JNCC Report 748

Technical assistance programme for effective coastal-marine management in the Turks and Caicos Islands (DPLUS119)

WP2: Status assessments for marine/coastal habitats within TCI territorial waters – Sensitivity assessments

Appendix 3: Sensitivity Assessment for the Turks and Caicos Islands coral and algal reef habitats

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JNCC Report 748: Technical assistance programme for effective coastal-marine management in the Turks and Caicos Islands (DPLUS119). WP2: Status assessments for marine/coastal habitats within TCI territorial waters – Sensitivity assessments

Appendix 3. Sensitivity Assessment for the Turks and Caicos Islands coral and algal reef habitats

Supplementary Material to the report 'Status assessments for marine/coastal habitats within Turks and Caicos Islands territorial waters' (Savage *et al.* 2023). This report was prepared as part of the Darwin Plus 119 project 'Technical assistance programme for effective coastal-marine management in Turks and Caicos Islands'.

Habitat

Coral/Algae

Description (taken from The Nature Conservancy benthic class description)

Includes fringing, patch, and deeper bank/shelf reefs. General coral reef class for areas not within a reef crest formation. Coral/Algae can exist in depths up to 25 m, depending on water column clarity, with a median depth of 7 m. Presence of live coral colonies or structure that is extensive or patchy with or without a living coral veneer. Could also be coral rock (old *Acropora* sp. or *Orbicella* sp.) framework. Gorgonians, sponges, and sparse seagrass and/or algae dominate the substrate between coral colonies. In sections fringing the shore, eroded reef framework with fossils of reef organisms might be observed in shallowest, intertidal sections. A sparse mixed assemblage of crustose coralline algae, encrusting species of algae and coral and macroalgae may occur in deeper sections. Patch reef and fringing reefs are typically dominated by a variety of macroalgae such as *Dictyota* spp., *Lobophora* spp., *Chaetomorpha* spp. Hard and soft corals commonly found include *Acropora cervicornis*, *Montastrea cavernoa*, *Orbicella* spp., *Pseudodiploria strigosa* and *Diploria labrynthiformis* along with sea plumes and sea fans. The community group of secondary dominance is relatively evenly split by hard corals and sponges.

Scientific name changes

Pseudodiploria strigosa previously named *Diploria strigosa*.

Orbicella spp. is comprised of three species *O. annularis* (previously named *Montastrea annularis*), *O. faveolata*, *O. franksi*.

These changes in scientific name were accounted for during the literature searches which informed this assessment.

Sensitivity characteristics/features

The coral/algae assemblage is comprised of both coral and algal communities. This assessment focuses on the sensitivities of the hard corals identified in the biotope description, *Acropora cervicornis*, *Montastrea cavernoa*, *Orbicella* spp., *Pseudodiploria strigosa* and *Diploria labrynthiformis*. The algae have been excluded from this assessment due to their tendency to dominate the benthic environment if coral cover is reduced, and subsequently change the community to a macroalgal dominated one. Algae are also likely to respond differently to pressures due to their different morphology and life history.

Resistance, Resilience, Sensitivity and Confidence score criteria

Resistance

Resistance is scored according to the below criteria.

Resistance	Description
None (N)	Key functional, structural, characterizing species severely decline and/or the physico-chemical parameters are also affected (e.g. removal of habitats causing change in habitats type). A severe decline/reduction relates to the loss of 75% of the extent, density or abundance of the selected species or habitat component (e.g. loss of 75% substratum - where this can be sensibly applied).
Low (L)	Significant mortality of key and characterizing species with some effects on physico-chemical character of habitat. A significant decline/reduction relates to the loss of 25-75% of the extent, density, or abundance of the selected species or habitat component (e.g. loss of 25–75% of the substratum).
Medium (M)	Some mortality of species (can be significant where these are not keystone structural/ functional and characterizing species) without change to habitats relates to the loss.
High (H)	No significant effects to the physico-chemical character of habitat and no effect on population viability of key/characterizing species but may affect feeding, respiration, and reproduction rates.

