Appendix F2

Australian Institute of Marine Science 2014

AIMS Expert Opinion on Recovery Trajectories of Coral Communities at Scott Reef

BROWSE FLNG DEVELOPMENT
Draft Environmental Impact Statement

EPBC 2013/7079
November 2014

Browse FLNG Development.
AIMS Expert Opinion on Recovery Trajectories of Coral Communities at Scott Reef. April 2014.

Executive Summary

This report has been prepared for Woodside Energy Ltd by the Australian Institute of Marine Science to provide information supporting environmental assessment of the Browse FLNG Development. AIMS provides estimates of the rates of recovery of coral communities at nine broad locations at Scott Reef following exposure to four hypothetical spill scenarios provided by Woodside (numbering is consistent with the spill scenarios presented in the Draft EIS):

- Scenario 1 – Well blow-out at Well Centre (TRE) in Scott Reef channel resulting in a 5 day surface release (3975 m^3 condensate) followed by a 72 day subsea release (69,696m^3 condensate)
- Scenario 4A – Major structural failure on an offtake vessel at Torosa resulting in a 24 hour 18000 m^3 condensate spill to the sea surface
- Scenario 4B – Major structural failure on an offtake vessel at Brecknock resulting in a 24 hour 18000 m^3 condensate spill to the sea surface
- Scenario 6 – Loss of containment during offtake from FLNG facility due to marine breakaway coupling failure resulting in 5 minute 461.5m^3 condensate spill to the sea surface

The expected levels of impact for each scenario were specified by Woodside (Table 1), and rationale for dosage thresholds are contained within Appendix 1. As there is little information available regarding the chronic effects of a hydrocarbon spill, only acute impacts to the reef's coral communities were considered, with not persistent affects to the physical environment and substrata. AIMS makes no comment here on the likely impact to coral communities following spill scenarios, but uses the predicted impacts provided by Woodside (Table 1) to infer the rates of recovery. The proposed rates of recovery have been informed by long-term changes in community composition and demographic data collected by AIMS for up to 16 years at shallow reef sites that demonstrate potential levels of coral recruitment, survival and growth under natural conditions.

Table 1: Maximum dissolved aromatic hydrocarbon dosages considered in hypothetical spill scenarios, and the associated predicted impacts on coral communities.

Dosage (maximum dissolved aromatic hydrocarbon)	Impact
38400 ppb hr^{-1}	*Major Mortality* – kills the majority of corals.
4800 ppb hr^{-1}	*Significant Mortality* – kills corals with moderate to high susceptibility to disturbances.
576 ppb hr^{-1}	*Sublethal Stress/Low Mortality* – causes stress, injury and/or mortality to a small proportion of the most susceptible corals.

At Scott Reef, recovery from disturbance has previously depended on four factors: the severity of the impact; processes affecting the recolonisation of new corals; the pre-disturbance community structure; and the occurrence of further disturbances. Two critical factors determining the rates of recovery following spill scenarios are largely unknown: the severity of the impact and the occurrence of future disturbances. The spatial extent of the impact and the proportion of colonies killed will significantly alter rates of recovery, but there is little or no knowledge of the effects of varying

hydrocarbon types and concentrations on corals. It is assumed here that all colonies within a community are killed following *Major Mortality*, and all of the more susceptible colonies are killed following *Significant Mortality*. However, most disturbances display a degree of patchiness, so if a small proportion (≈ 20%) of colonies within the area of impact survive then recovery is likely to be faster; recovery is also patchy, given inherent differences in the suitability of habitat patches for coral growth. Similarly, if the spatial extent of mortality is smaller than predicted, then recovery of some communities will be faster. Conversely, if all colonies are killed across several locations on the reef then recovery will be extremely slow, given that available genetic and oceanographic evidence indicates Scott Reef has little larval connectivity to other reefs in the region over ecological timescales. The occurrence of future disturbances at Scott Reef also has critical implications for recovery of communities, as was evident following the mass-bleaching in 1998. Recovery scenarios presented here are based the observed disturbance regime at Scott Reef in the last two decades (1994-2014), but climate change is expected to increase the frequency and/or severity of coral bleaching, monsoonal storms and cyclones. A more severe disturbance regime than previously observed at Scott Reef would significantly increase the predicted recovery times.

In order to provide estimated recovery periods, susceptibility to disturbance and resilience (depending on each area's community structure, and the ability of dominant corals to recover) were considered for locations affected by each scenario. Subsequent disturbances and the likely supply of spawned coral larvae were also considered, with the combination of these factors providing an estimated time to recovery. Given the uncertainty in many of the determining parameters, the assessment of recovery from disturbance is discussed in the context of four broad recovery periods:
1) Less than a Decade,
2) a Decade,
3) a Few Decades, being two to four decades, and
4) Several Decades, being five or more decades.

Recovery from *Sublethal Stress* is assumed to occur within 5 years and from *Low Mortality* within a decade. Recovery from *Significant* or *Major Mortality* would depend on the extent of the impact, rates of larval supply and recruitment, the abundance of corals of varying resistance and resilience to disturbance, and the background regime of disturbances at each location. Consequently, recovery scenarios were presented for communities at 9 locations at Scott Reef that varied in their exposure to impacts and the factors underlying their recovery. The names of the 9 locations are presented in Table 2.

Table 2: Location names and numbers for the coral communities considered in this assessment. A map showing the locations of the communities can be found in Fig. 7.

Reef	Location number	Location name
South Reef	1	Deep Lagoon (> 20 m)
	2	Inner West (including study location SL3)
	3	Inner South (including study location SL2)
	4	Inner East (including study location SL1)
	5	Outer East (including study location SS1)
North Reef	6	North Lagoon
	7	Outer Southwest (including study location SL4)
	8	Outer Southeast
	9	Outer Northeast (including study location SS2)

For the deep-water (> 20 m) corals (Location 1), communities are likely to have lower resistance and resilience to hydrocarbon concentrations than those in the shallows, and will be more significantly impacted if hydrocarbon plumes in the shallows also reduce light penetration to the depths over timescales of more than a few weeks. Because little is known of their distribution and ecology of deeper water species, recovery scenarios are least certain for the deep-water communities. We consider recovery to be a return to similar coral cover and community structure, but not the replacement of the largest and oldest colonies within the community.

Of the hypothetical spill scenarios presented, recovery would likely be slowest following Scenario 1 and Scenario 4A.

Scenario 1 would result in *Significant* to *Major Mortality* to 3 of the 9 communities considered, with recovery trajectories predicted to take from a Few Decades to Several Decades. The Deep Lagoon and Inner West at South Reef (Locations 1 and 2), and the Outer Southwest at North Reef (Location 7) were the communities worst affected and expected to have the slowest recovery times. For 4 of the 9 communities, recovery was predicted to take a Few Decades following *Significant Mortality*, and Less than a Decade for the remaining 2 communities exposed to *Sublethal Stress*/*Low Mortality*.

- **Scenario 4A** would result in *Significant* to *Major Mortality* to 3 of the 9 communities considered, with recovery trajectories predicted to take Several Decades or longer at 1 community (Location 6 – North Reef’s North Lagoon) and a Few to Several Decades at 2 communities (Locations 8 and 9 – North Reef’s Outer Southeast and Outer Northeast). For the remaining 6 communities, recovery was predicted to take from a Decade to a Few Decades following impacts ranging from *Sublethal Stress/Low Mortality* to *Significant Mortality*.

- **Scenario 4B** and **Scenario 6** had the fastest recovery rates, at Less than a Decade. For both scenarios, the impacts to communities were limited to *Sublethal Stress/Low Mortality*, with the exception of *Significant Mortality* in the deep-water communities in a small part of the South Reef lagoon (impacts were elevated to *Significant Mortality* given the increased susceptibility of deep-water communities). The recovery of all affected communities was predicted to take Less than a Decade, given the low level of impact and/or the small spatial extent of exposure. Five of the 9 communities were not exposed to hydrocarbons at any of the dosages considered in Scenario 6.

AIMS Expert Opinion on Recovery Trajectories of Coral Communities at Scott Reef

1. Background

This report has been prepared for Woodside Energy Ltd (hereafter Woodside) by the Australian Institute of Marine Science (hereafter AIMS) to provide information supporting environmental assessment of the Browse FLNG Development. This report considers the potential ongoing consequences to sensitive environments following a hydrocarbon spill. Scott Reef is a key sensitive receptor in proximity to the Browse FLNG Development area, and AIMS has been commissioned to provide an expert opinion on the recovery potential of Scott Reef following a major hydrocarbon spill of specified impact.

AIMS has studied coral communities at Scott Reef from 1994-2013. During this time, the reef has experienced a range of disturbances including thermally-induced coral bleaching, the impacts of tropical cyclones, and outbreaks of coral disease. These disturbances have varied in their severity, timing, and spatial extent. The information gained from observing how Scott Reef's various coral groups have been affected by these natural disturbances, and have subsequently recovered (or failed to recover), has provided the basis for estimates of recovery from hypothetical spill scenarios expressed in this report.

In order to assess Scott Reef's recovery potential from hydrocarbon exposure, this report first outlines the factors affecting the reefs' recovery from natural disturbance. The recovery trajectories of Scott Reef are initially explained generally, and then coral communities at locations within Scott Reef are considered individually, reflecting their differences in both susceptibility to, and recovery from, past disturbances. Finally, the report provides estimates of recovery for the coral communities, for each of the hypothetical spill scenarios.

In order to address the potential for corals to recover following acute impacts from a hydrocarbon spill at Scott Reef, Woodside provided AIMS with four spill scenarios that represent different orders of magnitude and impact (numbering is consistent with the spill scenarios presented in the Draft EIS):

- Scenario 1 - Well blow-out at Well Centre (TRE) in Scott Reef channel resulting in a 5 day surface release (3975 m^3 condensate) followed by a 72 day subsea release (69,696m^3 condensate)
- Scenario 4A - Major structural failure on an offtake vessel at Torosa resulting in a 24 hour 18000 m^3 condensate spill to the sea surface
- Scenario 4B - Major structural failure on an offtake vessel at Brecknock resulting in a 24 hour 18000 m^3 condensate spill to the sea surface
- Scenario 6 – Loss of containment during offtake from FLNG facility due to marine breakaway coupling failure resulting in 5 minute 461.5m^3 condensate spill to the sea surface

Based on these four spill scenarios, Woodside provided AIMS with a summary table of likely impacts to coral communities in different depths at North and South Scott Reef and Seringapatam (Appendix 1) and associated dosage plots overlaid onto a map of Scott Reef (Appendix 2). These data assumed that dosages would have impacts as described in Table 3. For information on how the dosage thresholds for impact were derived, see Appendix 1.

Table 3: Maximum dissolved aromatic hydrocarbon dosages considered in hypothetical spill scenarios, and the associated predicted impacts on coral communities.

Dosage (maximum dissolved aromatic hydrocarbon)	Impact
38400 ppb hr^{-1}	*Major Mortality* – kills the majority of corals.
4800 ppb hr^{-1}	*Significant Mortality* – kills corals with moderate to high susceptibility to disturbances.
576 ppb hr^{-1}	*Sublethal Stress/Low Mortality* – causes stress, injury and/or mortality to a small proportion of the most susceptible corals.

The extent of exposure to varying hydrocarbon concentrations (Appendix 2) and the summary table of impacts (Appendix 1) provided by Woodside were based on the interpretation of quantitative spill modelling in the four scenarios. AIMS makes no comment here on the likely impact to coral communities following hydrocarbon spills of varying magnitude and duration, but uses the predicted impacts provided by Woodside to consider the rates of recovery. Only coral communities are considered in this assessment.

2. Factors affecting the ability of Scott Reef to recover following disturbance

While there is a broad literature describing natural disturbance and recovery on coral reefs, there are no documented studies describing the recovery of coral communities from hydrocarbon spills similar to the scenarios investigated here. Consequently, to infer the recovery times for coral communities at Scott Reef following acute impacts from a hydrocarbon spill, we considered the detailed studies of recovery following the 1998 mass-bleaching of corals at Scott Reef. These data are presented in peer-reviewed publications and earlier reports to Woodside.

Mass-bleaching reduced coral cover by 80% across Scott Reef and after approximately 12 years the mean coral cover and community composition of the reef system had recovered (Figure 1). However, coral cover and community composition had not recovered at all locations and this variation was attributed to:

1. The severity of impacts and whether corals were killed, injured, or suffered sub-lethal stress.
2. Larval supply and recruitment of new corals.
3. Community structure and abundance of corals with varying resistance (susceptibility) and resilience (ability to recover – depending on reproductive output and growth) to disturbances.
4. Background disturbances (e.g. storms, cyclones, temperature anomalies, disease outbreaks) that often affected each location differently.

The influence of the above variables on the rates of impact and recovery of different coral communities at Scott Reef is discussed below. A summary of community recovery and the influence of these parameters following mass-bleaching in 1998 is presented in Appendix 4. We would expect these same parameters to influence the rates of recovery following acute impacts from a hydrocarbon spill of varying severity, assuming no residual toxic effects. For the purpose of this assessment and given the lack of data describing the recovery of coral communities from hydrocarbon spills, we assume similar patterns of recovery after both naturally occurring disturbances and exposure to hydrocarbons.

2.1 Severity of impacts and whether corals are killed, injured, or suffer sub-lethal stress

The recovery of coral reefs from severe disturbance is far quicker when the disturbance is patchy and when colonies are injured rather than killed. Most natural disturbances to coral reefs (e.g. cyclones) have patchy and selective impacts. Recovery is therefore facilitated by the regrowth of the surviving corals and the supply of new recruits from the less affected patches of reef. If disturbances kill most colonies over large areas, recovery will be far slower as it relies on new recruits arriving from more distant communities followed by subsequent generations of growth and recruitment. The 1998 mass-bleaching was a relatively uniform disturbance across the entire shallow reef system at Scott Reef, yet the recovery of communities was still fastest at the locations that were least impacted (Fig. 1). Consequently, the recovery of communities at Scott Reef from spill scenarios will be far slower if all colonies are killed (*Major Mortality*) over large areas (> 10 km) of the reef, than if only the least resistant colonies are killed or injured (*Significant Mortality* or *Sublethal Stress/Low Mortality*) over small (< 5 km) areas of the reef.

