Potential Adaptation Options

[1.1 **Habitat Management Actions** 2](#_Toc22920712)

[1.1.1 Reduce Landscape Stressors on Coastal Habitats 2](#_Toc22920713)

[1.1.2 Protect Critical Coastal Habitats Supporting Fisheries Species 3](#_Toc22920714)

[1.1.3 Restore Critical Coastal Habitats Supporting Fisheries Species 4](#_Toc22920715)

[1.1.4 Managed Realignment of Coastal Vegetation 5](#_Toc22920716)

[1.2 **Harvest Management Actions** 6](#_Toc22920717)

[1.2.1 Use Regulations to Protect Vulnerable Fish Populations 7](#_Toc22920718)

[1.2.2 Adjust Assessments and Harvest Control Rules to Account for Climate Vulnerability 7](#_Toc22920719)

[1.2.3 Diversify Catches to Relieve Pressure on Vulnerable Populations 8](#_Toc22920720)

[1.2.4 Precautionary Management of Emerging Fisheries 9](#_Toc22920721)

[1.2.5 Adjust Management Areas to Reflect Changes in Species Distributions 10](#_Toc22920722)

[**1.3 Sustainable Livelihoods and Economic Diversification Actions** 10](#_Toc22920723)

[1.3.1 Protect Existing Assets Against Climate-Related Impacts 11](#_Toc22920724)

[1.3.2 Improve Safety at Sea 12](#_Toc22920725)

[1.3.3 Facilitate Access to New Assets in Times of Need 13](#_Toc22920726)

[1.3.4 Enhance Post-Harvest Handling, Processing, and Marketing 14](#_Toc22920727)

[1.3.5 Diversify Livelihoods 15](#_Toc22920728)

* 1. **Habitat Management Actions**

***Overview***: Adapting to a changing climate includes a variety of strategies for protecting, restoring, and even creating valuable habitats for economically-important fish and invertebrate species. Reducing other cumulative stressors on critical habitats for fished species will help these marine ecosystems be more resilient to the effects of climate change and improve their ability to sustain existing and future fisheries. Adaptation actions in this class may be applied to either land or marine sites, and simple decision-rules can help to determine whether land-based management strategies will be more effective than ocean-based management strategies for promoting ecosystem recovery (Saunders *et al.*, 2017). In general, land-based restoration actions are more effective where most vegetation within coastal watersheds has already been lost or degraded but marine ecosystems are not declining at a rapid rate, while ocean-based restoration actions are more effective where most coastal watershed restoration is intact yet marine ecosystems continue to decline (Saunders *et al.*, 2017).

* + 1. Reduce Landscape Stressors on Coastal Habitats

***Rationale***: Coastal habitats facing stress from direct effects of climate change will be more vulnerable to the negative consequences of harmful inputs from land-based activities, particularly sedimentation and excessive nutrient loads. Reducing undesirable inputs to the marine environment is an important component of reducing cumulative stressors on coastal environments which can provide near term benefits and help these habitats be more resilient to climate change (Bell *et al.*, 2018, Andersson *et al.*, 2019). Moreover, reducing these cumulative stressors can help to achieve the maximum possible benefits from other adaptation options, including marine protected areas (Suchley and Alvarez-Filip, 2018) and habitat restoration initiatives (Björk *et al.*, 2008; McLeod and Salm, 2006; Spalding *et al.*, 2014).

Activities within this class include upland vegetation management for erosion control and sediment trapping (e.g., planting for slope stabilization, riparian buffers), improving sediment management practices during coastal development, reduction of marine dredging activities, and reductions of untreated wastewater discharge into coastal waters. These activities will have the added benefit of mitigating increased hazards related to more frequent and severe rainfall, flooding, and landslides, anticipated under future climate scenarios.

These types of adaptation actions have been described as win-win scenarios (Bell *et al.*, 2018), insofar as they provide both short-term (improving coastal water quality and preserving existing ecosystem productivity) and long-term benefits (increase ecosystem health and resilience to future climate change).

***Objectives met***: Adaptation to losses of productive fish habitats.

***Considerations for Implementation***: Vegetation management strategies will be among the simplest of these actions to implement at a range of scales, while implementing broader changes in coastal development practices and land use may first require regulatory reform that will be much more challenging. Site selection for implementation should be guided by a spatial site prioritization assessment using all available data on current habitat distributions, land use, and water quality. Implementation at priority sites will require stakeholder input and support as well as political will to counteract the perceived drawbacks of potential restrictions on land development and increased regulations on land-based activities (e.g., logging, resort development, land conversion to agriculture).

***Information Needs & Monitoring Connections***: At minimum, coastal managers can use direct observations of coastal erosion and terrestrial runoff into marine environments to identify potential implementation sites. Where available, coastal habitat maps, land use maps, precipitation maps, and marine water quality monitoring data (e.g., turbidity, nutrient levels and pH) can also be compared to more effectively identify and prioritize areas where action is needed or likely to be needed. Additional information from climate change projections of future precipitation and extreme weather patterns can help to refine lists of priority areas by considering how shifts in precipitation patterns, storm frequency and intensity, and coastal hydrology will affect both (1) runoff of terrestrial inputs and (2) the longevity and effectiveness of adaptation interventions under a future climate (West *et al.*, 2016).Explicitly incorporating these climate-smart design considerations will help to extend the useful lifetime of interventions under a future climate.

Following implementation, measures of turbidity and nutrient levels in key habitats, particularly before and after land-based management has been implemented, will provide observable evidence that these actions are working as intended to improve coastal habitat quality.

* + 1. Protect Critical Coastal Habitats Supporting Fisheries Species

***Rationale***: Coastal habitats including mangroves, seagrasses, and coral reefs are expected to experience adverse effects due to rising temperatures, decreasing pH, and an increasing frequency and severity of extreme weather events anticipated under a future climate. However, not all of these habitats will experience the same level of climate change risk due to natural variation in levels of exposure and vulnerability that can be exploited to increase climate resilience. For example:

* Some areas of marine habitats may benefit from reduced exposure to climate change due to their location in the seascape, such as coral reefs and seagrasses at greater depths (Bongaerts *et al*., 2010, Smith *et al.*, 2016), mangroves in areas that will allow for landward migration (McLeon and Salm, 2006), or any of these organisms occurring in small-scale variations in physical ocean conditions (microclimates) that are less sensitive to broader trends in temperature or pH (Woodson *et al.*, 2018)..
* Other areas of marine habitat may have already adapted to warmer temperatures or sea-level rise through natural phenotypic plasticity or evolutionary adaptation (McLeon and Salm, 2006, Howells *et al.*, 2016, Osman *et al.*, 2018).