Resilience

Resilience is scored according to the below criteria.

Resilience	Description
Very low (VL)	Negligible or prolonged recovery possible; at least 25 years to recover structure and function
Low (L)	Full recovery within 10–25 years
Medium (M)	Full recovery within 2–10 years
High (H)	Full recovery within 2 years

Sensitivity

Sensitivity is determined by a combination of the resistance and resilience score.

	Resistance			
Resilience	**None**	**Low**	**Medium**	**High**
Very low	High	High	Medium	Low
Low	High	High	Medium	Low
Medium	Medium	Medium	Medium	Low
High	Medium	Low	Low	Not sensitive

Confidence

The criteria for the three measures of confidence are displayed below.

Confidence level	Quality of evidence (QoE)	Applicability of evidence (AoE)	Degree of concordance (DoC)
High (H)	Based on peer reviewed papers (observational or experimental) or grey literature reports by established agencies on the feature (habitat, its component species, or species of interest).	Assessment based on the same pressures acting on the same type of feature (habitat, its component species, or species of interest) in the UK.	Agree on the direction and magnitude (of impact or recovery).
Medium (M)	Based on some peer reviewed papers but relies heavily on grey literature or expert judgement on feature (habitat, its component species, or species of interest) or similar features.	Assessment based on similar pressures on the feature (habitat, its component species, or species of interest) in other areas.	Agree on direction but not magnitude (of impact or recovery).
Low (L)	Based on expert judgement.	Assessment based on proxies for pressures (e.g. natural disturbance events).	Do not agree on direction or magnitude (of impact or recovery).

Recovery/resilience rates

The staghorn coral *Acropora cervicornis* is an extremely fast growing species with reported growth rates of 7.1–12.0 cm/yr in the Caribbean (Gladfelter *et al*. 1978; Smith 1988; Tunnicliffe 1981). This rapid growth combined with its ability to reproduce asexually by fragmentation (Tunnicliffe 1981) can lead to rapid growth of staghorn reefs. The massive corals *Montastrea cavernoa*, *Orbicella* spp., *Pseudodiploria strigosa* and *Diploria labrynthiformis* have much slower growth rates (0.32–1.1 cm/yr) (Smith 1988).

Orbicella annularis is one of the few massive Caribbean corals that can reproduce asexually (Highsmith 1982), however DNA evidence has shown that sexual reproduction is the predominant form of reproduction (Foster *et al.* 2007). This form of asexual reproduction by fragmentation is consistent with storm damage, which may allow it to recover from some forms of physical damage where live tissue is broken off.

Diploria labrynthiformis is a broadcast spawning simultaneous hermaphrodite. In Curacao this species was the first observed to spawn during six separate occasions, compared to the typical single event, with peak spawning during Spring and lesser spawning events in Summer and Autumn (Chamberland *et al*. 2017). *Diploria labrynthiformis* was observed to have a short planktonic phase followed by rapid settlement which suggests limited dispersal ability which is not usually seen in Caribbean broadcast spawning species. Minimum size for sexual maturity for this species is thought to be between 50–110 cm^2 (Weil & Vargas 2010).

Pseudodiploria strigosa is also a simultaneous hermaphrodite and broadcast spawner, however colonies around the Caribbean (Puerto Rico, Bermuda, and Panama) spawned in August and September (Weil & Vargas 2010). When gametes were exposed to higher temperatures (30, 31, 32°C/86.0, 87.8, 89.6°F) the rate of fertilisation was unaffected however the proportion of embryos with abnormal development increased (Bassim *et al.* 2002).

Montastrea cavernoa is a dioecious broadcast spawner which spawns during July, August, and/or September (Szmant 1991). The larval stage is expected to be able to settle after approximately 4 days with an estimated larval life expectancy of 15 days (Sturm *et al*. 2020).