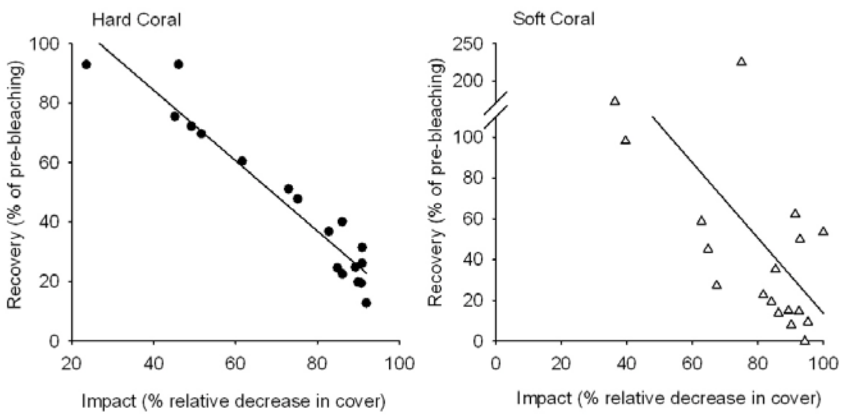
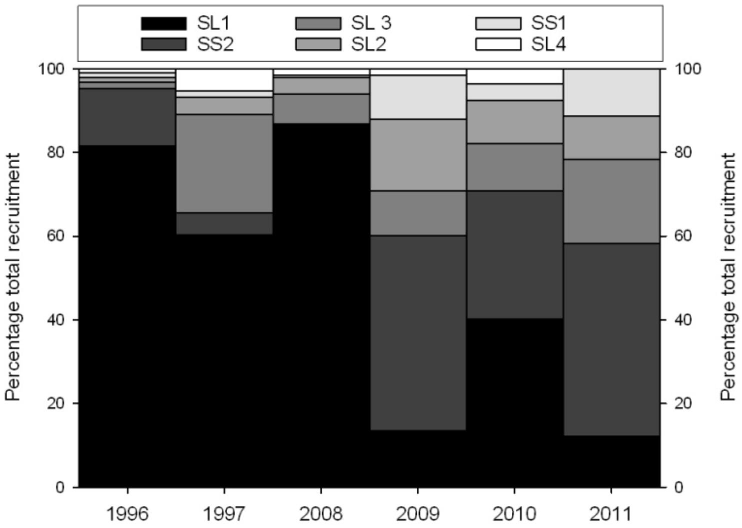


Fig. 1. After the 1998 mass-bleaching, the return to pre-bleaching coral cover at Scott Reef was fastest at the communities with the smallest relative impacts. However, the return to a pre-bleaching community structure usually took longer than a return to the previous coral cover, particularly for coral groups with a low resilience to disturbances due to low recruitment and slow growth.

2.2 Larval supply and recruitment of new corals

The recovery of communities following severe impacts that kill the majority of corals relies on sexual recruitment, which depends on the degree of connectivity to other communities and the annual supply of larvae. Connectivity among communities depends on the speed and direction of current flow, and the minimum and maximum period that larvae spend in the water column. The supply of larvae depends on whether communities upstream have been impacted by disturbances. Existing data indicates there is little ecological connectivity between Scott Reef and other reef systems in the region, but the fine-scale patterns of connectivity among locations at Scott Reef and between Scott and Seringapatam Reefs are largely unknown. However, it is known that the larvae of spawning corals probably disperse over distances of a few kilometres to less than 20 km, and that the larvae of brooding corals disperse over distances of less than a few kilometres. Additionally, the number of recruits during a given year varies considerably among the different locations at Scott Reef (Fig. 2). For example, the Inner East location at South Reef (SL1) and the Outer Northeast location at North Reef (SS2) have consistently high rates of recruitment, whereas the Outer Southwest location at North Reef (SL4) and the Outer Southeast location at South Reef (SS1) have consistently low rates of recruitment. Patterns of larval connectivity are responsible for this variation in recruitment and have important implications for the recovery of communities from a severe spill that kills many corals over an area of greater than a few kilometres (e.g. *Major Mortality*).

Fig. 2. The number of coral recruits at Scott Reef varies among the different locations, as indicated by the percentage of total recruitment over several years.



2.3 Abundance of resistant and resilient corals

Rates of recovery in communities depend on the relative abundance of coral groups with varying resistance and resilience to disturbances. Groups of corals tend to display similar levels of resistance to common disturbances, including storms and temperature anomalies. For the purpose of this assessment we assume that this also applies to hydrocarbon exposure, as there is very little information available regarding impacts and recovery after exposure to hydrocarbons. For example, corals such as branching *Acropora* or Pocilloporidae have the least resistance to disturbance, corals such as the massive *Porites* typically are most resistant, and other groups such as soft corals have moderate resistance (Fig. 3a). The abundance of corals with varying resistance to disturbances influences the magnitude of the impact, which in turn influences the rate of recovery (Fig. 1).

Additionally, groups of corals display varying levels of resilience to disturbances – resilience being the ability to recover according to their rates of larval production, recruitment and growth. Coral groups such as branching *Acropora* and Pocilloporidae tend to have high rates of recruitment and growth, whereas massive *Porites* and soft corals have low rates of recruitment and growth. Community resilience is also influenced by whether larvae (which facilitate recovery) typically disperse over large distances (> 10 km), as in many spawning corals, or over much shorter (few km) distances, as in brooding corals. Coral with larvae dispersing over large distances are able to recolonise other communities across the reef, while corals with larvae dispersing over short distances can significantly increase the recovery of communities locally, but not communities more than several kilometres away.

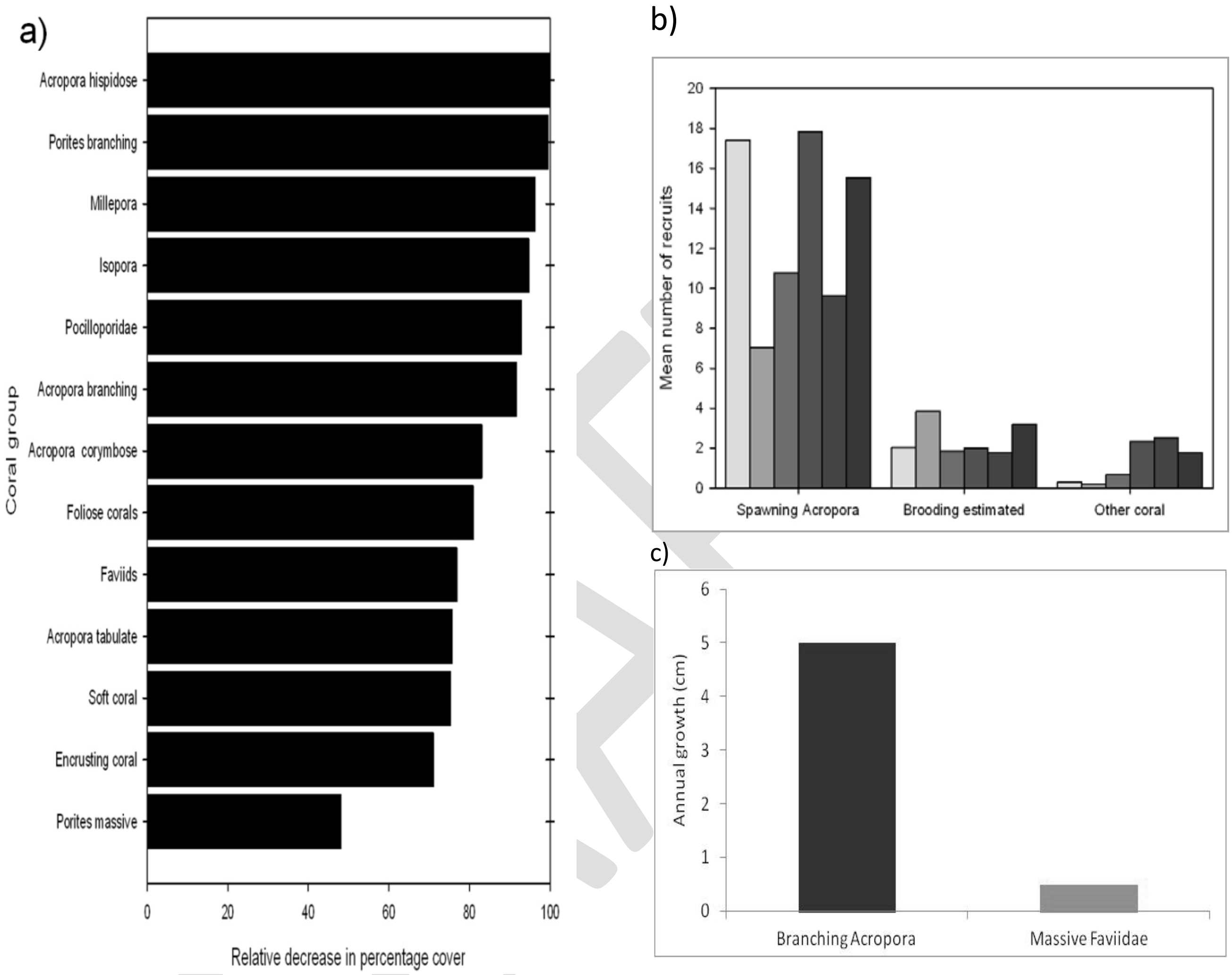
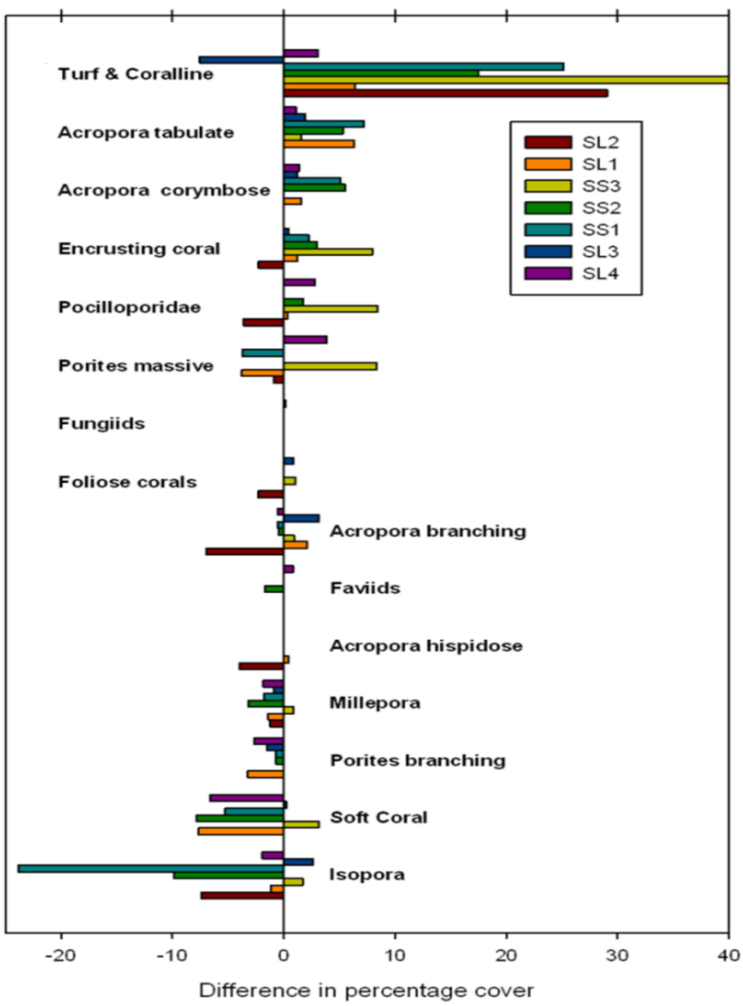


Fig. 3. Variation in resistance and resilience of coral groups at Scott Reef. a) Resistance of coral groups to mass-bleaching in 1998. Resilience of coral groups is influenced by their rates of b) coral recruitment and c) growth, both measured after the 1998 mass-bleaching.

Variation in the recovery of coral communities at Scott Reef following the 1998 mass-bleaching was strongly influenced by the resistance and resilience of the most abundant coral groups (Fig. 4), as well as differences in the severity of the temperature anomalies. For example, the table and corymbose *Acropora* corals were among the fastest to recover because they were moderately resistant to the mass-bleaching and very resilient due to their high rates of recruitment and growth. The soft corals and some massive corals were slow to recover, despite being among the more resistant corals, because of their low resilience (low recruitment and slow growth); the brooding corals (Pocilloporidae, *Isopora*) had not recovered at the worst-impacted sites because they were among least resistant and also had low resilience because recruitment depended on survivors producing larvae that recruited locally.

These patterns of resistance and resilience apply to the shallow-water corals, but such data do not exist for those in the deep lagoon (> 20 m) at South Reef. Deep-water corals rely on autotrophic nutrition, but light penetration to corals in the deep lagoon can be as low as 1% of that at the surface. Consequently, these corals may have limited surplus energy to resist disturbance and are more likely to be killed by moderate impacts, while lower rates of growth and larval production would reduce their resilience to disturbances.

Fig. 4. Resistance and resilience of coral groups at Scott Reef. Absolute differences in percentage cover of coral groups at locations across Scott Reef before the mass-bleaching (surveyed in 1997) and twelve years later. The differences in cover and rates of recovery were influenced by the severity of the impact and the resistance and resilience of coral groups.