Once identified, these habitats could be prioritized for protection to help contribute to future fisheries production and act as source populations to provide propagules for recolonization of broader coastal ecosystems (but see Smith *et al.*, 2016). However, some research cautions that climate refugia should be part of a broader portfolio that maximizes habitat diversity across protected area networks (McLeon and Salm, 2006, Björk *et al.*, 2008, Walsworth *et al.*, 2019). Protected area networks with greater habitat diversity were found to facilitate evolutionary adaptation among corals and achieve better conservation outcomes than protected area networks including only climate refugia sites. This is partly because this diversity helps to hedge against environmental variability that may cause refugia locations to shift over time.

***Objectives Met***: Adaptation to a changing physical environment. Adaptation to losses of productive fish habitats.

***Information Needs & Monitoring Connections***: Implementation of this management option will depend on a sufficient diversity, spatial resolution, and temporal resolution of physical monitoring data to identify climate change refugia, ensure these anomalies persist over time, and inform site selection. In many cases, this might be possible using existing remote sensing and monitoring data. For example:

* existing maps may be used to delineate refugia based on broader geographic characteristics (e.g., depth characteristics, such as the use of bathymetric maps to delineate mesophotic zone refugia;
* long-term field monitoring data could indicate areas that appear to be less affected by extreme climate events, perhaps experiencing greater short-term (diurnal) fluctuations but less sensitivity to regional patterns (e.g., Woodson *et al.*, 2019) and
* habitat suitability map projections under future climate scenarios from the earlier impact assessment in this project (Cheung *et al.*, 2019) could provide a starting point for identifying refuge regions at larger spatial and temporal scales.

After implementation, ongoing assessment data of habitat status would be valuable to confirm the site’s ongoing suitability as a refuge.

***Considerations for Implementation***: Protected area planning should consider the protection of climate refugia as one part of a broader strategy emphasizing the protection of a diverse portfolio of marine and coastal habitats (Beyer *et al.*, 2018). Adding or modifying new protected areas to existing networks may require adjustments to existing protected area networks which might be difficult to achieve under the current regulatory frameworks for delineating conservation areas, which are often cumbersome, slow-moving, and spatially fixed.

The success of any protected area strategy depends strongly on the capacity, resources, and political will to effectively enforce protected status so that the intended benefits of these protections are realized. Where these conditions are lacking, managers may consider implementation of community-based protected area management initiatives for additional support, or consider alternative adaptation strategies until these conditions are met.

* + 1. Restore Critical Coastal Habitats Supporting Fisheries Species

***Rationale***: Coastal habitats provide important ecosystem services contributing to climate change resilience, including as habitat for economically-important fisheries species, as coastal defenses against extreme weather, and as “blue carbon” sinks. Given that many of these habitats have been significantly degraded or lost across the Caribbean region, costal habitat restoration represents a key climate change adaptation strategy for the coastal fisheries sector (Guannel *et al.*, 2016, Wilson and Forsyth, 2018).

*Mangroves:* Mangrove forests are most vulnerable the impacts of effects of sea-level rise and extreme weather anticipated under future climate projections (McLeon and Salm, 2006). Beyond protecting the remaining healthy mangrove habitats, mangrove restoration can help to offset some anticipated climate change impacts on this type of habitat. Mangrove restoration can include (1) restoring hydrological function, flow, and sediment supply to existing but degraded mangrove habitats through excavation or backfilling and (2) planting seedlings as part of reforestation initiatives. There are numerous examples of successfully community-based mangrove restoration initiatives across tropical nations (McLeon and Salm, 2006).

*Seagrasses:* With regards to climate change, seagrasses are most vulnerable to increasing temperatures, which can cause extensive diebacks, and extreme weather, during which storms can uproot large areas of seagrass habitat. Moreover, these effects can be greatly exacerbated by poor water quality due to untreated sewerage discharge, land use practices, runoff and sedimentation (Björk *et al.*, 2008). In many cases, improving water quality is sufficient to encourage regrowth and expansion of damaged seagrass beds, and such measures can also be supplemented by seeding or transplantation of seedling or mature plants from donor beds. However, seagrass replanting projects are recognized as being labour intensive and having highly variable rates of success and may not be as cost-effective as improving water quality, which would have spin-off benefits for other coastal habitats (Björk *et al.,* 2008).

*Corals*: As with seagrasses, corals are most vulnerable to increasing temperature and ocean acidification anticipated with climate change, and these impacts can be exacerbated by poor water quality due to land use practices. Where water quality issues have been successfully addressed, artificial propagation of corals is one way some countries have sought to stem habitat loss due to coral bleaching and disease, and has been considered a cost-effective alternative to engineering-based approaches to coral reef restoration such as the installation of artificial reefs (Lirman and Schopmeyer, 2016). This ‘coral gardening’ approach is already being used for basic habitat restoration in many places; one study, published in 2012, documented over 60 individual coral gardening projects in Caribbean countries (Young *et al.*, 2012). This general habitat restoration strategy can be adapted to achieve more climate-resilient outcomes through assisted selection. In this scheme, fragments collected from local coral communities are propagated in aquaria under higher temperatures and/or lower pH to identify the most tolerant strains. These strains are then selected for propagation and outplanting to priority coral reef restoration sites. Adding an artificial selection component to existing or new coral gardening initiatives can help to make these types of projects more resilient to future climates (van Oppen *et al*., 2015; Morikawa and Palumbo, 2019). However, it is also important to bear in mind the potential drawbacks and unintended consequences that might arise in any strategy involving ‘assisted evolution’ (Filbee-Dexter and Smajdor, 2019).

***Objectives Met***: Adaptation to a changing physical environment. Adaptation to losses of productive fish habitats.

***Information Needs & Monitoring Connections***: Implementation of this restoration action should begin with site selection and prioritization assessments. These assessments will rely on information about past and present habitat distribution and conditions to identify and prioritize sites where environmental quality is sufficient to ensure the success of restored habitats. Practical guidelines on site selection criteria and other aspects of restoration vary by habitat and are available for mangroves (McLeon and Salm, 2006), seagrasses (Björk *et al*., 2008), and coral reefs (Grimsditch and Salm, 2006, Lirman and Schopmeyer, 2016, Frias-Torres *et al.*, 2018).