Immediately after a disturbance event a new habitat might form dominated by fast growing *Acropora cervicornis, Porites porites*, and *P. furcate*. However, these species are weak competitors and would eventually be displaced by the slower growing massive corals, although it is not possible to estimate how long it would take for a reef to recover. Depending on the disturbance it could take at least 50 years, or the community might shift to a macroalgal dominated assemblage (Smith 1988).

Resilience Assessment

Where resistance is 'None' or 'Low' and there is significant mortality to the characterising species, resilience is assessed as 'Very Low' (greater than 25 years). This is based on the extremely slow growth rates for the massive coral species and the single spawning events for *Psuedodiploria strigosa* and *Montastra cavernoa* (Smith 1988; Szmant 1991; Weil & Vargas 2010). It is likely that after a disturbance event the habitat will change into an intermediary state where is it dominated by *Acropora cervicornis* or macroalgae. The massive corals are, however, strong competitors and would eventually outcompete *Acropora cervicornis* to return to the previous habitat, however this may take up to 50 years (Smith 1988). Very large (greater than 2 m) individual massive corals can take centuries to grow and if these are destroyed recovery will take a significant length of time.

Where resistance is 'Medium', resilience is assessed as 'Low'. Although slow growing, these species can recover from injury. Species such as *Acropora cervicornis* and *Orbicella annularis* have been observed to reproduce asexually by fragmentation (Highsmith 1982; Tunnicliffe 1981) so sections of live tissue which are removed by damage have a chance to regrow into a new colony.

The confidences associated with the resilience scores are 'High' for Quality of Evidence (QoE), 'Medium' for Applicability of Evidence (AoE) (studies are from other Caribbean islands rather than Turks and Caicos Islands) and 'High' for Degree of Concordance (DoC).

Pressure Theme	Pressure	Revised Benchmark	Sensitivity Assessment											
			Resistance	Confidence Assessment			Resilience	Confidence Assessment			Sensitivity	Confidence Assessment		
				QoE	AoE	DoC		QoE	AoE	DoC		QoE	AoE	DoC
Physical pressures	Physical loss (to land or freshwater habitat)	Permanent loss of existing saline habitat within site	**N**	H	H	H	**VL**	H	H	H	**H**	H	H	H
			Evidence base - *i.e. evidence and citations for the given resistance and resilience scores:*											
			The permanent physical loss of a marine habitat to land or freshwater would cause an irreversible change to that habitat, to which marine species would have no resistance and be unable to recover. Resistance is therefore '**None'**, resilience is '**Very low'** and overall sensitivity is '**High'**. Due to the nature of this pressure, confidence is considered 'High'.											
	Physical change (to another seabed type)	Change from sedimentary or soft rock substrata to hard rock or artificial substrata or vice-versa.	N	H	H	H	**VL**	H	H	H	**H**	H	H	H
			Evidence base - *i.e. evidence and citations for the given resistance and resilience scores:*											
			The larvae of coral species require a hard substrate to settle and grow in order for their skeleton to attach to a solid surface. If the hard substrate were replaced with a soft substrate, the original habitat would need to be removed. This would destroy the existing reef and remove the habitat and associated species. All habitats are therefore assessed as having a '**High'** sensitivity to this pressure, as resistance is likely to be '**None'** and, it is a permanent change, so resilience is '**Very low'**.											
		Change in 1 Folk class (based on UK SeaMap simplified classification (Long, D. 2006. BGS detailed explanation of seabed sediment modified Folk classification))	**NR**	NR	NR	NR	**NR**	NR	NR	NR	**NR**	NR	NR	NR
			Evidence base - *i.e. evidence and citations for the given resistance and resilience scores:*											
			The larvae of coral species require a hard substrate to settle and grow in order for their skeleton to attach to a solid surface. As a hard substrate is a necessity for the characterising species, a change in soft sediment type is assessed as '**Not relevant**´ for this habitat.											
	Abrasion/ disturbance of the substrate on the surface of the seabed	Damage to seabed surface features (species and habitats)	**N**	H	M	H	**VL**	H	M	H	**H**	H	M	H
			Evidence base - *i.e. evidence and citations for the given resistance and resilience scores:*											
			The staghorn coral *Acropora cervicornis* experiences reduced production from photosynthesis and increased respiration as a result of tissue abrasion. Tissue abrasion is often the consequence of incidental contact by recreational divers with the colony. A study by Paradis et al., (2019) found that abrasion of 15% of the coral surface reduced photosynthesis to approximately 1/3 that of non-											