2.4 Future disturbance regimes

In addition to the exposure of different communities to disturbances, the number, frequency and type of disturbances that occur during the predicted recovery periods (< a Decade to Several Decades) will influence rates of recovery. Globally, the frequency and diversity of disturbances to coral reefs is increasing. Scott Reef's distance from resident human populations means it largely escapes many local pressures associated with overpopulation, such as decreased water quality and overfishing, although the reef is still subject to traditional fishing by Indonesians which has dramatically reduced target stocks. Scott Reef will also be affected by climate change, with the most likely consequences being an increase in the number and/or severity of temperature anomalies and coral bleaching events, outbreaks of coral disease, monsoonal storms and tropical cyclones. Elevated water temperatures in 1998 reduced coral cover across all of Scott Reef by around 80%. By 2010, the coral communities had mostly recovered from the mass-bleaching, despite the varying impact of three cyclones, a second bleaching event and an outbreak of disease. But, between 2010 and early 2013, an additional two bleaching events and a severe monsoonal storm impacted the reef (Fig. 5), causing the first mean decrease in coral cover at Scott Reef since the mass-bleaching in 1998.

The extent to which disturbances increase at Scott Reef in the next few decades will be critical in determining the ability of the reef to recover from any single severe impact, such as a hydrocarbon spill. Regardless of the type of disturbance (and assuming no chronic effects, such as residual toxicity in the case of a hydrocarbon spill), most existing evidence suggests that Scott Reef is able to recover from a severe disturbance and several moderate disturbances occurring every one or two decades. If more severe, frequent disturbances reduce coral cover so severely that reproduction is compromised, then recovery over ecological timescales is unlikely given the lack of connectivity to other reefs in the region. For individual coral groups, reductions in abundance that dramatically slow recovery due to Allee effects[1] is unknown, but at the entire-community level it is hypothesised that if total coral cover at all locations across the reef decreases to less than ≈10%, long -term recovery may be compromised.

[1]'Allee effects' refer to the reduction in reproductive success when population density is low. For corals, the likelihood of gamete fertilisation and therefore larval production decreases with a reduced population density and an increased distance between colonies.

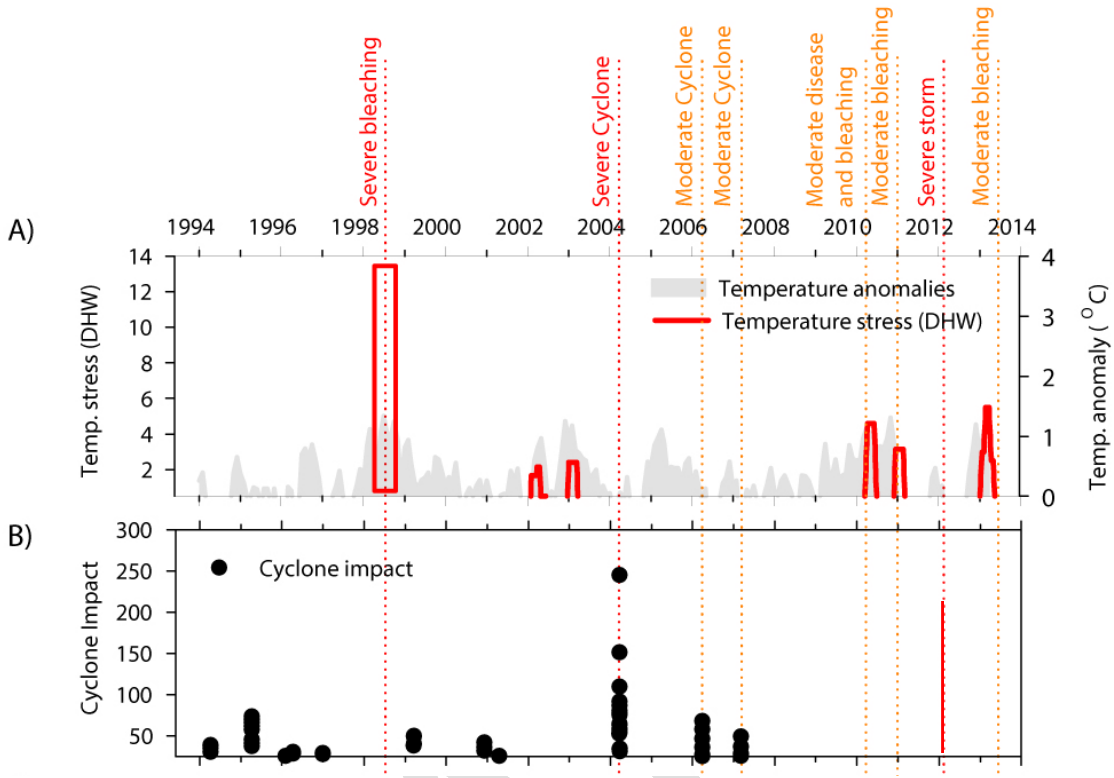


Fig. 5. Frequency of significant disturbances at Scott Reef over two decades. Disturbances included temperature anomalies and coral bleaching (1998, 2010, 2011, 2013), coral disease (2010), cyclones and severe storms (2004, 2006, 2007, 2012). Severe disturbances are indicated in red and moderate disturbances in orange.

3. Predicting recovery of coral communities following disturbance

Estimating the recovery of coral communities is complex, due to differences among the communities themselves, as well as variability in subsequent disturbances and differences in the biological characteristics that influence recovery. Following the mass-bleaching in 1998, communities across Scott Reef were impacted by a Category 5 Cyclone in 2004 and several additional but more moderate disturbances. Ten years after the mass-bleaching, the total cover of hard corals at the shallowest (1-6 m depth) reef slope locations had returned to between 50% and 80% of their previous level (Appendix 3), and to between 50% and 150% at the reef slope (9 m) (Appendix 4). This large variation in recovery was driven by differences in impact severity, larval recruitment and the community structure. Additionally, the return of coral cover was not equivalent to a return to the previous community structure. Some coral groups within some communities were still far from their previous cover, despite the recovery of total coral cover (Appendix 5).

Recovery trajectories for entire coral communities are difficult to predict, and can vary even for a single population under controlled modelling scenarios. For example, we considered a population model for a species of table *Acropora* at Scott Reef. This species was among the most resilient following the mass-bleaching in 1988 and is likely to be among the fastest to recover from a hydrocarbon spill, provided impacts are restricted to one or a few communities. Assuming that recovery is facilitated by the supply of larvae from other communities and that all the larvae produced by colonies recruit to their natal community (self-seeded), a return to a previous population size and structure could take between 10 and 30 years (Fig. 6). For example, if the entire population is killed by the disturbance, and recovery is facilitated by both the supply of recruits from uneffected populations *and* by the corals recolonising the local population, then recovery will take around 23 years if there are no subsequent disturbances (Fig. 6a), and around 30 years if a disturbance (e.g. cyclone, bleaching) kills 50% of the population each decade (Fig. 6b). Recovery will be faster if a proportion of the population survives; if 10% of the population survive locally then the population will return to its previous structure within approximately 11 years (Fig. 6c), and within approximately 15 years if a subsequent disturbance kills half the population within that period (Fig. 6d). Confidence intervals around even these simple projections are in the order of a few to several years and this coral is among the fastest growing and most resilient of all at Scott Reef. Recovery trajectories for large massive corals under similar scenarios will be several decades longer and more variable. The simplistic population model described here does not account for a range of important variables, such as multiple disturbances each decade, a proportion of larvae being carried away from the location and density-dependent reductions in growth and survival. For these reasons, it is not realistic to propose recovery scenarios with an accuracy of less than decades and they are presented here as four periods:

1) Less than a Decade
2) a Decade,
3) a Few Decades, being two to four decades, and
4) Several Decades, being five or more decades.

For the hydrocarbon spill scenarios, recovery from *Sublethal Stress* is assumed to occur within 5 years, and from *Low Mortality* within a Decade. Recovery from *Significant* or *Major Mortality* depended on the extent of the impact, rates of larval supply and recruitment, the abundance of corals of varying resistance and resilience to disturbance, and the background regime of disturbances at each location. Certainty in recovery periods is far greater for the shallow-water communities than for the deep-water communities, for which very little data exist. The periods of recovery also depend on how recovery is defined. A return to previous coral cover typically occurs faster than a return to previous community composition, given that the most susceptible corals are the slowest to recover. In particular, it will take many decades for the largest and oldest corals within the community to be replaced. For example, some of the largest *Porites* and perhaps soft coral colonies are over 100 years old. In these scenarios, we consider recovery to be a return to previous coral cover and community structure, with the exception of the replacement of the largest and oldest colonies within the community.

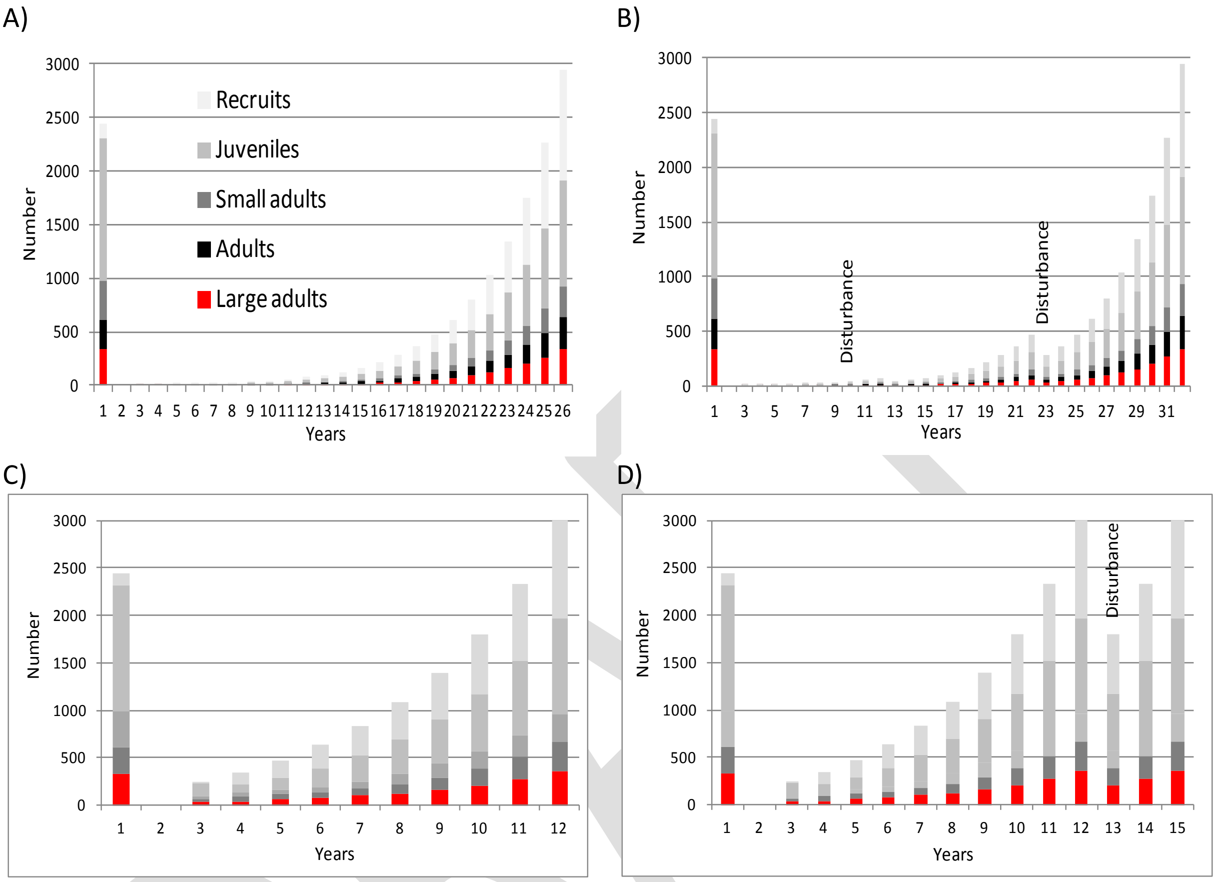


Fig. 6 The time taken for populations of *Acropora spicifera* to recover from an acute disturbance, based on a return to a similar number of large adults and adult colonies. The population projection models assume mean rates of larval supply from unaffected communities, that all larvae produced by the recolonising corals remain within the population, and there are no density dependent reductions in growth and survival- these assumptions will speed the projected rates of recovery. A) All corals are killed by the disturbance and there are no other disturbances; B) all corals are killed and another disturbance kills half the corals each decade; C) ten percent of the corals survive and there are no other disturbances; D) ten percent of the corals survive and an additional disturbance kills half the corals within a decade.

4. Susceptibility of communities and locations at Scott Reef to disturbance

The impacts to coral communities at Scott Reef were grouped into shallow-water (≤ 20 m depth) and deep-water (≥ 20 m) communities. Deep -water communities are located only in the South Reef lagoon, and shallow-water communities include the reef slope habitats at North and South Reef and the lagoon at North Reef. Communities were further divided according to their position on the reef and the known variation in background conditions, community structure and exposure to background disturbances, all of which influence their rates of recovery following disturbances. This resulted in 11 different community locations (Fig. 7), of which the two on the western side of South and North Reef were excluded because of their low cover and diversity of corals, leaving 9 remaining communities.