Following implementation, the condition of restored communities should be monitored over time using, for example, standard reef health protocols measuring indicators such as coral cover, growth rates, physical damage, disease, and associated fish community diversity and abundance. Long-term field monitoring data from these ‘tolerant’ reefs and other habitats can then be compared to data from outplanted reefs that did not use assisted selection and to natural reefs as controls to measure the benefits of assisted selection. More recent studies have also recommended monitoring indicators to assess the socio-economic benefits of coastal habitat restoration programs, including enhancing conservation awareness, local stewardship and livelihood opportunities (Hein *et al.* 2017).

***Considerations for Implementation***: Straightforward and ‘low-tech’ coastal habitat restoration activities can be labour-intensive but achievable at small scales. The most accessible and inexpensive form of restoration will be mangrove restoration through planting in shallow coastal habitats easily reached on foot or by small vessels (Bayraktarov *et al.,* 2016). More challenging and costly forms of coastal restoration will include propagation and outplanting of deeper seagrasses and corals. Restoration in underwater areas will require access to equipment and expertise for SCUBA diving to access restoration sites which is not readily available in all communities. Notably, restoration of terrestrial vegetation first can help to improve outcomes for marine-based habitat restoration later on (Hernández-Delgado *et al*., 2014, Bayraktarov *et al*., 2016).

Implementing an assisted coral selection and outplanting strategy at scales expected to yield significant benefits will require more substantial resources, personnel, and existing or acquired expertise in artificial coral propagation. Artificial propagation and assisted selection could potentially be carried out at a suitable central location (e.g., laboratories at the fisheries agency or a local university), and the resulting coral fragments distributed out to local community groups for further propagation and outplanting (van Oppen *et al.,* 2015). This type of community-based coral gardening has been successfully implemented in Jamaica as part of the C-FISH project, and can help to provide alternative employment and facilitate local ownership of solutions (C-FISH 2016).

Some of the costs of habitat restoration can be significantly offset using volunteer and/or community-based approaches (Hernández-Delgado *et al.*, 2014, Bayraktarov *et al.,* 2016), and there are also opportunities to finance restoration of coastal vegetation through blue carbon project financing initiatives (Hejnowics *et al.*, 2015).

* + 1. Managed Realignment of Coastal Vegetation

***Rationale***: Mangrove forests and seagrass beds provide important habitat for economically-valuable fisheries species. Future sea-level rise may increase the likelihood of flooding in low-lying land, which creates opportunities for landward migration of coastal vegetation. In many areas, this natural landward migration will be prevented by coastal land use and infrastructure, but there is increasing interest in undertaking ‘managed realignment’ where landward migration is guided in a controlled way. This strategy is a useful alternative to more costly installation, fortification, or maintenance of artificial coastal defenses such as seawalls (Spalding *et al.,* 2014). Promoting managed realignment during landward migration of mangroves and other coastal vegetation will help to maintain access to important spawning and rearing habitats for many economically important species (Bell *et al*., 2018). This strategy will also provide “blue carbon” sequestration services (Duarte *et al.,* 2013, Serrano *et al*., 2019) and increase the resilience of coastal lands to uncontrolled flooding and erosion during storms (Chang, 2006; Spalding *et al,.* 2014), because mangroves stabilize coastal sediments. The benefits of mangrove forests are enhanced when seagrasses and fringing corals are also present, pointing to the value of an integrated coastal zone management strategy (Guannel *et al.*, 2016).

This adaptation strategy has been described as a lose-win scenario (Bell *et al*., 2018a), because benefits will primarily accrue in the future as precipitation increases, and sea levels continue to rise, and flooding becomes more frequent.

***Objectives Met***: Adaptation to losses of productive fish habitats.

***Information Needs & Monitoring Connections***: Site selection for managed realignment would be identified from both historical and current flood maps and vegetation habitat maps developed using field surveys and/or remote sensing data. Schill *et al.* (2014, pp. 16-18) illustrate a simple approach to identifying potential sites for implementation based on existing mangroves and land characteristics. Progress towards project objectives could be monitored by tracking the establishment of new habitat locations, the increase in total habitat, and public use of new habitats through, for example, adoption as new fishing areas.

***Considerations for Implementation***: Areas of intact coastline with a high likelihood of coastal flooding should be earmarked for protection from future development. Where coastal infrastructure currently blocks the influx of water, channels, bridges, and other bypasses should be planned or modified to allow for more controlled coastal flooding that will allow landward migration of mangroves and seagrasses. These actions may require substantial capital works and higher costs, which can potentially be offset through regional or international adaptation funding programs. As with more general forms of habitat restoration, successful implementation of managed realignment will depend on political will and community support in the face of potential restructuring of existing infrastructure and restrictions on coastal land development that may be perceived as disruptive to local communities and businesses.

## Harvest Management Actions

***Overview***: Climate change is expected to influence both the productivity and the distribution of many Caribbean fish species. Decreases in productivity will require actions to avoid excessive fishing pressure on stocks with reduced capacity to sustain levels of harvest that may have been sustainable in the past. Shifts in distribution may reduce fishing opportunities in some regions but create new opportunities in other regions. Adaptation to these changes will require actions that influence the amount, composition, and distribution of harvests. Reef-dependent fishes and benthic invertebrates are, in general, expected to be more vulnerable than pelagic species due to greater cumulative stressors from land-based activities. As a result, some harvest-based adaptation strategies include shifting fishing efforts toward pelagic species. Because climate change impacts on fisheries are expected to occur at broad spatial scales, there will also be a need to coordinate some adaptation strategies across affected nations. All these actions fall within the scope of existing fisheries management frameworks, and there is increasing recognition that improving regional capacity, rigor, and effectiveness in fisheries management will go a long way towards offsetting many of the anticipated negative effects of climate change on fisheries (Gaines *et al.,* 2018, Gourlie *et al.*, 2018). However, it should also be noted that the simplest fishing regulations will also be the easiest to effectively enforce, and so fisheries managers should strive for adequate enforcement of existing regulations before adding new regulatory requirements.