Pressure Theme	Pressure	Revised Benchmark	Sensitivity Assessment											
			Resistance	Confidence Assessment			Resilience	Confidence Assessment			Sensitivity	Confidence Assessment		
				QoE	AoE	DoC		QoE	AoE	DoC		QoE	AoE	DoC
			abraded corals. Together with an increase in respiration this resulted in a photosynthesis:respiration ratio 47% lower than non-abraded colonies. A lower P:R ratio reduced the colonies' ability to meet metabolic demand and reduced energy available for growth. Abrasion was also found to encourage infection from coral diseases (Paradis *et al*. 2019). On the coral reefs on Bonaire in the Caribbean, branching corals such as *Acropora cervicornis* were 35.5% less abundant at heavily dived sites compared to lightly dived sites (Lyons *et al.* 2015). Massive corals including *Orbicella annularis* were 30.9% less abundant in the heavily dived sites. Heavily dived sites off Grand Cayman also possessed less cover of *Orbicella annularis* than lightly dived sites, with the cover increasing with distance from the mooring buoys where dives started. Heavily dived sites also had greater amounts of dead coral and coral rubble. Divers primarily damage corals by direct impact with the colonies (Tratalos & Austin 2001) Anchor damage has also been found to cause large amounts of abrasion damage as the anchor chain sweeps across coral reefs. Twenty percent of an *Acropora cervicornis* reef at the Fort Jefferson National Monument in the Caribbean off the Florida coast was destroyed by boat anchors – evidenced by large amounts of coral which had been rebroken several times into rubble (Davis 1977). Smith (1988) reported that Scleractinia corals, such as those present at the coral/algae reefs in TCI, experienced severe damage by the anchor chain of a cruise ship off Grand Cayman in the Caribbean. The anchor head crushed the corals it impacted and the anchor chain either crushed or scraped the living tissue off corals. The chain swung laterally and the area damaged increased with distance from the anchor head. At 70 m from the anchor the chain's lateral movement was 50 m. This anchor damage totally destroyed 2148 m^2 of coral reef and another 1004 m^2 suffered mortality after being covered by coral fragments (Smith 1988). **Sensitivity Assessment** Abrasion damage from anchors and chains can cause significant damage to species with no evidence that organisms will survive contact. On a smaller scale, physical contact by recreational divers has also been found to cause tissue damage by abrasion and breakage of sections of live coral, causing a decrease in branching and massive corals at heavily dived sites. However, the impacts are likely to be less extensive than those from anchors. Resistance has therefore been assessed as **'None'**, resilience '**Very Low**', and overall sensitivity '**High**'.											
	Penetration and/or		**N**	H	M	H	**VL**	H	M	H	**H**	H	M	H

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<tr><th>Pressure Theme</th><th>Pressure</th><th>Revised Benchmark</th><th colspan="12">Sensitivity Assessment</th></tr>
<tr><th rowspan="2"></th><th rowspan="2"></th><th rowspan="2"></th><th rowspan="2">Resistance</th><th colspan="3">Confidence Assessment</th><th rowspan="2">Resilience</th><th colspan="3">Confidence Assessment</th><th rowspan="2">Sensitivity</th><th colspan="3">Confidence Assessment</th></tr>
<tr><th>QoE</th><th>AoE</th><th>DoC</th><th>QoE</th><th>AoE</th><th>DoC</th><th>QoE</th><th>AoE</th><th>DoC</th></tr>
<tr><td rowspan="2"></td><td rowspan="2">disturbance of the substrate below the surface of the seabed, including abrasion</td><td rowspan="2">Damage to sub-surface seabed</td><td colspan="12">Evidence base - i.e. evidence and citations for the given resistance and resilience scores:</td></tr>
<tr><td colspan="12">See above evidence for surface abrasion.</td></tr>
<tr><td rowspan="3"></td><td rowspan="3">Smothering and siltation changes (depth of vertical sediment overburden)</td><td rowspan="3">‘Light’ deposition of up to 5 cm of fine material added to the seabed in a single, discrete event</td><td>M</td><td>H</td><td>H</td><td>M</td><td>L</td><td>H</td><td>M</td><td>H</td><td>M</td><td>H</td><td>M</td><td>M</td></tr>
<tr><td colspan="12">Evidence base - i.e. evidence and citations for the given resistance and resilience scores:</td></tr>
<tr><td colspan="12">Sediment and increased turbidity are known to have negative impacts on coral species including causing death by smothering, reducing coral growth by abrasion, smothering or blocking sunlight, preventing larvae from settling, and modifying growth forms (Loya 1976).