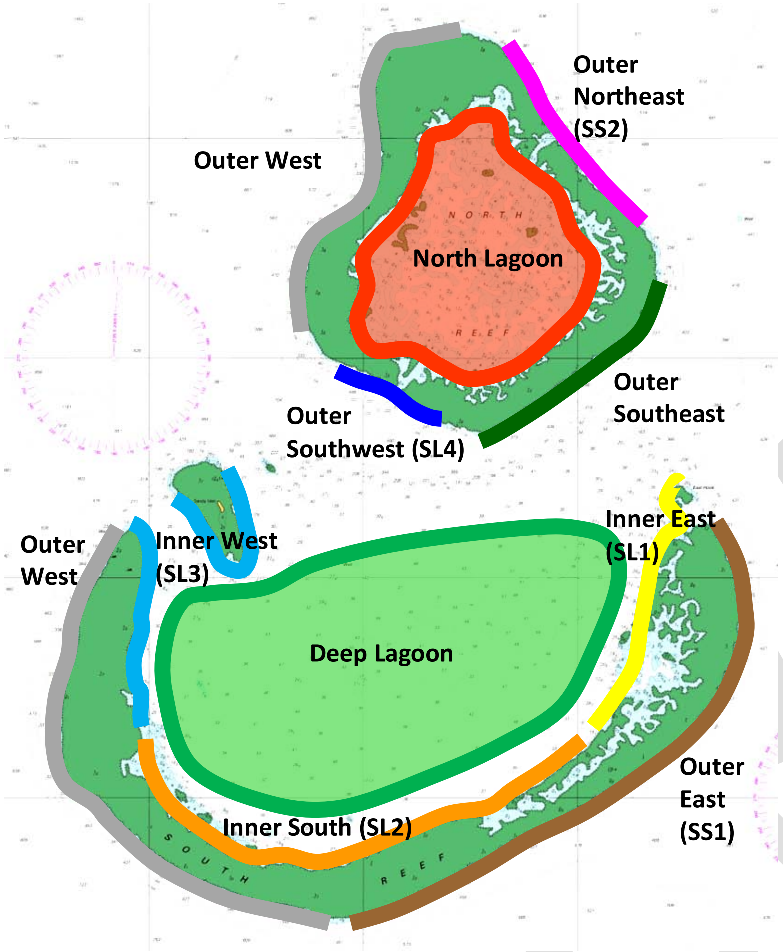


Fig. 7. Community locations at Scott Reef and their susceptibility to major disturbances. Groups are distinguished by their habitat conditions and community structure. Susceptibility is based on the variable supply of coral recruits and exposure to likely background disturbances, with high susceptibility resulting in slower recovery from a major acute disturbance such as a hydrocarbon spill. Background rates of growth and survival for coral groups are assumed to be similar at all locations and are altered by exposure to disturbances. Communities in the Deep Lagoon (> 20 m) have moderate exposure to several disturbances, but have a high susceptibility to disturbances because they exist in a marginal habitat are likely to have low resistance and resilience to disturbances. The Outer West locations have low cover and diversity of corals, due to their exposure to wave energy from seasonal storms, and are not considered further in this report.

	Reef	Location	Recruit limited	Storm	Cyclone	Temperature	Disease
1	South Reef	Deep Lagoon	High*	Low	Low	Medium*	Medium*
2	South Reef	Inner West	Medium	High	High	Low	Low
3	South Reef	Inner South	Medium	Medium	Medium	High	High
4	South Reef	Inner East	Low	Medium	Low	Medium	Medium
5	South Reef	Outer East	Low	Low	High	Medium	Low
6	North Reef	North Lagoon	High*	Medium	Medium	High	High
7	North Reef	Outer Southwest	High	High	High	Low	Low
8	North Reef	Outer Southeast	Medium*	Low	Medium	Medium*	Low
9	North Reef	Outer Northeast	Low	Low	High	High*	Medium

*Low certainty in susceptibility ranking.

1. South Reef: Deep Lagoon (> 20 m)

The deep-water (> 20 m) communities are found only in the lagoon at South Reef and are regionally significant; they may also exist within a marginal habitat. There is currently only rudimentary habitat mapping for Scott Reef, although modelling approaches by AIMS hope to improve this, particularly for the deep lagoon. Many species that dominate the shallower habitats (e.g. *Acropora* and Poritidae) are rare in the deep, with species of *Montipora*, *Pachyseris* and soft corals among the most abundant. These populations are thought to have a patchy distribution throughout the deep lagoon. The size and spacing of coral-dominated patches is unknown, but will have important implications for recovery from disturbances given that the deep-water corals are not supplied with larvae from other oceanic reefs or from other habitats within Scott Reef or Seringapatam Reef. Recovery will depend on the local production of larvae by the surviving corals within the deep lagoon and their recruitment to impacted areas. Yet, the modes of reproduction for the deep-water corals and their patterns of connectivity are also unknown. For example, it is not known whether the populations on the western side of the deep lagoon will spawn larvae that disperse and aid the recovery of those on the eastern side.

Despite their significance, very little is known about the deep-water corals in the South Lagoon. Their distribution and community structure, physical environment, modes of reproduction, rates of growth and survival, and patterns of connectivity, all remain unknown. At least some knowledge of all of these parameters is required to make accurate estimates of rates of impact and recovery from disturbances, so the recovery scenarios proposed here for the deep-water corals are the least informed and the least certain.

The susceptibility rankings given to shallow-water corals are unlikely to apply to the deep, and all deep-water corals are likely to have low resistance and low resilience to disturbance. Based on what is known of their physiology, the deep-water corals rely entirely on autotrophic nutrition and light penetration to this depth is comparatively low. Consequently, they may have limited surplus energy to resist disturbance and are more likely to be killed by moderate impacts (*Sublethal Stress/Low Mortality, Significant Mortality*). Additionally, they are also likely to have lower rates of growth and larval production than the shallow-water corals, reducing their resilience to disturbances. Rates of growth for deep-water corals are likely to be less than a few cm yr^{-1}. Given slow growth and low reproductive output, the persistence of deep-water communities may rely on low rates of mortality and a lack of natural disturbances. If so, they have a limited capacity to recover from severe disturbances causing high rates of mortality.

Historically, the deep-water communities probably escaped many of the disturbance affecting those in the shallows. However, there is increasing evidence of rising ocean temperatures are also affecting deep-water corals. Recent (2010-2013) temperature anomalies at Scott Reef have affected reef slope communities to depth of over 30 m, but it is not known whether the deep-water communities in the South Lagoon were also affected. The exposure of the deep-water corals to bleaching is uncertain; they may be more exposed to temperature anomalies because they sit in a semi-enclosed lagoon with reduced water movement, or less exposed because of the flow of cool water from the channel into the deep lagoon. Of further concern are the future effects of ocean acidification, which are predicted to impact deep-water corals most severely. If the deep-water communities were affected by a severe bleaching event then the consequences would be significant and recovery would take several decades. If a severe bleaching event (or other disturbance) were to occur in the same decade as severe impacts from a hydrocarbon spill, recovery would be unlikely to occur over ecological time scales.

Assuming no additional disturbances, and no chronic effects, recovery from hydrocarbon spills of varying severity will take between less than a decade and more than several decades. In the best case scenario, recovery from *Sublethal Stress* to a small proportion of the community would take around five years. If impacts result in the death of some corals within a small area of the habitat, then recovery may take a Few Decades; surviving corals produce larvae that recruit throughout the habitat over several years, which then grow and become large colonies within a decade, which then produce the recruits that grow and return coral cover and diversity to its previous levels. In the worst-case scenario, a higher proportion of corals are killed over a larger area of the habitat. Survivors will take longer than five years to recover from *Sublethal Stress*, longer than a decade to become large colonies, and a low density of survivors reduces reproductive output and recruitment. If reproductive output and connectivity among communities is also low, and/or corals brood rather than spawn larvae, then recovery of communities may take Several Decades or longer.

2. *South Reef: Inner West (including study location SL3)*

The Inner West communities exist in a high-energy environment and are dominated by corals with robust growth forms. Massive *Porites* and Faviidae, brooding *Isopora* and soft corals are among the most common corals. Existing data suggest an easterly flow of water through the deep channel between North and South Reef, past Sandy Islet. Consequently, the recovery of the Inner West communities from *Significant* or *Major Mortality* may not be aided by a large supply of larvae from other communities, given the low cover and diversity of communities upstream, in the Outer West. Local survivors will also be crucial for recovery due to the life histories of the dominant corals. Massive *Porites* have a high resistance to disturbance, but a low resilience following severe disturbances as they have low rates of larval production and slow growth; brooding *Isopora* have a very low resistance to disturbance and their resilience is determined by the number of local survivors because their brooded larvae disperse over short distances; soft corals have a moderate resistance to disturbance but a low resilience due to low rates of recruitment and slow growth.

The Inner West location is regularly exposed to monsoonal storms, and has also been affected by numerous cyclones. Future disturbances of this nature will slow recovery following a severe disturbance. However, the communities are less exposed to other disturbances, particularly temperature anomalies, because water temperatures are lowered by the flow of cool water through the deep channel and past Sandy Islet. The recovery of these communities following disturbances that kill a small proportion of colonies is likely to be relative quick, taking between a Decade and a Few Decades, but recovery from a disturbance that kills many of the colonies throughout the community will take Several Decades or longer, particularly if the largest and oldest *Porites* and soft corals are killed.

3. *South Reef: Inner South (including study location SL2)*

The communities at South Reef's Inner South exist in the most sheltered environment at Scott Reef, in an area characterised by low current flow, high residence times, and relatively high turbidity. The coral communities reflect these habitat conditions, being dominated by *Acropora* and Pocilloporidae with branching and more fragile growth forms. Existing data suggest a slow flow of currents in an easterly direction along the reef slope towards the northeast part of the inner lagoon. These coral communities have intermediate rates of recruitment, possibly with a moderate to high degree of self-seeding. Consequently, the rate of recovery of the South Lagoon communities from *Significant* or *Major Mortality* may be increased by the supply of larvae from communities at the Inner West provided they have not been severely affected, particularly given the dominance of spawning corals. However, a degree of self-seeding due to slow current speeds also means recovery will rely on the production of larvae by local survivors, particularly for brooding Pocilloporidae. Communities here have a low resistance to disturbance and many corals will be killed by scenarios causing *Significant* to *Major Mortality*, although the dominant species also have a high resilience to disturbance (given sufficient local survivors), due to typically high reproductive output and rates of growth.

The Inner South communities are relatively sheltered from monsoonal storms and cyclones, but they are susceptible to temperature anomalies causing coral bleaching and outbreaks of disease. These communities had intermediate rates of recovery from the 1998 mass-bleaching; the dominant corals had low resistance to mass-bleaching and the subsequent disturbances, but recovery was facilitated by a high degree of community resilience. However, these communities are likely to be among the most susceptible to future temperature anomalies, and possibly some of the most severe cyclones and storms. The recovery of communities at Inner South from disturbances causing *Significant Mortality* is likely to take a Decade, and a Few Decades for disturbances causing *Major Mortality*, depending on the extent of the impacts and whether communities to the west are also affected.

4. *South Reef: Inner East (including study location SL1)*

The coral communities at South Reef's Inner East exist in a habitat of mixed conditions, which is reflected in their diverse mix of coral species. Existing data suggest that coral larvae may become concentrated in eddies at the Inner East following their dispersal from communities further west, and this location (SL1) has among the highest rates of coral recruitment at Scott Reef. Consequently, the recovery of communities at the Inner East Slope from *Major* or *Significant Mortality* will be aided by the supply of larvae from other parts of South Reef, providing that these communities are also not affected. The mix of corals at the Inner East location includes species with varying degrees of resistance from, and resilience to, disturbance. The recovery of spawning corals will be aided by larval supply from other communities, but the recovery of brooding corals or those with low reproductive output will still depend strongly on the number of local survivors.

In addition to a mix of habitat conditions and coral types, the Inner East communities are exposed to a mix of disturbances, but most are of low or moderate severity. The relatively low exposure to disturbances, the abundance of corals with moderate to high resistance and/or resilience to disturbance, and the high rate of larval supply, led to the fastest rates of recovery from the 1998 mass-bleaching; with the exception of massive *Porites* and soft corals given their low resilience following severe impacts. Consequently, the recovery of the Inner East communities from disturbances causing *Significant* or *Major Mortality* is predicted to be faster than for most other communities at Scott Reef, and is likely to take between a Decade and a Few Decades.

5. *South Reef: Outer East (including study location SS1)*

Communities on the Outer East of South Reef are exposed to the open ocean and the easterly trade winds through winter. Dominant corals here are branching *Acropora* and *Isopora*, massive *Porites* and Faviidae, and encrusting corals and Pocilloporidae. Existing data suggest a flow of currents and larvae away from the Outer East to the north. The extent of coral communities on the southern-most part of the Outer East is unknown, but the rates of coral recruitment to the Outer East study location (SS1) are among the lowest at Scott Reef. Consequently, recovery from *Significant* to *Major Mortality* will not be aided by the supply of larvae from other communities. Recovery will also depend on the abundance of local survivors following disturbance, as some dominant corals depend on the regrowth of survivors and/or the local production of brooded larvae.

The Outer East is exposed to cyclonic winds and waves from the east and has previously been affected by recurrent temperature anomalies and coral bleaching. The low rates of recruitment, coupled with the low resilience of dominant corals following severe impacts, mean that the massive *Porites,* branching *Isopora* and *Acropora,* and soft corals have still not recovered from the 1998 mass-bleaching. The lack of larval supply, the life histories of the dominant corals and the moderate exposure to background disturbances means that these communities are likely to take a Few Decades to recover from *Significant Mortality*, and Several Decades or longer to recover from *Major Mortality*.

6. North Reef: North Lagoon

There is little information about the habitat conditions and coral communities within the North Reef Lagoon. Existing information suggests low water flow and high residence times within the lagoon, although some tidal flushing over the reef flat and through the southwest channel is likely. The coral communities are apparently dominated by massive *Porites* bommies scattered throughout the lagoon, many of which rise to within a few metres of the surface and may be tens of metres in diameter. The tops and sides of these bommies provide an important habitat for a mix of other corals, particularly various Acroporidae and Pocilloporidae. The lagoon floor consists of rubble and particularly sand, and ranges in depth from several metres to approximately 20 m. Scattered over the lagoon floor are large stands of staghorn *Acropora* and other associated species, but their distribution is largely unknown. There is no information about connectivity among coral communities within the North Lagoon or with other habitats. Connectivity among communities within the lagoon is likely and some larval exchange between the lagoon and the outer slope communities on the east and west side of North Reef is also possible. The recovery of some spawning corals within the North Lagoon, such as the spawning Acroporidae and Pocilloporidae on and around bommies, from disturbances causing *Significant* or *Major Mortality* will be aided by the supply of larvae from other bommies, provided they are not also affected. However, the recovery of the most abundant coral groups is unlikely to be rapidly increased by larval supply from other areas and will depend strongly on local survivors. The massive *Porites* in the North Lagoon are among the most resistant of all corals to disturbance, but if killed they have a very low resilience due to their low reproductive output and slow rates of growth. Also, the branching *Acropora* that dominate the lagoon floor are among the least resistant and least resilient corals to disturbance (in the absence of local survivors) because they have low rates of recruitment and rely on asexual growth for propagation.