### 1.2.1 Use Regulations to Protect Vulnerable Fish Populations

***Rationale***: A changing climate brings a new set of stressors to fish populations already under pressure from coastal pollution, habitat loss, and fishing. One way to help mitigate the effects of climate change is to reduce other stressors, including fishing pressure where populations are presently fully or over-exploited. To some degree, changes in everyday fisheries management can help to offset the declines in productivity caused by a changing climate, while allowing some fishing to continue. In particular, managing fishery harvest in ways that maintain diversity within a fish population can improve the resilience of these populations to climate change. Diversity can result from a greater range of ages or sizes of fish in the population, more genetic variation (sub-populations), and abundance across a wide spatial range. Harvest regulations such as size limits, catch limits, seasonal and spatial closures, and restrictions on types of gear to be used, are all tools that can be used to maintain or increase diversity of exploited fish populations. Importantly, the potential benefits of harvest regulations strongly depend on effective enforcement.

***Objectives Met***: Adaptation to declines in growth and productivity of harvested species, and to changes in the distribution of fishing effort.

***Information Needs & Monitoring Connections***: General indicators of population status including abundance, age/length composition, and spatial distribution of species of concern can be used to determine the need for regulation changes and indicators of fishing effort can subsequently indicate whether adequate protection has been provided.

***Considerations for Implementation***: Successful implementation will depend on four key factors:

1. availability of assessment data to inform decision makers of the need for regulations for different fisheries;
2. ability to evaluate which regulatory changes are most likely to produce the desired outcomes (e.g., through conceptual models, simulations, or comparisons with other jurisdictions);
3. adequate consultation with fishing communities to ensure that the measures are understood and broadly supported;
4. sufficient capacity to enforce the prescribed regulations, either by governments or using self-policing fishers cooperatives or other community-based organizations.

Bell *et al*. (2018a) offer a broad list of suggestions for implementation of regulatory strategies at both the community and national level, and Melnychuk *et al.* (2014) discuss the merits of flexibility in the timing of season openings and closings to better adapt to uncertainty about future climate.

1.2.2 Adjust Assessments and Harvest Control Rules to Account for Climate Vulnerability

***Rationale***: Climate change will affect the growth, distribution, survival rates, and vulnerability to capture of numerous exploited fish species in ways that influence the level of harvest that can be sustainably removed from exploited populations. For managed species where suitable harvest levels are determined by stock assessments and the application of a harvest control rule, these management procedures should be revised to account for the forecasted effects of future changes to climate on population dynamics and fishery operations. Some species are expected to experience altered growth and mortality patterns in the future, as indicated by analyses presented in an earlier phase of this project. Ecosystem effects of climate change may also change the operational characteristics of fisheries (e.g., catchability, size/age-specific vulnerability), which influence interpretation of assessment data and consequently the specification of a sustainable harvest rule. There is evidence that some types of harvest control rules (i.e., where mortality rates vary with assessed stock biomass or environmental conditions) are more resilient to climate change effects on productivity than rules that are more rigid (i.e., where mortality rates are fixed at some reference point) (Kritzer *et al.*, 2019).

***Objectives Met***: Adaptation to declines in growth and productivity of harvested species, and to changes in the distribution of fishing effort.

***Information Needs & Monitoring Connections***: Some form of stock assessment, including credible estimates of stock biomass and fishing rates, is essential for application of a harvest control rule. This level of monitoring information is only likely to be available for the most valuable fisheries in countries with relatively high assessment capacity (e.g., conch and lobster).

***Considerations for Implementation***: This adaptation strategy is only relevant to relatively well-developed, intensive fisheries for which harvest control rules are used to guide management. For these fisheries, modeling should be used to evaluate the performance of alternative policies in the face of uncertainty about future fishery characteristics under future climate scenarios (e.g., by accounting for relative changes in growth and survival rates across species as in Kritzer *et al.,* 2019). Once a robust strategy has been identified using simulation, or experience from other, similar fisheries, implementation will depend on maintenance of an informative assessment program, and the ability to enforce changes to the harvest policy.

1.2.3 Diversify Catches to Relieve Pressure on Vulnerable Populations

***Rationale***: Vulnerability to climate change varies widely across fisheries species. Reducing fishing pressure on those species projected to be “first and worst” affected by climate impacts will help to mitigate the climate impacts on these fish populations. However, more restrictive regulations intended to protect vulnerable species (see above) will not mitigate the impacts on the fishers that depend on these species. Another strategy is to encourage the diversification of harvests to include greater use of less vulnerable species that should be able to sustain higher exploitation rates, and less use of more vulnerable species (Bell *et al,*. 2018). Having a diverse portfolio of fishing opportunities (species, habitats) improves outcomes for fishers during times of change (e.g., Cline *et al.,* 2017, Young *et al.,* 2018).

One prominent example of this strategy is encouraging a shift in fishing effort from reef-dependent species to offshore pelagic species through the use of fish aggregating devices (FADs), which help to concentrate pelagic species in a small area and improve harvest efficiency. This has been described as a ‘win-win’ strategy because it increases access to fish in the near term, and sets the stage for communities to continue to fill a gap in access to nearshore coastal resources as coral reefs and the inshore stocks they support continue to degrade (Bell *et al*., 2018a). FAD fishing programs have been successfully implemented as part of broader climate change adaptation initiatives for fisheries in several Pacific Island Countries and Territories (Bell *et al*., 2018 a, b), and has also been implemented in several Caribbean states including Guadeloupe, Martinique, Dominica (Mathieu *et al*., 2014) and Haiti (Valles, 2014). In this case, diversifying catches may also help to diversify livelihoods as many pelagic fish may also be targeted through guided recreational fishing as part of the tourism sector (C-FISH 2016, diversification of livelihoods discussed further later in this chapter).

***Objectives Met***: Adaptation to declines in growth and productivity of harvested species and to changes in the distribution of fishing effort

***Information Needs & Monitoring Connections***: Decisions about where fisheries effort should be reduced or increased require an understanding of both the current status of fished species and their anticipated vulnerability to climate change under future climate projections. Information on current status can be obtained through general fisheries monitoring programs which collect data on age/length composition, spatial distribution, and indices of abundance. Information on future vulnerability of each species under climate change can be obtained from model forecasts from the vulnerability and impact assessment phase of this project. These sources of information can help managers to craft harvest diversification strategies that reduce pressure on more vulnerable species and shift effort towards species whose populations are currently considered robust and are expected to remain so under future climates.