Increased sedimentation was observed to increase the mortality rate of samples of Acropora cervicornis from Florida. When sedimentation was increased to double the natural rate (60 $mg.cm^{-2}$) for one week, mortality increased from 10% to 50%, and when exposed to four times the natural rate (120 $mg.cm^{-2}$) mortality increased to 70% (De Marchis 2017).

In addition, sedimentation has been recorded to prevent the settlement of coral larvae on algal turf. In a laboratory study, Speare et al. (2019) found that larval stages of Orbicella faveolata and Acropora palmata collected from the Florida Keys settled onto bedrock covered by algal turf. However, compared to sediment loaded algal turf, settlement was reduced by 13 and 10 times respectively.

In other studies, adult coral samples of Acropora cervicornis and Pseudodiploria strigosa off Puerto Rico showed no significant effects of sedimentation up to doses of 800 $mg.cm^{-2}$. An application of 800 $mg.cm^{2}$ did, however, cause death to underlying tissue of Orbicella annularis (Rogers 1983). Smothered areas of corals were subsequently colonised by algae.

In a study by Abdel-Salam et al. (1988), when samples of Acropora palmata, Pseudodiploria strigosa, and Orbicella annularis from the U.S. Virgin Islands were exposed to 600 mg of sediment they exhibited an increase in respiration, most likely due to the energy required to remove sediment from their surface. Furthermore, Acropora palmata and Orbicella annularis both showed a decrease in photosynthesis when covered by sediment. All three species experienced a photosynthesis:respiration ratio of <1 when exposed to sediment, as the level of production could not compensate for the increase in respiration. However, the hemispherical massive corals Orbicella annularis and Psuedodiploria strigosa had a significantly greater rate of sediment removal (maximum 50.42 and</td></tr>
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Pressure Theme	Pressure	Revised Benchmark	Sensitivity Assessment											
			Resistance	Confidence Assessment			Resilience	Confidence Assessment			Sensitivity	Confidence Assessment		
				QoE	AoE	DoC		QoE	AoE	DoC		QoE	AoE	DoC
			50.66 mg.cm^{-2}.h^{-1} respectively) than *Acropora palmata* (maximum 4.22 mg.cm^{-2}.h^{-1}) (Abdel-Salam *et al.* 1988). This may be explained by differences in environmental conditions where these species prefer to grow. For example, *Acropora palmata* grows in shallow areas where water movement is greater, which may aid in sediment removal. The different growth morphologies may also reflect sediment clearing rate: *Acropora palmata* has broad branches which accumulate sediment, whereas sediment doesn't accumulate on the hemispherical species (Abdel-Salam *et al*. 1988). Further studies on *Orbicella* sp. found they experienced greater partial mortality closer to the mouth of rivers off St Lucia than further out to sea. Rates of deposited sediment at corals close to the river mouth were approximately 3 mg.cm^{-2}.day^{-1}, compared to those far from the river where rates were approximately 2 mg.cm^{-2}.day^{-1} (Nugues & Roberts 2003). Coral reef communities off Puerto Rico were also found to be altered by elevated levels of sedimentation and turbidity (Loya 1976). Where sedimentation and turbidity were low (3.0 mg.cm^{-2}.day^{-1} and 1.5 Formazin Turbidity Units (FTU) respectively) coral diversity (Shannon diversity index (H)) and living cover were high (H = 2.196 and cover = 79%). However, at a reef with greater sedimentation and turbidity (15 mg.cm^{-2}day^{-1} and 5.5 FTU), diversity and cover were lower (H = 1.830 and cover = 30%). *Montastrea cavernosa* was identified as an efficient remover of sediment, possessing a greater relative abundance in the coral cover of a reef with approximately four times greater sedimentation than a less sedimented reef (Loya 1976). Other species including *Pseudodiploria strigosa* appeared to succeed in heavy sedimentation areas. (Loya 1976). Observations of *Montastrea cavernosa* off Panama also showed it is capable of clearing sediment from its surface at rates of 345 mg.cm^{-2}.day^{-1} (Lasker 1980). **Sensitivity Assessment** Caribbean corals have been observed to be able to remove settled sediment from their surface by active measures, however they do suffer impacts such as increased respiration, decreased photosynthesis, tissue damage by abrasion, and reduced larval settlement. The massive species seem to have a greater ability to remove sediment compared to species with branching morphologies, however there was little evidence for *Acropora cervicornis* so *Acropora palmata* has been used as a proxy to gather evidence. *Acropora palmata*, however, has broader branches which would make sediment accumulation easier and could reduce this species' ability to remove sediment (Abdel-Salam *et al.* 1988). Therefore, a direct comparison between the *Acropora* species is not possible.											