The North Lagoon communities are relatively sheltered from storms and cyclones, but are exposed to temperature anomalies and outbreaks of disease due to high residence times and low current speeds. The branching *Acropora* in the lagoon were among the worst affected by the 1998 mass-bleaching and probably have not yet recovered, although the extent of their distribution before and after the mass-bleaching is unknown; the effects on massive *Porites* and other corals are also unknown. The recovery of North Lagoon communities from disturbances causing *Significant* to *Major Mortality* will depend critically on whether a large part of the lagoon is affected and on the frequency of severe temperature anomalies in the future. Assuming only part of the lagoon is impacted and a low frequency of mass-bleaching, communities are likely to recover from *Significant Mortality* within a Few Decades and *Major Mortality* within Several Decades.

7. North Reef: Outer Southwest (including study location SL4)

The communities adjacent to the channel at North Reef's Outer Southwest exist within a high-energy environment and are exposed to the largest waves and highest current speeds of all the locations at

Scott Reef. Consequently, communities are dominated by massive and encrusting corals, particularly *Porites* and Faviidae, as well as brooding *Isopora* and soft corals. Existing data provides evidence of the easterly flow of currents through the deep channel towards the Inner Northeast part of South Reef and/or along the Outer Northeast of North Reef. The coral communities at the Outer Southwest (SL4) have among the lowest rates of recruitment of all locations at Scott Reef, as many of the larvae produced within this community are probably carried away by currents. A potential source of recruits on the Outer West has few coral communities. Consequently, the recovery of these communities from *Significant* or *Major Mortality* will not be aided a large supply of larvae from other communities and will depend on the abundance of local survivors. Recovery will also rely on the local abundance of survivors due to the life histories of dominant corals.

North Reef's Outer Southwest has a variable exposure to common disturbances, having a low exposure to temperature anomalies and coral bleaching due to the flow of cool water from the channel, but a high exposure to monsoonal storms and cyclones to the west. For example, a monsoonal storm during 2012 had a dramatic impact on these communities and reduced coral cover to less than that following the mass-bleaching in 1998, whereas the communities were among the least impacted by the mass-bleaching due to the smaller temperature anomalies and the abundance of corals of relatively high resistance. This interplay between impact severity and the resistance and resilience of coral groups was evident in the recovery of the communities following mass-bleaching in 1998. The impact of the temperature anomaly in 1998 on the massive *Porites* was relatively small and within a decade they had recovered, largely through the regrowth of surviving colonies. In contrast, the soft corals and brooding *Isopora* were less resistant to the temperature anomaly and were more severely impacted, and have not yet recovered given their dependence on local survivors for resilience. The recovery of communities at the Outer Southwest will depend critically on the extent of the disturbances and the proportion of colonies that are injured or killed, in addition to their exposure to future storms and cyclones. The lack of larval supply, the life histories of the dominant corals and their likely exposure to additional disturbances means recovery from scenarios causing *Significant Mortality* is likely to take a Few Decades and from *Major Mortality* likely to take Several Decades or longer.

8. North Reef: Outer Southeast

There is little existing information about the habitat conditions and coral communities in the Outer Southeast area of North Reef. There is no quantitative information about the coral communities, but limited observations suggest a relatively high cover and diversity of corals. Existing data provides evidence of the easterly flow of currents and larvae through the deep channel to either the Inner East part of South Reef and/or the Outer Northeast part of North Reef. However, it is not known whether larvae are carried to, or away from the Outer Southeast. Consequently, it is also unknown whether the recovery of communities here will be aided by the supply of larvae from other communities, or the degree to which the recovery of communities from *Significant* or *Major Mortality* will rely on the supply of spawned or brooded larvae, and/or regrowth of surviving colonies.

The communities at the Outer Southeast are relatively sheltered from monsoonal storms but exposed to cyclonic winds and waves from the east; their exposure to temperature anomalies and coral bleaching is uncertain, and may be reduced by the flow of cool water intrusions through the channel or increased by the flow of warm water from the North Lagoon over the reef flat. Given the lack of available data for these communities, it is difficult to predict their rates of recovery, but may be in the order of a Decade to a Few Decades for *Significant Mortality*, and a Few to Several Decades for *Major Mortality*.

9. *North reef: Outer Northeast (including study location SS2)*

The Outer Northeast community is exposed to open ocean and the easterly trade winds through the winter months. The coral communities are dominated by branching *Acropora* and *Isopora*, massive *Porites* and Faviidae, encrusting corals and Pocilloporidae. Existing data suggest a flow of currents and larvae away from parts of South Reef towards the north, and communities on the Outer Northeast have among the highest rates of recruitment at Scott Reef. Consequently, recovery from *Significant* to *Major Mortality* will be aided by the supply of larvae from other communities for spawning corals, but for brooding corals and those with low reproductive output and growth the local survivors will also be important for recovery.

The Outer Northeast is sheltered from monsoonal storms but is periodically exposed to cyclonic wind and waves. These communities have a variable exposure to temperature anomalies, given their proximity to the open ocean and the periodic flow of warmer water from the North Reef lagoon over the reef flat. In the past, corals here have been moderately affected by multiple bleaching events and were severely impacted by the 1998 mass-bleaching, due partly to high abundances of corals with low resistance to the disturbance. The recovery of different coral groups from the mass-bleaching reflect differences in resistance and resilience to severe disturbances. The brooding *Isopora* and the soft corals have not yet recovered because of their moderate to low resistance to temperature anomalies, their low resilience to severe disturbances, and their exposure to a category 5 cyclone. Conversely, high rates of larval supply and recruitment resulted in certain *Acropora* species recovering quickly and now exceeding their pre-bleaching abundance. The recovery of the Outer Northeast communities from disturbances that cause *Significant Mortality* is likely to take between a Decade and a Few Decades, and will be fastest for the spawning corals assuming the sources of larval supply are not affected. Recovery from disturbances that cause *Major Mortality* is likely to take between a Few and Several Decades, depending on the extent to which other communities are affected and the proportion of local survivors for corals whose resilience relies on the production of brooded larvae or the regrowth of injured colonies.

10. *North and South Reef: Outer West*

There have been no quantitative surveys of the Outer West reef slope at North or South Reef, apart from initial surveys in the early 1990s. These data, coupled with more recent observations, suggest the Outer West habitats have a low coral cover (≤ 5%) and diversity. The shallow (< 10 m) western margin is exposed to wind and swell from monsoonal storms, which have probably resulted in the formation of a wide reef flat with few corals on the shallow slope. The extent of coral or other benthic communities on the deeper (> 10 m) slope is unknown. Coral cover and diversity are likely much higher in the southern part of the Outer West, where the reef has a more south-westerly aspect, although this is currently unknown. Impact scenarios were provided for the Outer West, but recovery scenarios are not discussed based on the assumption or low cover and diversity of coral communities and their exposure to seasonal monsoonal storms.

5. Recovery of Scott Reef's coral communities from hypothetical hydrocarbon spill scenarios

The four hypothetical spill scenarios considered represent disturbances ranging in severity from causing widespread major mortality; to causing low mortality in a localised area (see Appendix 1 for definitions of impact magnitude, and Appendix 2 for spatial extents of the different impact magnitudes). For the purposes of this assessment, we examined the locations affected by the scenarios and considered their susceptibility to disturbance, and likelihood of subsequent disturbances. The supply of spawned coral larvae was also considered, in order to provide an estimated time to recovery. As the recovery from disturbances at Scott Reef has been found to be spatially variable, it was necessary to consider coral communities separately at the 9 locations defined in Fig. 7.

Scenario 1 – Well blow-out at Well Centre (TRE) in Scott Reef channel resulting in a 5 day surface release (3975 m^3 condensate) followed by a 72 day subsea release (69,696m^3 condensate)

In Scenario 1, *Major* and *Significant Mortality* is predicted at both North and South Reef. *Sublethal Stress/Low Mortality* occurs over a large proportion of both reefs (see Appendix 2, Table 1, for more detail regarding the location and extent of predicted mortality). Plots showing the location of the hypothetical hydrocarbon dosages expected in this scenario can be found in Appendix 2, Figs 1 – 4.

Recovery periods range from a Decade to Several Decades or longer for communities at the 9 locations considered (Table 4).

For the communities in the Deep (> 20 m) Lagoon at South Reef (Location 1), recovery from *Significant* to *Major Mortality* is predicted to take a Few to Several Decades.

In the shallow-water (< 20 m) habitat, recovery is predicted to take Several Decades for communities at three locations, of which two had *Significant* to *Major Mortality* (Locations 2 and 7) and one had *Significant Mortality* (Location 5).

Recovery is predicted to take a Few Decades for communities at three locations that suffered *Significant Mortality* (Locations 4, 6 and 8), and less than a Decade for the remaining community locations that suffered only *Sublethal Stress/Low Mortality* (Locations 3 and 9).

Table 4. Recovery scenarios for coral communities at Scott Reef following Scenario 1. Red indicates major mortality, processes that slow recovery, or a slow rate of recovery; orange indicates significant mortality, processes that have a moderate influence on recovery, and a intermediate rate of recovery; yellow indicates sub-lethal impact, processes that aid recovery, and a relatively rapid rate of recovery. The most susceptible groups of corals include those that are worst impacted by typical disturbances and/or those that are slow to recover due to low rates of recruitment and/or growth. *Little supporting information and low certainty; # Deep-water corals are likely to have lower resistance to disturbances than their shallow-water counterparts. Mortality to deep-water communities will be far greater if the hydrocarbon plume in shallow-water (< 20 m) reduces light penetration for more than a few weeks.

			IMPACT				RECOVERY	
		LOCATION	Scenario Impact	Susceptible corals	Subsequent disturbances		Spawned larval supply	Rate of recovery
1	South Reef	Deep Lagoon (> 20 m)	*Significant* to *Major*[#]	All	Bleaching, disease		Low*	Few to Several decades*
2	South Reef	Inner West (including study location SL3)	*Significant* to *Major*	Brooding *Isopora*, massive *Porites*, soft corals	Storms, cyclones		Low to moderate	Several decades
3	South Reef	Inner South (including study location SL2)	*Sublethal/Low Mortality*	Branching *Acropora*	Bleaching, disease		Moderate	< Decade
4	South Reef	Inner East (including study location SL1)	*Significant*	Mix of corals	Moderate bleaching, disease, storms, cyclones		High	Decade to few decades
5	South Reef	Outer East (including study location SS1)	*Significant*	Brooding *Isopora*, massive *Porites*, soft corals	Moderate cyclones, bleaching		Low	Several decades
6	North Reef	North Lagoon	*Significant*	Staghorn *Acropora*, massive *Porites*	Bleaching, disease		Low to moderate *	Few decades
7	North Reef	Outer Southwest (including study location SL4)	*Significant* to *Major*	Brooding *Isopora*, massive *Porites*, soft corals	Storms, cyclones		Low	Several decades
8	North Reef	Outer Southeast	*Significant*	Mix of corals*	Cyclone, bleaching*		Moderate *	Few decades*
9	North Reef	Outer Northeast (including study location SS2)	*Sublethal/Low Mortality*	Mix of corals	Cyclone, bleaching		High	< Decade

Scenario 4A - Major structural failure on an offtake vessel at Torosa resulting in a 24 hour 18000 m^3 condensate spill to the sea surface

In Scenario 4A, there is *Major Mortality* at North Reef only, while *Significant Mortality* is predicted at both North and South Reefs. *Sublethal Stress/Low Mortality* occurs at both reefs (see Appendix 2, Table 2, for more detail regarding the location and extent of predicted mortality). Plots showing the location of the hypothetical hydrocarbon dosages expected in this scenario can be found in Appendix 2, Figs 5 – 8.

Recovery periods range from a less than a Decade to Several Decades or longer for communities at the 9 locations considered (Table 5).

For the communities in the Deep (> 20 m) Lagoon at South Reef (Location 1), recovery from *Sublethal Stress/Low Mortality* to *Significant Mortality* is predicted to take from less than a Decade to a Few Decades.

In the shallow-water (< 20 m) habitat, recovery is predicted take Several Decades or longer for communities at one location (Location 6), and a Few to Several Decades at two locations (Locations 8 and 9), all of which had *Significant* to *Major Mortality*.

Recovery is predicted to take a Few Decades at two locations (Locations 5 and 7), a Decade to a few Decades at two locations (Locations 2 and 4), and a Decade at one location (Location 3), after exposure to impacts ranging from *Sublethal Stress/Low Mortality* to *Significant Mortality*.

Table 5. Recovery scenarios for coral communities at South and North Reef following Scenario 4A. Red indicates major mortality, processes that slow recovery, or a slow rate of recovery; orange indicates significant mortality, processes that have a moderate influence on recovery, and a intermediate rate of recovery; yellow indicates sub-lethal impact, processes that aid recovery, and a relatively rapid rate of recovery. The most susceptible groups of corals include those that are worst impacted by typical disturbances and/or those that are slow to recover due to low rates of recruitment and/or growth. #Deep-water corals are likely to have lower resistance to disturbances than their shallow-water counterparts. Mortality to deep-water communities will be far greater if the hydrocarbon plume in shallow-water (< 20 m) reduces light penetration for more than a few weeks. *Little supporting information, least certain.