As harvest diversification strategies are implemented, monitoring data on catch composition and fishing effort will help to track the effectiveness of these interventions for diverting harvest away from more vulnerable species and habitats.

***Considerations for Implementation***: Strategies for diversifying harvests are very flexible and can be adapted in their scope and scale to fit within the capacity constraints of implementing agencies.

Implementation of these interventions typically requires incentives to change existing fishing practices, which might include training in new fishing methods, exchange programs or subsidies to support acquisition of different fishing gear, or subsidies for fuel to offset increased travel time to offshore fishing grounds (Bell *et al.,* 2018b). Research on past initiatives suggests that without incentives, changes to fishing practices may be less than hoped for (Matthieu *et al*., 2014).

However, encouragement of new fishing methods and areas must be carried out with careful consideration for unintended consequences. For example, studies in Guadeloupe, Martinique, and Dominica have shown that the anticipated benefits of FAD initiatives are constrained by competition for limited number of FADs, increased market saturation for pelagic fish, greater variability in fishing success due to seasonal migrations of pelagic species and loss of FADs in strong seasonal currents, and increased fuel prices, which led many fishers returning to the harvest of benthic species (Mathieu *et al*., 2013). The authors of these studies concluded that FAD initiatives alone are not sufficient to reduce pressure on inshore resources without simultaneous implementation of regulations to directly reduce inshore fishing effort.

1.2.4 Precautionary Management of Emerging Fisheries

***Rationale***: Shifts in the distributions of some marine species may result in the development of new fisheries opportunities around species or locations not historically targeted. In light of likely declines in other fishing opportunities, there may be a risk of excessive exploitation of these new populations before they are successfully established in an opportunistic ‘race to fish’ where alternative opportunities are limited. Fisheries managers can use information on the projected distributions of species under future climates to proactively identify and plan for likely emerging fisheries (Karp *et al.,* 2019). A precautionary approach has been recommended for these emerging fisheries to allow the population to increase to levels where long-term sustainable harvest is possible. A temporary moratorium on emerging fisheries may be the most effective option, potentially followed by an experimental fishery to assess population abundance and appropriate harvest levels (Pinsky *et al*., 2014). Although not related to climate change, this approach has been implemented for the emerging sea cucumber fishery in Jamaica which developed rapidly in response to new export market opportunities in Asia. Following an initial period of opportunistic fishing, the fishery was closed for assessment, followed by issuance of experimental fishing permits associated with strict monitoring requirements to explore sustainability of the fishery (per A. Murray, Jamaica Fisheries Division). This model could be repeated over time as new fishing opportunities may arise due to shifting species distributions under a future climate, and can help to protect the establishment of stocks that could be important in the future.

***Objectives met***: Adaptation to shifts in species distributions

***Information Needs & Monitoring Connections***: Fisheries-independent monitoring of species occurrence and fisheries-dependent monitoring of catch composition will be essential to detecting new species as they begin to establish populations and will also help to validate climate projections of species range shifts produces in earlier phases of this project.

***Considerations for Implementation***: Catch data should be regularly assessed for evidence of new species in the harvests or trends in the relative abundance of previously-rare species in the harvests. When this occurs, a rapid early response in the forms of moratoriums or other fishing restrictions on these species will be critical to minimizing the negative effects of precautionary management (i.e., investment in gear that is subsequently subject to restrictions) until safe levels of exploitation can be determined. At the same time, outreach efforts to inform fishers of emerging new opportunities and training in suitable harvesting techniques will help to manage expectations and sustainably capitalize on opportunities as they arise.

1.2.5 Adjust Management Areas to Reflect Changes in Species Distributions

***Rationale***: The benefits of some marine protected areas (including no-take and limited-take areas) for their intended conservation purpose may be expected to decline over time due to species range shifts under future climate scenarios (e.g., Davies *et al.,* 2016; Woodson *et al*., 2019). As the impacts of climate change at local scales become more apparent through long-term monitoring, some boundaries may need to be re-evaluated and moved, or there may be a need to transition to a more flexible spatial management framework, to maintain conservation benefits under future climate scenarios. When establishing new management areas, or refining zones within existing management areas, it will be important to explicitly address climate resilience as part of the decision-making process (e.g., Keller *et al*., 2009, Davies *et al*., 2016). Establishment of effective management area networks high a high degree of connectivity across broader regions can help to mitigate against localized climate change effects.

***Objectives Met***: Adaptation to shifts in species distributions

***Information Needs & Monitoring Connections***: Local-scale assessment of habitat conditions, species distributions, and how they change over time will inform the need for changes in management area boundaries, particularly when examined in the context of knowledge about habitats that are resilient to climate change (see 2.1.1 above).

***Considerations for Implementation***: Improving the climate resilience of management area networks requires spatial analysis to examine overlaps between area boundaries, the distribution of species and habitats of conservation concern, and indicators of future climate change resilience. In their simplest form, these types of analyses have used general indicators of reef resilience (e.g., depth, structural complexity, coral cover) as proxies for climate resilience (e.g., Davies *et al.,* 2016). In the case of the Caribbean, existing management area boundaries can instead be overlaid with high-resolution projections of species range shifts under future climate scenarios produced earlier in this project for a more direct assessment of anticipated conservation effectiveness in light of climate change. These types of information can be used as inputs to spatial conservation decision-support software like MARXAN to produce data-driven recommendations for refining protected area network boundaries to optimize their effectiveness under future climate scenarios (Davies *et al.,* 2016; also see Chapter G). In considering the role of climate change considerations in protected area planning, a review of case studies from multiple geographic regions concluded that strictly protected reserves are the best option for climate resilience when faced with an uncertain future, and provide added value as scientific reference sites for studying climate change effects in the absence of other stressors (Hopkins *et al*., 2016). As noted earlier in this section, successful implementation of this strategy relies entirely on sufficient capacity and commitment to strong enforcement of protected areas.