Pressure Theme	Pressure	Revised Benchmark	Sensitivity Assessment											
			Resistance	Confidence Assessment			Resilience	Confidence Assessment			Sensitivity	Confidence Assessment		
				QoE	AoE	DoC		QoE	AoE	DoC		QoE	AoE	DoC
			Based on the available evidence, at the benchmark level for this pressure, resistance is assessed as ‘**Medium**’, resilience is ‘**Low**’, and overall sensitivity is ‘**Medium**’.											
		‘Heavy’ deposition of up to 30 cm of fine material added to the seabed in a single discrete event	**N**	H	H	M	**VL**	H	M	H	**H**	H	M	M
			Evidence base - *i.e. evidence and citations for the given resistance and resilience scores:*											
			In addition to the information provided above for ‘light’ smothering and siltation, a study by Thompson *et al.* (1980, p. 16) in Erftemeijer *et al.* (2012), showed that *Acropora cervicornis* exhibited sublethal stress after 12 hours when buried in 10–12 cm of reef sand, and experienced complete mortality within 72 hours. *Pseudodiploria strigosa* also displayed sublethal stress and partial bleaching within 24 hours of burial under 10–12 cm of reef sand. Furthermore, when *Orbicella annularis* was buried under 10–12 cm reef sand it experienced 40% tissue loss within 24 hours, and 90% tissue loss within 72 hours, and *Montastraea cavernosa* displayed 30% tissue loss after 72 hours buried under 10–12 cm of reef sand, with the remaining tissue in decay (Thompson *et al.* (1980, p. 16) in Erftemeijer *et al.* (2012)) **Sensitivity Assessment** Caribbean corals possess the ability to remove settled sediment from their surface, however the rate at which sediment is removed varies by species. There is no evidence for impacts at the upper threshold of this benchmark (a single deposition of 30 cm sediment), however evidence at levels of 10–12cm (Thompson *et al.* (1980) in Erftemeijer *et al.* (2012)) suggest that this would be too great an amount for a coral to remove before mortality occurred. Therefore, resistance is assessed as ‘**None**’, resilience is ‘**Very Low**’, and overall sensitivity is ‘**High**’.											
Pollution and other chemical pressures	Organic enrichment	Total Organic Carbon (TOC) greater than 1.67 mg/L	**M**	H	M	M	**L**	H	M	H	**M**	H	M	M
			Evidence base - *i.e. evidence and citations for the given resistance and resilience scores:*											
			The addition of organic carbon on reefs can have profound effects on the mortalities of coral colonies. Samples of *Orbicella annularis* from Panama exposed to heightened concentrations of lactose (25 mg/L) in laboratory studies experienced significantly greater mortality compared to controls (90 vs 10%), with the lethal time until 50% mortality (LT_{50}) of 21 days (Kuntz *et al.* 2005). These experiments also observed that the probability of mortality increased significantly with continued exposure, indicating that a chronic presence of increased organic carbon in the environment has an increasingly potent effect over time. At lower concentrations (5 mg/L) sublethal effects were observed such as progressive mortality at the coral edge (Kuntz *et al*. 2005). Furthermore, in another study on *Orbicella annularis* from Panama, Kline *et al.*											