			IMPACT				RECOVERY	
LOCATION			Scenario impact	Susceptible corals	Subsequent disturbances		Spawned larval supply	Rate of recovery
1	South Reef	Deep Lagoon (> 20 m)	*Sublethal/Low Mortality* to *Significant*#	All	Bleaching, disease		Low*	< Decade to Few Decades
2		Inner West (including study location SL3)	*Sublethal/Low Mortality* to *Significant*	Brooding *Isopora*, soft corals	Storms and cyclones		Low to moderate	Decade to Few Decades
3		Inner South (including study location SL2)	*Sublethal/Low Mortality* to Significant	Branching *Acropora*	Bleaching, disease		Moderate	Decade
4		Inner East (including study location SL1)	*Significant*	Mix of corals	Moderate bleaching, disease, storms, cyclones		High	Decade to Few Decades
5		Outer East (including study location SS1)	*Significant*	Brooding *Isopora*, soft corals	Moderate cyclones, bleaching		Low	Few Decades
6	North Reef	North Lagoon	*Significant* to *Major*	Branching *Acropora*, massive *Porites*	Bleaching, disease		Low to moderate*	Several Decades or longer
7		Outer Southwest (including study location SL4)	*Significant*	Brooding *Isopora*, soft corals	Storms, cyclones		Low	Few Decades
8		Outer Southeast	*Significant* to *Major*	*Acropora*, massive *Porites*, brooding *Isopora*, soft corals*	Cyclone, bleaching*		Moderate*	Few to Several Decades*
9		Outer Northeast (including study location SS2)	*Significant* to *Major*	Massive *Porites* , massive Faviidae, brooding *Isopora*, soft corals*	Cyclone, bleaching		Low*	Few to Several Decades

Scenario 4B - Major structural failure on an offtake vessel at Brecknock resulting in a 24 hour 18000 m^3 condensate spill to the sea surface

In Scenario 4B, there is no *Major Mortality* at either North or South Reef. Some *Significant Mortality* is predicted and *Sublethal Stress/Low Mortality* occurs at both reefs (see Appendix 2, Table 3, for more detail regarding the location and extent of predicted mortality). Plots showing the location of the hypothetical hydrocarbon dosages expected in this scenario can be found in Appendix 2, Figs 9 – 12.

Recovery periods are all less than a Decade for communities at the 9 locations considered (Table 6).

For the communities in the Deep (> 20 m) Lagoon at South Reef (Location 1), recovery from *Sublethal Stress/Low Mortality* to *Significant Mortality* is predicted to take less than a Decade, because only a small part of the habitat was impacted.

In the shallow-water (< 20 m) habitat, recovery is predicted take less than a Decade at all communities (Locations 2 – 9) because the impacts were restricted to *Sublethal Stress/Low Mortality.* We assumed that recovery form *Sublethal/Low Mortality Stress* is likely to occur within all coral groups within approximately 5 years, and that recovery from low levels of mortality in the least resistant corals is facilitated by the production of larvae by spawning corals at adjacent locations and the local production of brooded larvae and asexual growth by the many survivors.

Table 6. Recovery scenarios for coral communities at Scott Reef following Scenario 4B. Red indicates major mortality, processes that slow recovery, or a slow rate of recovery; orange indicates significant mortality, processes that have a moderate influence on recovery, and a intermediate rate of recovery; yellow indicates sub-lethal impact, processes that aid recovery, and a relatively rapid rate of recovery. The most susceptible groups of corals include those that are worst impacted by typical disturbances and/or those that are slow to recover due to low rates of recruitment and/or growth. *Little supporting information, least certain. #Deep-water corals are likely to have lower resistance to disturbances than their shallow-water counterparts. Mortality to deep-water communities will be far greater if the hydrocarbon plume in shallow-water (< 20 m) reduces light penetration for more than a few weeks. *Little supporting information, least certain

			IMPACT				RECOVERY	
LOCATION			Scenario impact	Susceptible corals	Subsequent disturbances		Spawned larval supply	Rate of recovery
1	South Reef	Deep Lagoon (> 20 m)	*Sublethal/Low Mortality* to *Significant*#	All	Bleaching, disease		Low*	< Decade
2	South Reef	Inner West (including study location SL3)	*Sublethal/Low Mortality*	Mix	Storms and cyclones		Low to moderate	< Decade
3	South Reef	Inner South (including study location SL2)	*Sublethal/Low Mortality*	Mix	Bleaching, disease		Moderate	< Decade
4	South Reef	Inner East (including study location SL1)	*Sublethal/Low Mortality*	Mix	Moderate bleaching, disease, storms, cyclones		High	< Decade
5	South Reef	Outer East (including study location SS1)	*Sublethal/Low Mortality*	Mix	Moderate cyclones, bleaching		Low	< Decade
6	North Reef	North Lagoon	*Sublethal/Low Mortality*	Mix	Bleaching, disease		Low to moderate*	< Decade
7	North Reef	Outer Southwest (including study location SL4)	*Sublethal/Low Mortality*	Mix	Storms, cyclones		Low	< Decade
8	North Reef	Outer Southeast	*Sublethal/Low Mortality*	Mix	Cyclone, bleaching*		Moderate*	< Decade
9	North Reef	Outer Northeast (including study location SS2)	*Sublethal/Low Mortality*	Mix	Cyclone, bleaching		High	< Decade

Scenario 6 – Loss of containment during offtake from FLNG facility due to marine breakaway coupling failure resulting in 5 minute 461.5m^3 condensate spill to the sea surface

In Scenario 6, there is no *Major* or *Significant Mortality* at either North or South Reef. *Sublethal Stress/Low Mortality* occurred at both reefs (see Appendix 2, Table 4, for more detail regarding the location and extent of predicted mortality). Plots showing the location of the hypothetical hydrocarbon dosages expected in this scenario can be found in Appendix 2, Fig 13 – 15.

Recovery periods are all less than a Decade for communities at the 9 locations considered (Table 7).

For the communities in the Deep Lagoon (> 20 m) at South Reef (Location 1), recovery from *Sublethal Stress/Low Mortality* to *Significant Mortality* is predicted to take less than a Decade, because only a small part of the habitat was impacted.

In the shallow-water (< 20 m) habitat, recovery is predicted take less than a Decade at all communities (Locations 2 – 9) because impacts were restricted to *Sublethal Stress/Low Mortality.* It is assumed that recovery form *Sublethal Stress* is likely to occur within all coral groups within approximately 5 years, and that recovery from low levels of mortality in the least resistant corals would be facilitated by the external supply of spawned larvae from unaffected parts of the lagoon, locally-produced brooded larvae, and asexual growth by the many survivors in the affected area.

Table 7. Recovery scenarios for coral communities at Scott Reef following Scenario 6. Red indicates major mortality, processes that slow recovery, or a slow rate of recovery; orange indicates significant mortality, processes that have a moderate influence on recovery, and a intermediate rate of recovery; yellow indicates sub-lethal impact, processes that aid recovery, and a relatively rapid rate of recovery. The most susceptible groups of corals include those that are worst impacted by typical disturbances and/or those that are slow to recover due to low rates of recruitment and/or growth. *Little supporting information, least certain. [#]Deep-water corals are likely to have lower resistance to disturbances than their shallow-water counterparts. Mortality to deep-water communities will be far greater if the hydrocarbon plume in shallow-water (< 20 m) reduces light penetration for more than a few weeks. *Little supporting information, least certain.

			IMPACT				RECOVERY	
LOCATION			Scenario impact	Susceptible corals	Subsequent disturbances		Spawned larval supply	Rate of recovery
1	South Reef	Deep Lagoon (> 20 m)	None					
2	South Reef	Inner West (including study location SL3)	None					
3	South Reef	Inner South (including study location SL2)	None					
4	South Reef	Inner East (including study location SL1)	None					
5	South Reef	Outer East (including study location SS1)	*Sublethal/Low Mortality*	Brooding *Isopora*, Pocilloporidae	Moderate cyclones, bleaching		Low	< Decade
6	North Reef	North Lagoon	*Sublethal/Low Mortality*	Staghorn *Acropora*, Acroporidae, Pocilloporidae	Bleaching, disease		Low to moderate*	<Decade
7	North Reef	Outer Southwest (including study location SL4)	None					
8	North Reef	Outer Southeast	*Sublethal/Low Mortality*	Mix	Cyclone, bleaching*		Moderate*	< Decade
9	North Reef	Outer Northeast (including study location SS2)	*Sublethal/Low Mortality*	Brooding *Isopora*, Pocilloporidae	Cyclone, bleaching		High	< Decade

APPENDICES

Appendix 1: Definitions of impact magnitude as a result of contact with hydrocarbon as supplied by Woodside. Impacts are based on maximum hydrocarbon dosages (see Appendix 2).

The summaries of potential impact from hypothetical spill scenarios presented in Appendix 1 and Appendix 2 were provided by Woodside as a basis on which to consider the recovery potential of Scott Reef.

The scale of potential impacts from four spill scenarios representing different orders of magnitude and impact are summarised in Appendix 2, and are based on spill trajectories derived from modelling of the spill scenarios (RPS APASA 2014). The magnitude of indicative potential impacts due to in-water toxicity effects at different depth intervals across the reef are estimated against three dissolved aromatic hydrocarbon dosage thresholds (i.e. high, moderate and low dose). The definitions of indicative consequence to corals from exposure to the different dosage levels are described in the table below.

The thresholds have been derived from a global review of ecotoxicology data on multiple species by French et al. (1999) and French McCay (2002 and 2003). Based on this review, it was found that species lethal sensitivity (fish and invertebrates) to dissolved aromatics exposure greater than four days (96 hour LC50) under different environmental conditions varied from 6 ppb to 400 ppb, with an average of 50 ppb (French McCay 2002). These concentrations provide the basis for the ecotoxicity thresholds adopted, and are equivalent to dosage thresholds of 576, 38,400 and 4,800 ppb-hr [2] respectively.

Exposure to concentrations above the low dosage threshold of 576 ppb-hr is expected to result in sublethal stress and low mortality in sensitive coral species. Exposure to concentrations above the moderate dosage threshold of 4,800 ppb-hr is expected to result in mortality among species that have average sensitivity to toxicity effects, with such species likely to include a significant portion of coral species. Exposure to concentrations above the high dosage threshold of 38,400 ppb-hr is expected to result in mortality among species that are more tolerant to toxicity effects, with such species likely to include the vast majority of coral species.

Exposure	Magnitude	Consequence
High	Major mortality	Adults: Potential for mortality among species that are more tolerant to toxicity effects, with such species likely to include the vast majority of coral species. Mortality expected to affect the vast majority of coral species, which is likely manifested by high incidence of mortality (% dead coral cover) in a coral assemblage that have been exposed at these levels. Gametes & larvae: For any spawned coral gametes and larvae, fertilization and larvae development are expected to impaired, if exposure coincides with major spawning events, with potential for near total reduction in coral recruitment.
Moderate	Significant mortality	Adults: Potential for mortality among species that have average sensitivity to toxicity effects, with such species likely to include a significant portion of coral species. Mortality expected to affect a significant proportion of coral species, which is likely manifested by a significant incidence of mortality (% dead coral cover) in a coral assemblage. Gametes & larvae: Potential for impairment to fertilization and larvae development to virtually all coral species, if exposure coincides with major spawning events, with potential for major reduction in coral recruitment.
Low	Sub-lethal stress / low mortality	Adults: Potential for mortality among species that have the highest sensitivity to toxicity effects. Mortality expected to affect a small proportion of coral species, which is likely manifested by a low incidence of mortality (% dead coral cover) in a coral assemblage that have been exposed at these levels. Gametes & larvae: Potential for impairment to fertilization and larvae development to a significant portion of coral species, if exposure coincides with major spawning events, with potential for significant impact to coral recruitment.

[2] ppb-hr is an adjusted dosage that expresses the concentration (ppb) required to elicit an LC50 response based on 1 hour of exposure. The thresholds derived from laboratory ecotoxicology tests are adjusted to this shorter exposure time because an organism in the marine environment may not be exposed as long as a test organism in the laboratory (96 hours) for a toxic response to be elicited.

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RPS APASA (2014), Browse FLNG Development –Quantitative Spill Risk Assessment. Prepared for Woodside Energy Ltd.

French DP (2000), Estimation of oil toxicity using an additive toxicity model, in: Proceedings, 23rd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, June 14-16, 2000, Vancouver, Canada, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada.

French McCay DP (2002), Development and application of an oil toxicity and exposure model, OilToxEx, Environmental Toxicology and Chemistry 21(10): 2080-2094.

French McCay DP (2003), Development and application of damage assessment modelling: example assessment for the North Cape oil spill. Marine Pollution Bulletin 47: 9-12.

Appendix 2: Impact scenarios and hydrocarbon dosage plots as supplied by Woodside.

Summary tables of plausible worst case impacts to Scott Reef for the different spill scenarios are provided in the tables below. Plots for surface (0-10 m depth) and deep (40-60m depth) water layers and intermediate depths are also provided.