**1.3 Sustainable Livelihoods and Economic Diversification Actions**

***Overview***: Many of the anticipated impacts of climate change on marine habitats, fish and shellfish populations, and the fisheries that rely upon them will have significant social and economic repercussions for harvesters, fishing communities and national and reginal economies (Bell *et al*., 2018). In addition, many of the conservation-oriented adaptation strategies being proposed for the fisheries sector, such as increased fisheries regulation, come with their own challenges that may in some cases cause further hardships to fishing communities unless they are mitigated through complementary socio-economic adaptation strategies (Shaffril *et al.,* 2017; Savo, 2017, Cinner *et al*., 2018). Socio-economic adaptation strategies for the fisheries sector fall into five broad areas (Cinner *et al.,* 2018):

1. Protecting existing assets and providing new assets to draw on in times of need
2. Increasing flexibility to change livelihood strategies
3. Supporting community organization and collective action
4. Supporting learning and information-exchange to inform decision-making
5. Empowering communities with agency through participatory decision-making

These types of adaptation strategies are explored further in the remainder of this section.

1.3.1 Protect Existing Assets Against Climate-Related Impacts

***Rationale***: Sea-level rise as well as an increasing frequency and severity of extreme weather anticipated under a future are expected to have significant impacts on coastal infrastructure important to the fisheries sector by causing damage and loss of physical assets. Many existing assets within the fisheries sector are vulnerable to physical damage due to sea level rise and extreme weather, including fishing gear, vessels, piers, processing facilities and markets, as well as transportation infrastructure. Adaptation strategies to better protect these assets include:

* enhancing natural coastal defenses including mangroves, seagrasses, and coral reefs through restoration and the creation of green belts and buffer zones (Spalding *et al*., 2014, Guannel *et al.,* 2016, described previously in this chapter),
* managing realignment to guide redistribution of the shoreline around critical resources (Duarte *et al*., 2013, Spalding *et al*., 2014, described previously in this chapter),
* implementing coastal development setbacks to prohibit infrastructure development in high-risk coastal areas (Mycoo and Chadwick, 2012; Mycoo, 2018),
* maintaining, reinforcing, or building soft or hard coastal defenses including groynes, seawalls, revetments, and emergent or submerged breakwaters, to ‘hold the line’ or ‘advance the line’ of coastal protection (Mycoo and Chadwick, 2012; Mycoo 2018), and
* investing in the development of safe harbours and anchorages, vessel haul-out and storage facilities, as well as adopting the use of bumper rails and fenders at piers to reduce weather-related damage and loss of fishing vessels and help to lower marine insurance premiums (Tietze and van Anrooy, 2018).

***Objectives Met***: Adaptation to a changing physical environment

***Information Needs & Monitoring Connections***: Setting priorities for asset hardening requires an understanding of vulnerability and risk. This can be accomplished by first mapping land use vulnerability, incorporating data from historical maps, land use maps, asset distribution maps, remote sensing and aerial photography, shoreline erosion rates, and damage assessments from past storms. This information can then be used to carry out a broader climate change vulnerability assessment of specific land uses, sites, and development plans that can be used to select and prioritize among the above adaptation strategies (Elsharouny, 2016). Governments undertake post-disaster damage and loss assessments, which reveal relative vulnerabilities to hazard events.

***Considerations for Implementation***: Strategies for protection of coastal infrastructure should ideally be implemented as part of a broader coastal zone management strategy, and are most effective when using several complementary approaches (Mycoo and Chadwick, 2012).

Natural coastal defenses are preferred for their additional benefits in providing supporting habitat for important fisheries species. While managed realignment is also an attractive nature-based solution, a high degree of coastal development and property investments coupled with limited landmass for relocation across many Caribbean island states is likely to lead to strong economic and political resistance to this strategy (Mycoo and Chadwick, 2012).

Artificial coastal defenses may be necessary in some circumstances, but care should be taken to consider their higher initial and long-term costs as well as their impact on natural ecosystems. Depending on their location, hard shoreline defenses can contribute to coastal squeeze during landwards migration of mangroves, seagrasses, and sandy beaches (Mycoo and Chadwick, 2012, Elsharouny, 2016).

A range of guiding documents and protocols are available to enable accounting for climate change risk in the design of individual physical assets (e.g., Scott *et al*., 2013).

1.3.2 Improve Safety at Sea

***Rationale***: Climate change is expected to increase the frequency and severity of poor weather conditions at sea, including extreme weather events, with significant implications for both catches and the safety of fisherfolk while at sea. These increasing risks are expected to be further multiplied as more fishers travel farther from the coast to pursue pelagic fish species in an effort to diversify their catch in the face of shifting fish populations (ILO, 2014; Monnereau and Oxenford, 2017). Adaptation measures to reduce this risk include:

* Inspections to verify maintenance records and assess seaworthiness of vessels, which may also be set as a condition of licensing or obtaining insurance (Tietze and van Anrooy, 2018).
* Training in vessel maintenance and the implementation of safety-at-sea practices, protocols, and equipment to prepare for maritime emergencies (Monnereau and Oxenford, 2017). These types of training sessions are already offered by fisheries authorities in many Caribbean nations, and many others have been provided across the region by various international and non-governmental organizations (Monnereau and Oxenford, 2017; Tietze and van Anrooy, 2018).
* Purchase and use of dedicated safety equipment including VHF radios, navigation lights, compass and charts or navigational global positioning systems (GPS), vessel monitoring systems (VMS), rain gear, life vests, flares, and fire extinguishers to use during emergencies (Monnereau and Oxenford, 2017; C-FISH, 2016; Tietze and van Anrooy, 2018). Among these, VHF radios are particularly important to reduce the current reliance of many fisherfolk on mobile phones, which cease to be an effective mode of emergency communication once more than a few miles from shore (Tietze and van Anrooy, 2018).
* Implementation of early warning systems to alert fishers of maritime emergencies in time to take countermeasures (e.g., not going out to sea, securing vessels and gear). The Fisheries Early Warning and Emergency Response (FEWER) mobile app is just such an early warning system that has recently been launched in the Caribbean as a deliverable under the Investment Plan for the Caribbean Regional Track of the Pilot Program for Climate Resilience (PPCR) (CRFM, 2018). This app includes modules to record and report current weather conditions, receive emergency alerts, contact emergency services, and report damages and missing persons following emergencies. The app streamlines safety at sea information and services into a single channel that is expected to improve fisher use of these services to prepare for and respond to emergencies at sea.