Pressure Theme	Pressure	Revised Benchmark	Sensitivity Assessment											
			Resistance	Confidence Assessment			Resilience	Confidence Assessment			Sensitivity	Confidence Assessment		
				QoE	AoE	DoC		QoE	AoE	DoC		QoE	AoE	DoC
			(2006) observed a five-fold average increase in mortality (36.6% vs 7.3% with controls) when exposed to various dissolved organic carbon (DOC) treatments, including 25 mg/L of lactose, starch, galactose, and glucose, and 12.5 mg/L of glucose. These treatments caused progressive loss of tissue and rapid sloughing of coral tissue. The same study also investigated the impacts of increased concentrations of particulate organic matter (POM) collected from the coral reefs. 10x and 100x concentrations caused significantly greater quantities of bleaching on coral samples. Measurement of microbial action within the surface mucopolysaccharide layer (SML) showed that an increase in organic carbon (glucose 25 mg/L) caused significantly greater microbial production after 26 hours than control or elevated nutrient samples (Kline *et al.* 2006). This indicated that increased DOC caused an increase in microbial activity which could lead to increased coral mortality due to a disruption between the coral and its associated microbiota. Kline *et al*. (2006) proposed that increased DOC would lead to benthic communities dominated by macroalgae as coral cover is reduced. Organic enrichment can also impact corals by fuelling an increase in benthic cyanobacterial mats (BCMs). Reefs with a large BCM cover were characterised by greater macroalgae cover and lower coral cover. BCMs can reduce coral settlement, alter coral-microbial communities, and act as coral pathogens (Brocke *et al*. 2015). Around the Caribbean island of Curaçao, Brocke *et al.* (2015) proposed that run off from urbanised areas stimulated phototrophic blooms and enhanced organic matter concentrations on reefs. The degradation of this organic matter then fuelled BCM growth. Furthermore, organic enrichment can have significant secondary impacts on coral reefs, as the increased abundance of organic carbon fuels the growth of species which can lead to other pressures. Sargassum brown tides (Sbt) are caused when large quantities of *Sargassum* sp. wash up on beaches and decays. This releases large quantities of organic carbon and nutrients (such as nitrogen and potassium), increases turbidity (causing a decrease in light), decreases dissolved oxygen and decreases pH (van Tussenbroek *et al.* 2017). Corals on a reef in the Mexican Caribbean saw a significant increase in partial mortality from 9.3 to 20.2% after a Sbt event in 2015. **Sensitivity Assessment** Organic enrichment causes an increase in mortality and partial mortality of coral colonies, which can be due to anthropogenic or natural inputs. Organic enrichment is difficult to assess in natural conditions as it often occurs concurrently with several other pressures (nutrient enrichment, deoxygenation, decrease in pH, decrease in light). However, the available evidence means that											