Scenario 1 - Well blow-out at Well Centre (TRE) in Scott Reef channel resulting in a 5 day surface release (3975 m3 condensate) followed by a 72 day subsea release (69,696m3 condensate)

Table 1: Description of plausible worst case impacts to Scott Reef habitats for Scenario 1

Reef Location	Habitats	Dissolved Aromatic Hydrocarbon Dosage Threshold (ppb hr)	Impact Magnitude	Where	Spatial Extent
South Reef	Deep lagoonal	38,400	Major mortality	Margin of channel	~1% of the deep lagoon of South Reef
		4,800	Significant mortality	Northern portion of the lagoon	~30% of the deep lagoon of South Reef
		576	Sublethal stress/ low mortality	Whole lagoon	~100% of the deep lagoon of South Reef
	Shallow water	38,400	Major mortality	East side of Sandy Islet	~2% of shallow water habitat of South Reef
		4,800	Significant mortality	Mostly east and west side, all Sandy Islet, and large patch at the south	~40% of shallow water habitat of South Reef
		576	Sublethal stress/ low mortality	Whole reef	~100% of shallow water habitat of South Reef
North Reef	Deep lagoonal	38,400	Major mortality	none	None
		4,800	Significant mortality	Southwest central lagoon	~20% of the deep lagoon of North Reef
		576	Sublethal stress/ low mortality	Whole lagoon	~100% of the deep lagoon of North Reef
	Shallow water	38,400	Major mortality	Southern portion of North Reef	~5% of shallow water habitat of North Reef
		4,800	Significant mortality	Across east, south and west North Reef	~70% of shallow water habitat of North Reef

Reef Location	Habitats	Dissolved Aromatic Hydrocarbon Dosage Threshold (ppb hr)	Impact Magnitude	Where	Spatial Extent
		576	Sublethal stress/ low mortality	Whole reef	~100% of shallow water habitat of North Reef

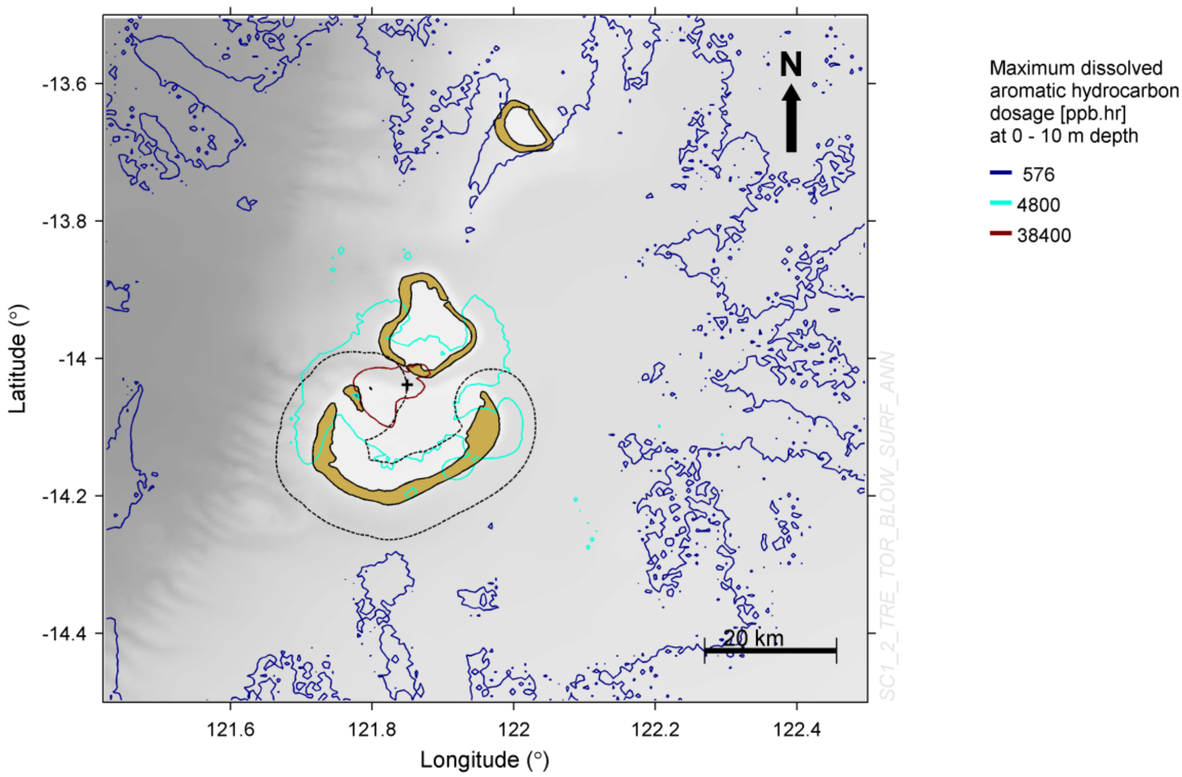


Figure 1 Scenario 1 - Maximum dissolved aromatic hydrocarbon dosage in shallow waters (0-10m depth

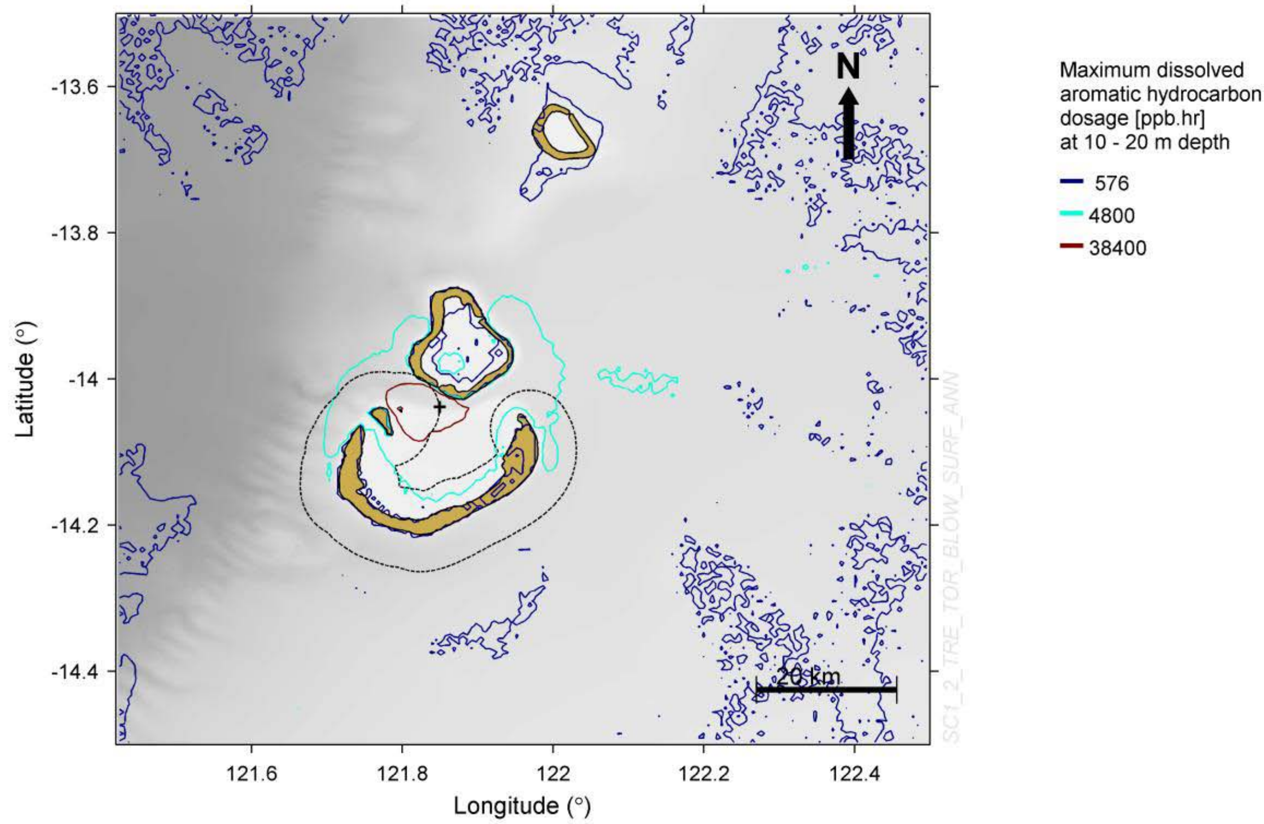


Figure 2 Scenario 1 - Maximum dissolved aromatic hydrocarbon dosage in shallow waters (10-20 m depth)

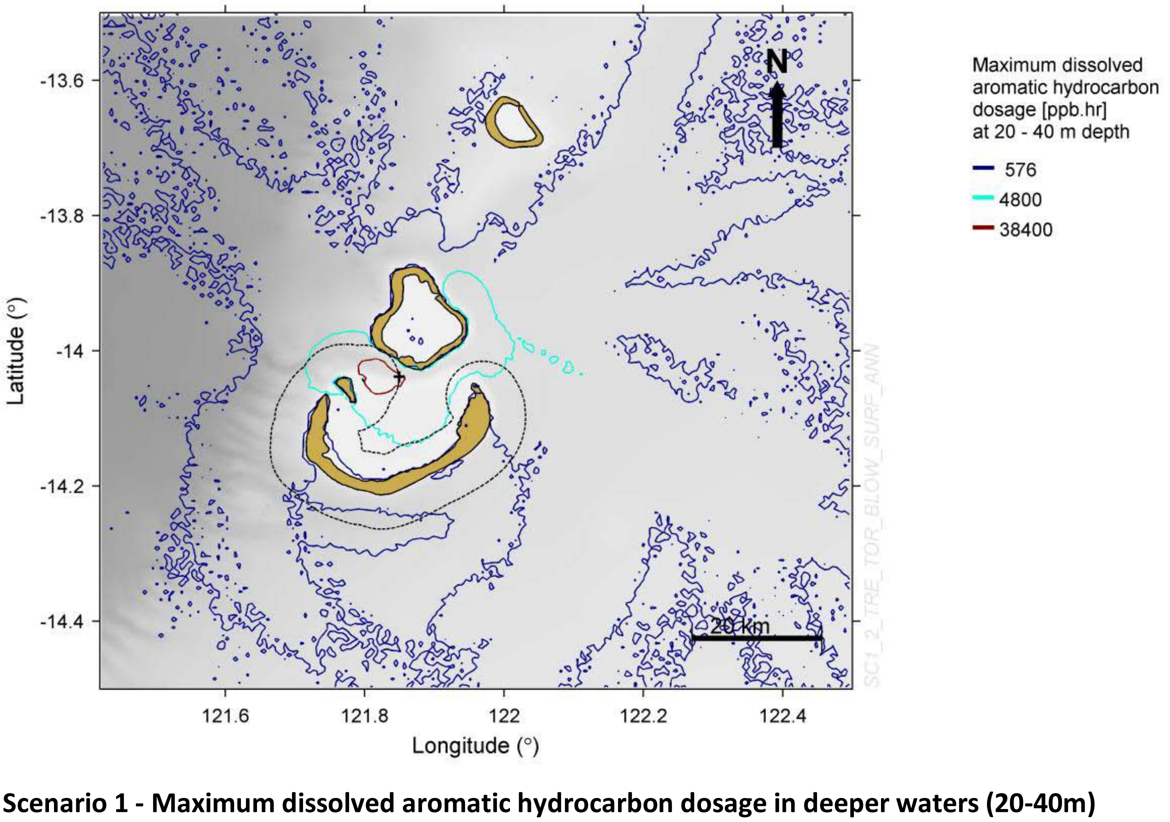


Figure 3 Scenario 1 - Maximum dissolved aromatic hydrocarbon dosage in deeper waters (20-40m)

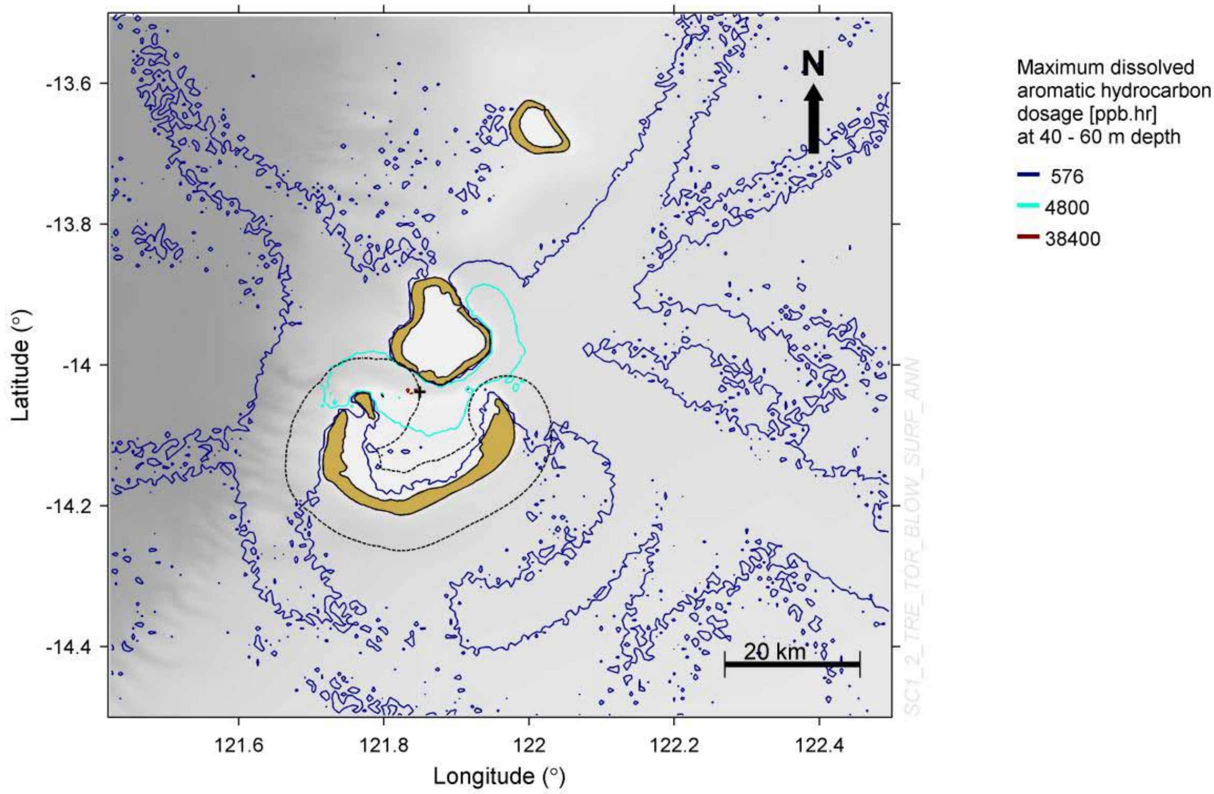


Figure 4 Scenario 1 - Maximum dissolved aromatic hydrocarbon dosage in deep waters (40-60m)

Scenario 4A - Major structural failure on an offtake vessel at Torosa resulting in a 24 hour 18000 m^3 condensate spill to the sea surface

Table 2: Description of plausible worst case impacts to Scott Reef habitats for Scenario 4A

Reef Location	Habitats	Dissolved Aromatic Hydrocarbon Dosage Threshold (ppb hr)	Impact Magnitude	Where	Spatial Extent
South Reef	Deep lagoonal	38,400	Major mortality	none	None
		4,800	Significant mortality	none	None
		576	Sublethal stress/ low mortality	Northwest margin	~2% off the deep lagoon of South Reef
	Shallow water	38,400	Major mortality	none	None
		4,800	Significant mortality	Most of southeast and east side as well as northwest side and Sandy Islet and patch at the south of the reef	~50% of shallow water habitat of South Reef
		576	Sublethal stress/ low mortality	Whole reef except patch in southwest corner	~95% of shallow water habitat of South Reef
North Reef	Deep lagoonal	38,400	Major mortality	Central lagoon	~10% of the deep lagoon of North Reef
		4,800	Significant mortality	Central lagoon	~60% of the deep lagoon of North Reef
		576	Sublethal stress/ low mortality	Central lagoon	~60% of the deep lagoon of North Reef
	Shallow water	38,400	Major mortality	Southeast side and patches on south and east side	~25% of shallow water habitat of North Reef
		4,800	Significant mortality	Whole reef except west and north margins of North Reef	~95% of shallow water habitat of North Reef
		576	Sublethal stress/ low mortality	Whole reef	~100% of shallow water habitat of North Reef