***Objectives Met***: Adaptation to a changing physical environment

***Information Needs & Monitoring Connections***: TBC

***Considerations for Implementation***: Where resources are limiting, training is the least resource-intensive adaptation option to improve safety at sea. General safety-at-sea training has been implemented as part of a number of adaptation projects throughout the Caribbean, particularly those promoting shifting effort to offshore fisheries (e.g., C-FISH, 2016). More specialized training in the proper use of early warning systems is also desirable and was recently undertaken as part of the launch of the FEWER early warning app (CRFM, 2018). Trainings should be offered regularly to account for limited capacity, turnover in the fishing fleet, and forgetting what was learned over time. Some of the techniques and protocols taught in these types of trainings will require specific supplies, and additional funding can be invested in the purchase and distribution of safety equipment across the fishing fleet, either through fisheries cooperatives or to individuals. However, donations of physical assets must be considered carefully and accompanied by follow-up incentives, monitoring, training, or reporting requirements to ensure they are being used as intended. For example, it has been proposed that safety-at-sea training and equipment be a requirement for obtaining insurance on fishing vessels (Tietze and van Anrooy, 2018).

1.3.3 Facilitate Access to New Assets in Times of Need

***Rationale***: As climate change progresses, the fishing sector will require access to new assets to help them adapt to gradual changes in sector operations as well, help them recover from acute losses following extreme weather events, and help them undertake broader community-scale adaptation projects.

Broadening access to credit is an extremely important financial measure for helping fishers acquire new fishing gear and vessels to adapt to new fishing opportunities and can also be helpful for replacing lost assets (Shaffril et al. 2017). However, many fishermen have difficulties accessing credit through formal institutional arrangements due to barriers including illiteracy, high bureaucratic burden, lack of adequate collateral, inability to arrange a co-signer, inflexible repayment schedules, and fear of losing assets. As a result, fishermen may prefer to resort to informal credit arrangements through family and social networks to enable adaptation until formal credit becomes more accessible and flexible to meet the needs of the small-scale fisheries sector (Haque et al., 2015). Because access to some fishing opportunities may increase travel distances and fuel consumption, duty-free concessions on more fuel-efficient engines and fuel subsidies from governments and/or fisheries associations can also help to offset the costs of travelling farther to fish (CANARI, 2015, Young *et al.,* 2018). While subsidies can be a useful tool, they should involve very clear goals, transparent implementation, and regular monitoring to prevent unintended consequences including maladaptation, dependence, and overcapacity which can lead to overexploitation of fisheries stocks (Khan *et al.,* 2006, Bell *et al.,* 2018a).

Access to affordable insurance and social assistance programs is most important for replacing vessels, equipment, and income lost following extreme weather events which may prevent fish harvesters, processors, or sellers from earning income (Shaffril *et al*., 2017, Tietze and van Anrooy, 2018). However, much of the Caribbean’s small-scale fisheries sector has limited or no access to affordable insurance (Monnereau and Oxenford, 2017). A recent review of insurance needs in the wider Caribbean fisheries sector found that 97% of fishing vessels and assets were not insured despite the availability of marine insurance and that less than 20% of fishers had health or life insurance policies, where the primary reason given by fishers for not obtaining insurance was because they could not afford it (Tietze and van Anrooy, 2018). What might be considered affordable varies across Caribbean nations, but was reported as being an average of 2.6% of total insurable asset value among fisherfolk surveyed (Tietze and van Anrooy, 2018).

At broader scales, regional and national adaptation funds (e.g., the Community Disaster Risk Reduction Fund of the Caribbean Development Bank) can help communities to implement larger-scale adaptation projects, such as purchasing freezers to store fish, funding the installation and maintenance of FADs, or implementing coral reef restoration programs (Shaffril et al., 2017). Several important multilateral funds in this class were established under the United Nations Framework Convention on Climate Change (UNFCCC) regime to support adaptation projects and include the Least Developed Countries Fund (LDCF), the Special Climate Change Fund (SCCF), the Adaptation Fund (AF), and the Green Climate Fund (GCF). A retrospective analysis of awards from these funds shows they have been used to finance several adaptation projects in the fisheries sector, including some in the Caribbean, making up roughly 6% of all adaptation projects funded. The types of projects funded have included modification of laws or policies, assessing projected climate change impacts on fisheries, operationalizing fisheries monitoring systems, reducing ecosystem and fishing-related stressors on fish stocks, and improving fishing communities’ resilience in terms of food security and livelihoods (Guggisberg, 2018). However, these funds do not currently provide a harmonized and searchable marker dedicated to fisheries-related adaptation. This can make it harder for nations to know these funds can be used for fisheries-related adaptation projects and more difficult for organizations to track regional progress towards climate change adaptation in the fisheries sector (Guggisberg, 2018).

In the absence of these financial support systems, an inability to cope with the increasing costs of implementing adaptation measures may force some individuals and businesses to close and some fisherfolk to migrate and/or seek employment in other sectors (ILO 2014).

***Objectives Met***: Adaptation to a changing physical environment and adaptation to variations in fishery production

***Information Needs & Monitoring Connections***: TBC

***Considerations for Implementation***: Improving fisherfolk access to assets for facilitating adaptation in times of need will require (1) reforms to application processes that account for the constraints of fisherfolk who may have few physical assets and little formal education as well as (2) financial support from regional and/or multilateral agencies to help make these reforms financially viable for credit and insurance service providers.

Barriers to obtaining credit could be reduced by streamlining application processes for the fisheries sector to provide simplified forms and application assistance for applicants who may not be literate, relaxing requirements for collateral and co-signers, and more flexible repayment schedules that account for the irregularity and uncertainty in fish catches inherent to this sector and more likely to increase under future climate projections (Haque et al., 2015).

Barriers to obtaining insurance have already been reduced to some extent by the launch of the Caribbean Catastrophe Fisheries Risk Insurance Facility (CCRIF), which supports locally-based marine insurance companies to help offset the costs of settling many simultaneous claims following extreme weather events in exchange for making policies more accessible to those working in the fisheries sector (Tietze and van Anrooy, 2018, [www.ccrif.org](http://www.ccrif.org)). This institution’s Caribbean Oceans and Aquaculture Sustainability FaciliTy (COAST) fisheries parametric insurance policies provide coverage for fisherfolk and other players in the fisheries industry to enable them to recover quickly after weather-related events. CCRIF also offers a complementary Livelihood Protection Policy, a type of micro-insurance policy that provides rapid financial support to vulnerable people whose livelihoods are interrupted by extreme weather events. Increasing participation in these insurance programs should be a priority of climate change adaptation initiatives for fishing communities. As one example for incentive, it has been proposed that obtaining insurance could become a requirement for obtaining vessel registrations, and could also carry obligations to engage in climate-smart behavior including proper vessel maintenance and use of safety equipment (Tietze and van Anrooy, 2018).

