

**Rodriguez-Dominguez, A., Connell, S. D., Baziret, C. and Nagelkerken, I.** (2018). Irreversible behavioural impairment of fish starts early: Embryonic exposure to ocean acidification. *Marine pollution bulletin* **133**, 562-567.

**Russell, B. D., Connell, S. D., Findlay, H. S., Tait, K., Widdicombe, S. and Mieszkowska, N.** (2013). Ocean acidification and rising temperatures may increase biofilm primary productivity but decrease grazer consumption. *Phil. Trans. R. Soc. B* **368**, 20120438.

**Samoilys, M., Osuka, K., Muthiga, N. and Harris, A.** (2017). Locally managed fisheries in the Western Indian Ocean: a review of past and present initiatives, iv+ 40p: by: the Western Indian Ocean Marine Science Association (WIOMSA).

**van der Elst, R. P., Groeneveld, J. C., Baloi, A. P., Marsac, F., Katonda, K. I., Ruwa, R. K. and Lane, W. L.** (2009). Nine nations, one ocean: A benchmark appraisal of the South Western Indian Ocean Fisheries Project (2008–2012). *Ocean & coastal management* **52**, 258-267.