Pressure Theme	Pressure	Revised Benchmark	Sensitivity Assessment											
			Resistance	Confidence Assessment			Resilience	Confidence Assessment			Sensitivity	Confidence Assessment		
				QoE	AoE	DoC		QoE	AoE	DoC		QoE	AoE	DoC
			resistance is assessed as ‘**Medium**’, therefore resilience is ‘**Low**’, and the sensitivity is ‘**Medium**’.											
Biological pressures	Introduction of microbial pathogens	The introduction of relevant microbial pathogens or metazoan disease vectors to an area where they are currently not present (e.g. *Martelia refringens* and Bonamia, Avian influenza virus, Haemorrhagic Septicaemia virus).	**L**	H	M	H	**VL**	H	M	H	**H**	H	M	H
			Evidence base - *i.e. evidence and citations for the given resistance and resilience scores:*											
			There are numerous coral diseases present in the Caribbean which affect a wide range of species, however most recently the TCI has experienced an outbreak of Stony Coral Tissue Loss Disease (SCTLD) (Heres *et al.* 2021). The exact cause of the disease is still unknown however bacteria from the orders Rhodobacterales and Rhizobiales are found in greater abundances in diseased tissue compared to apparently healthy and unaffected tissue, and are thought to play a role in SCTLD (Rosales *et al.* 2020). Observations in Florida by the National Oceanic and Atmosphere Administration (NOAA) have identified *Diploria labyrinthiformis* and *Psuedodiploria strigosa* as Highly susceptible to SCTLD and *Orbicella* sp. and *Montastraea cavernosa* as Intermediately susceptible, while *Acropora cervicornis* is a Low susceptible species, meaning it is rarely affected during outbreaks. In the TCI, SCTLD has been found to significantly decrease coral cover, diversity and richness (Heres *et al.* 2021). Coral cover was found to decrease by 62% (Heres *et al.* 2021) which was similar to observations seen in Florida (Walton *et al.* 2018). Surveys in 2020 on reefs south of South Caicos did not observe several species, including *Diploria labrynthiformis,* for the first time (Heres *et al.* 2021). The presence of SCTLD has been found to change the community composition of coral reefs and reduce coral cover. The disease is characterised by rapid spread, rapid tissue loss, and rapid mortality of corals affected. At Flat Cay, US Virgin Islands, the rate of tissue loss from SCTLD was recorded as up to 35 times greater than other loss from other diseases such as white plague, black band, or white syndrome (Meiling *et al.* 2020). *Psuedodiploria strigosa* and *Diploria labrynthiformis* were observed to experience tissue loss rates of 6.56 ± 1.78 and 8.02 ± 1.57 cm^2/day respectively, with the rate of tissue loss positively correlated with area of tissue available (Meiling *et al.* 2020). Meiling *et al.* (2020) also recorded a 65% mortality of monitored corals during the six-month duration of their observations. In Mexico, SCTLD has a greater prevalence in species which contribute to habitat complexity, including the massive corals *Diploria labrynthiformis, Psuedodiploria strigosa,* and *Montastraea cavernosa,* while having a low prevalence in non-habitat building species (Alvarez-Filip *et al*. 2019). This could cause significant changes to the assemblage due to a change in the abundance of characteristic species. At another site in the Mexican Caribbean, susceptible coral colonies experienced an increase in mortality											

Pressure Theme	Pressure	Revised Benchmark	Sensitivity Assessment											
			Resistance	Confidence Assessment			Resilience	Confidence Assessment			Sensitivity	Confidence Assessment		
				QoE	AoE	DoC		QoE	AoE	DoC		QoE	AoE	DoC
			from 1% to 58% in eight months, while prevalence of the disease decreased from 57% to 12% (Estrada-Saldívar *et al*. 2020). The loss of susceptible coral species caused a change in community composition resulting from the decrease in cover by the dominant species *Siderastrea siderea* and *Psuedodiploria strigosa* (58 and 90% declines in relative abundance respectively) while the less susceptible species *Agaricia agaricites* and *Porites astreoides,* experienced a slight increase in relative cover (Estrada-Saldívar *et al.* 2020). **Sensitivity Assessment** Corals infected with the disease experience rapid tissue loss and mortality which has led to community composition changes. Based on the few studies in the TCI and the results of SCTLD in other Caribbean areas, resistance is assessed as '**Low**' and resilience is '**Very Low**'. Therefore, sensitivity is '**High**'.											

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