1.3.4 Enhance Post-Harvest Handling, Processing, and Marketing

***Rationale***: Even where adaptation measures are successful in maintaining fish harvest, climate change has the potential to impact post-harvest processing and marketing in other ways. Enhancing post-harvest handling, processing, and marketing can help to preserve and extend the benefits of pre-harvest adaptation strategies. Enhancing post-harvest practices can help to significantly extend the shelf life of the catch and maintain market access to fish during interruptions in supply. This class of adaptation strategies includes measures such as (Bell *et al*., 2018a; CANARI, 2015; Dunstan *et al*., 2018; Tietze and van Anrooy, 2018):

* food safety training programs (e.g., HAACP),
* purchase of coolers, ice machines, and freezers to bank catches for future use,
* fortifying power infrastructure (e.g., solar power, wind power, generators) to offset the electricity costs of cold storage and protect against power loss that would lead to spoilage of catch, and
* training in traditional methods of food preservation (e.g., smoking, salting, and drying) that do not rely on a power supply.

These measures will help to stabilize the supply of fish, reduce the likelihood of food-borne disease or pathogens affecting fish consumers, and better meet food safety requirements for additional export markets (CANARI, 2015; Dunstan *et al*., 2018).

Where adaptations for maintaining the catch include diversifying catches, additional incentives may be needed to help promote the consumption of new types of fish not commonly consumed in the past. Subsidies for processors and markets may help to incentivize adoption of new, more sustainable fish species into the fish value chain (Bell *et al*., 2018a).

***Objectives met***: Adaptation to a changing physical environment, adaptation to variations in fishery production, enhanced post-harvest productivity

***Information Needs & Monitoring Connections***: TBC

***Considerations for Implementation***: Where resources are limited, training in food safety and traditional methods of preservation may be the most accessible adaptation strategy within this class. Where more resources are available, improving ice production and cold storage infrastructure can be one of the most effective ways to prolong the shelf life of fish catches and stabilize market availability during interruptions in supply. However, these types of infrastructure improvements should proceed only after careful feasibility studies to ensure their long-term viability. Many infrastructure projects built using funds from short-term development projects are likely to fail if they do not adequately account for operating costs (e.g., electric bills) and long-term maintenance needs (e.g., local availability of parts and expertise for repair in case of breakdowns). These types of projects are more likely to be successful where they are implemented in partnership with a local organization (e.g., fishing cooperative, fish market, fisheries authorities) which can oversee long-term maintenance and funding for continued operations.

1.3.5 Diversify Livelihoods

***Rationale***: Dependence on fisheries and extraction of marine resources is highly relevant to climate change adaptation, as the more dependent fisherfolk households and fishing communities are on fisheries, the harder it will be to bounce back from severe disturbances in production. Diversification within and across economic sectors is a common strategy to improve the adaptive capacity of fisherfolk across the fish value chain (ILO, 2014; Savo *et al*.; 2017; Cinner *et al*., 2018). Diversification within the sector includes diversification of fishing methods, catch, post-harvest processing and marketing as already discussed in prior sections. Diversification across sectors may include engaging in alternative or supplementary economic activities to reduce dependence on fisheries, such as expanding participation in marine tourism, aquaculture, agriculture, or other market opportunities, such as seamoss farming (ILO, 2014; CANARI, 2015). Diversification will not only help communities be more resilient to climate change impacts on fisheries, but it will also reduce the likelihood of vulnerable community members pursuing unsustainable practices to support themselves (e.g., illegal fishing, see Ahmed *et al.*, 2019).

***Objectives Met***: Adaptation to a changing physical environment, adaptation to variations in fishery production

***Information Needs & Monitoring Connections***: Livelihood diversification strategies can be more successful by first conducting surveys to assess interest in a range of alternative livelihoods among those employed in the fisheries sector. Monitoring the types and extent of diversification activities by target communities, as well as perceived barriers, can inform programmatic adjustments. Independent evaluation of the effectiveness and impact of programs and initiatives to support livelihood diversification is also critical and should seek to uncover impact differentiated by sex and social groups that may be underserved in the absence of special accommodations.

***Considerations for Implementation***: Diversification of livelihood activities can be extremely challenging and often fail for financial, social, cultural, and environmental reasons. In recognition of these challenges, many practitioners have published lessons learned and best practices for implementation of livelihood diversification initiatives in small-scale fisheries households and communities that are summarized briefly here (Gillett *et al*., 2008; APFIC, 2010).

Those currently employed in the fisheries sector will need significant support to facilitate the transition to an alternative livelihood, including financial assistance, skills development training (including business skills), and mentorship. Without these supports, many in the sector will not be able to make a successful transition to alternative livelihoods. Implementing complementary adaptation strategies that improve access to credit and additional training can help to reduce these barriers (Bell et al., 2018a, Cinner *et al.,* 2018). Even where supports are available, fisherfolk may be reluctant to change occupations. Many fisherfolk ground their sense of self in their fishing occupation, location, and lifestyle that may make it challenging to transition into alternative employment, especially where the alternatives being offered are considered unattractive (Cinner *et al*., 2018). Alternative occupations that share similar skillsets with the fisheries sector (e.g., recreational fishing guide, boat tours, or engine mechanic) may be more attractive options for diversification.

Livelihood diversification often requires long timeframes to achieve profitability and cannot be effectively accomplished through a few short training sessions. Without adequate long-term mentorship and support to work through common start-up challenges, participants are more likely to return to their original occupations after support is withdrawn (Gillett *et al*., 2008). A review of past initiatives has suggested that fostering partnerships with existing businesses may be a more successful long-term strategy for livelihood diversification than encouraging fisherfolk to start new livelihood endeavors from scratch (Gillett *et al*., 2008).

Finally, livelihood diversification must be undertaken in parallel with other enabling reforms of management, governance, and policy frameworks to be most successful. For example, livelihood diversification should occur in parallel with management measures to prevent the continued degradation of the fisheries resource base to ensure that the ecological benefits of this strategy are fully realized (APFIC, 2010).