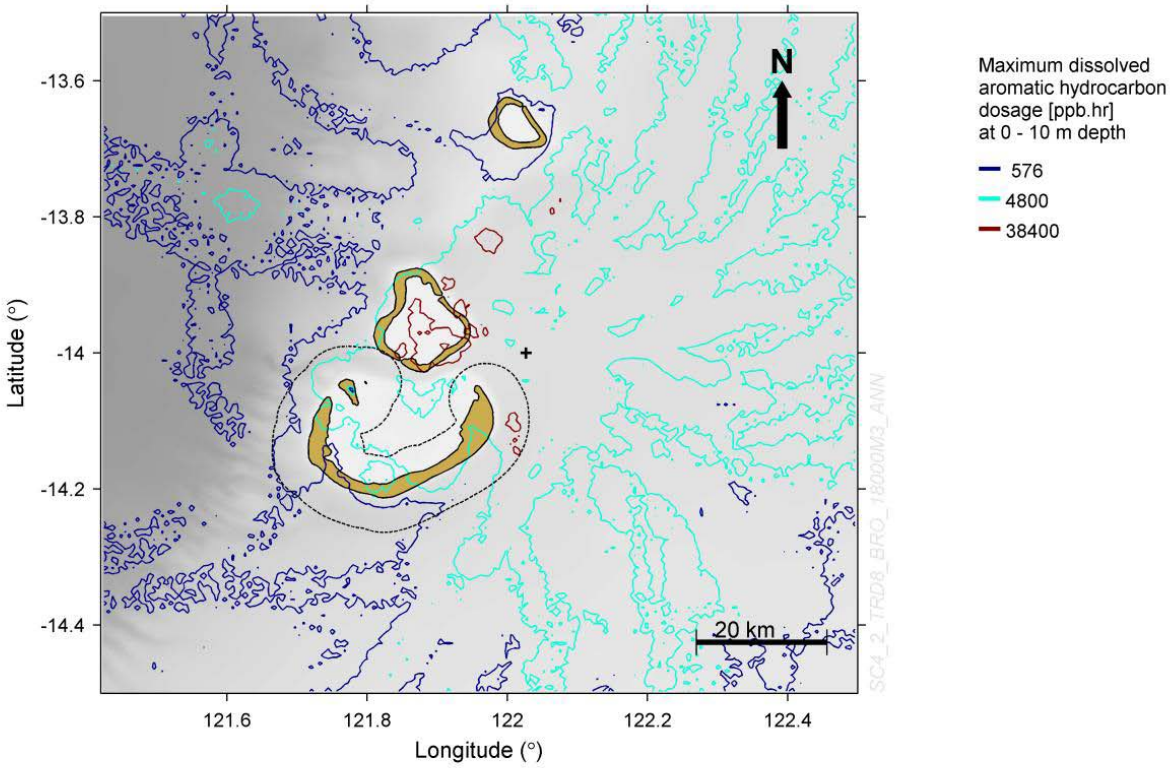


Figure 5 Scenario 4A - Maximum dissolved aromatic hydrocarbon dosage in shallow waters (0-10m depth

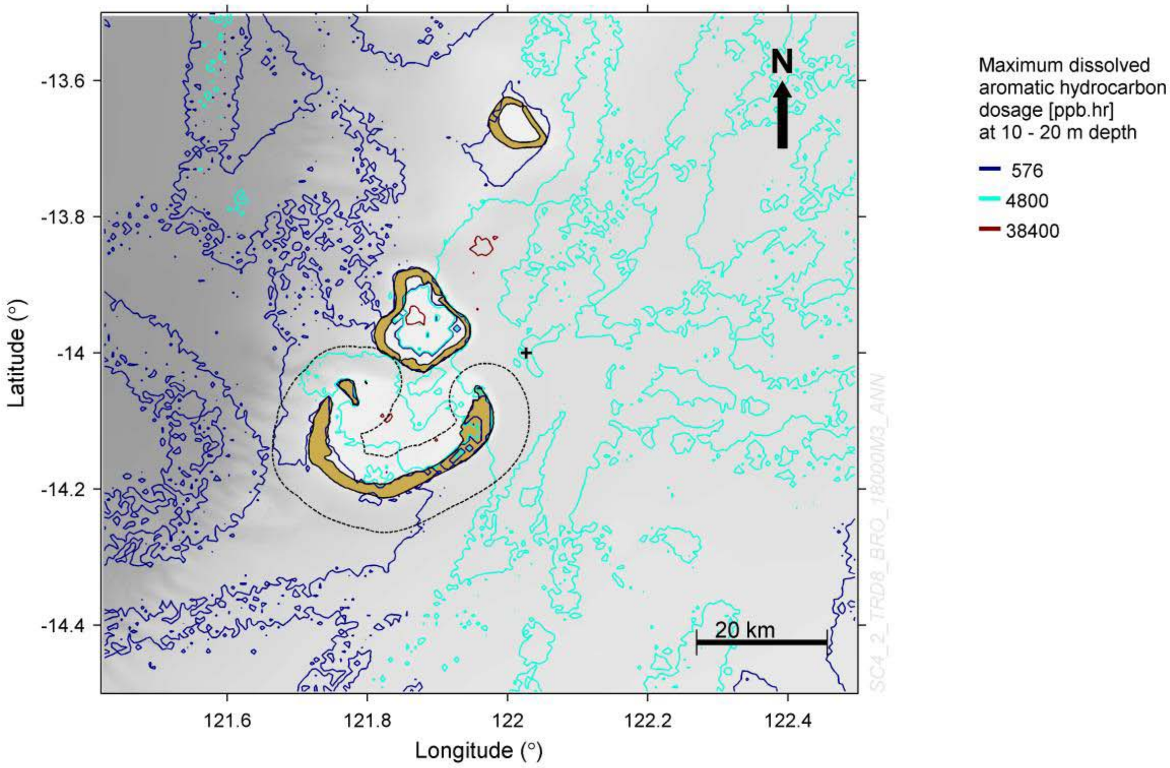


Figure 6 Scenario 4A - Maximum dissolved aromatic hydrocarbon dosage in shallow waters (10-20 m depth)

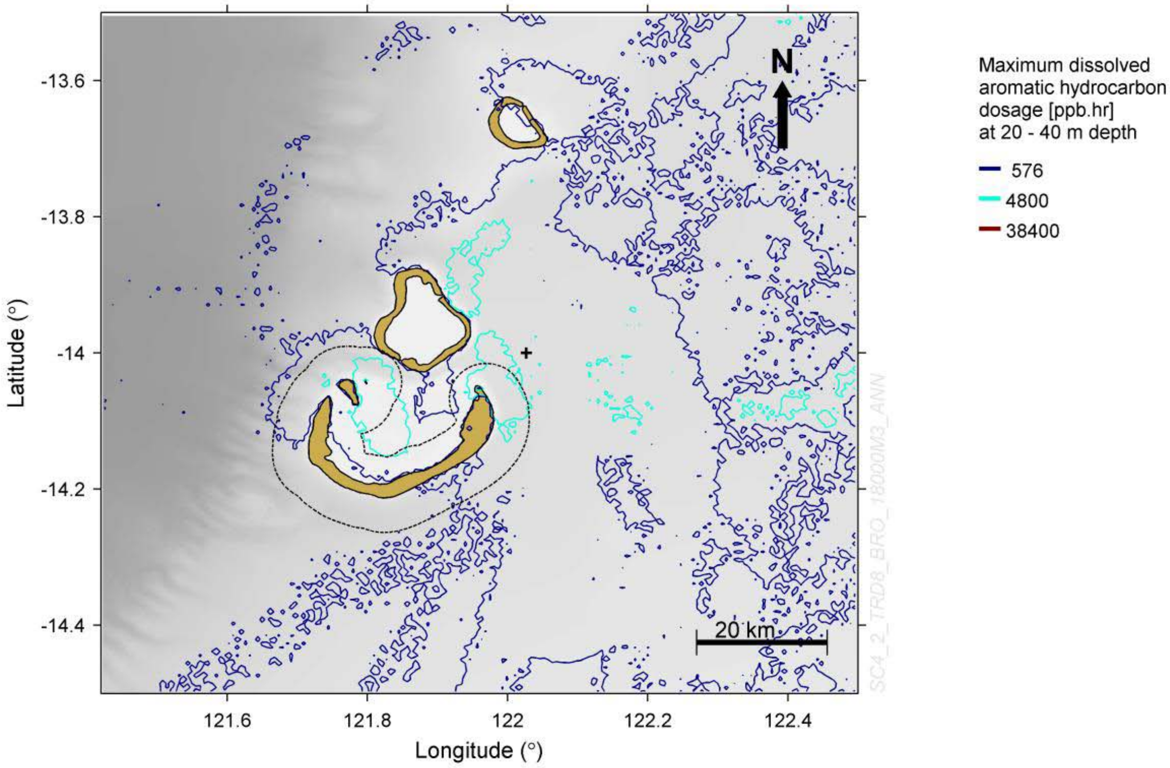


Figure 7 Scenario 4A - Maximum dissolved aromatic hydrocarbon dosage in deeper waters (20-40m)

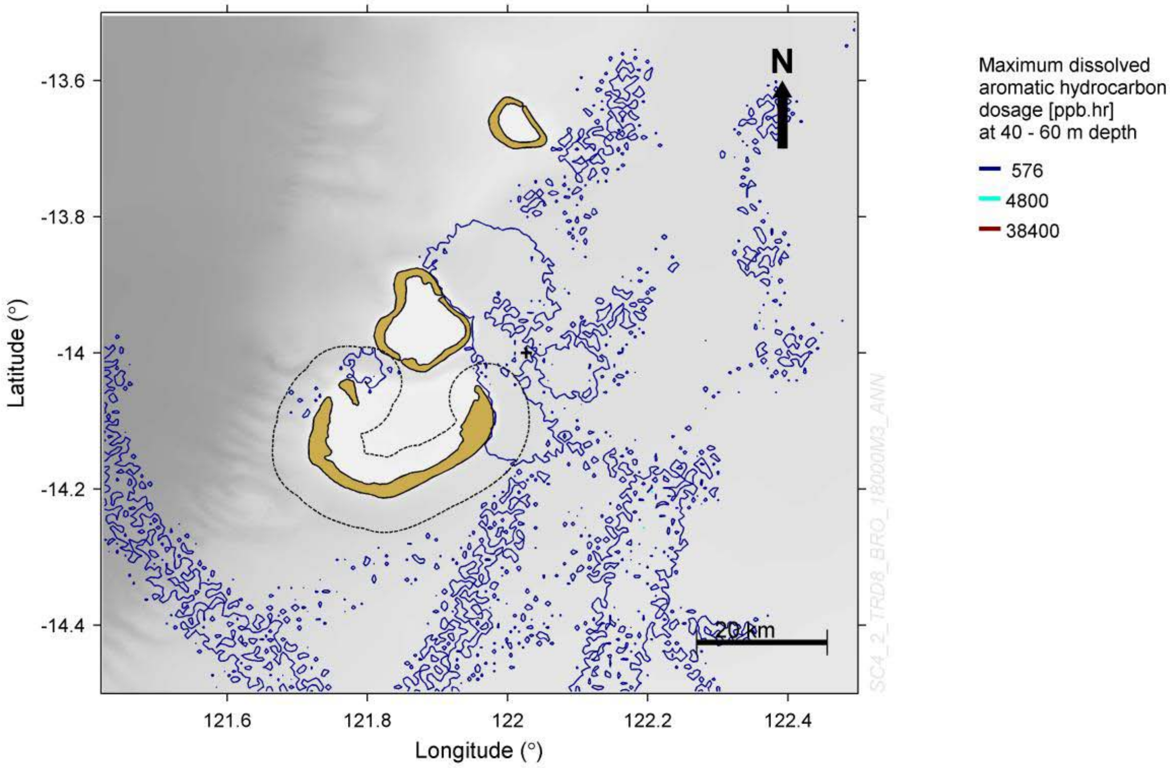


Figure 8 Scenario 4A - Maximum dissolved aromatic hydrocarbon dosage in deep waters (40-60m)

Scenario 4B - Major structural failure on an offtake vessel at Brecknock resulting in a 24 hour 18000 m^3 condensate spill to the sea surface

Table 3: Description of plausible worst case impacts to Scott Reef habitats for Scenario 4B

Reef Location	Habitats	Dissolved Aromatic Hydrocarbon Dosage Threshold (ppb hr)	Impact Magnitude	Where	Spatial Extent
South Reef	Deep lagoonal	38,400	Major mortality	None	None
		4,800	Significant mortality	None	None
		576	Sublethal stress/ low mortality	Two small isolated patches at northwest and east side of the lagoon	~<1% of deep lagoonal waters habitats at Scott Reef
	Shallow water	38,400	Major mortality	None	None
		4,800	Significant mortality	Outer margin of the south side of the reef	~5% of shallow water habitats of South Reef
		576	Sublethal stress/ low mortality	Most of the reef including Sandy Islet except large inner parts of west side and small inner sections at the southwest of the reef ,	~80% of shallow water habitats of South Reef
North Reef	Deep lagoonal	38,400	Major mortality	None	None
		4,800	Significant mortality	None	None
		576	Sublethal stress/ low mortality	None	None
	Shallow water	38,400	Major mortality	None	None
		4,800	Significant mortality	Patch on the northeast side	~2% of shallow water habitats of North Reef
		576	Sublethal stress/ low mortality	North and northeast side of the reef	~40% of shallow water habitats of North Reef

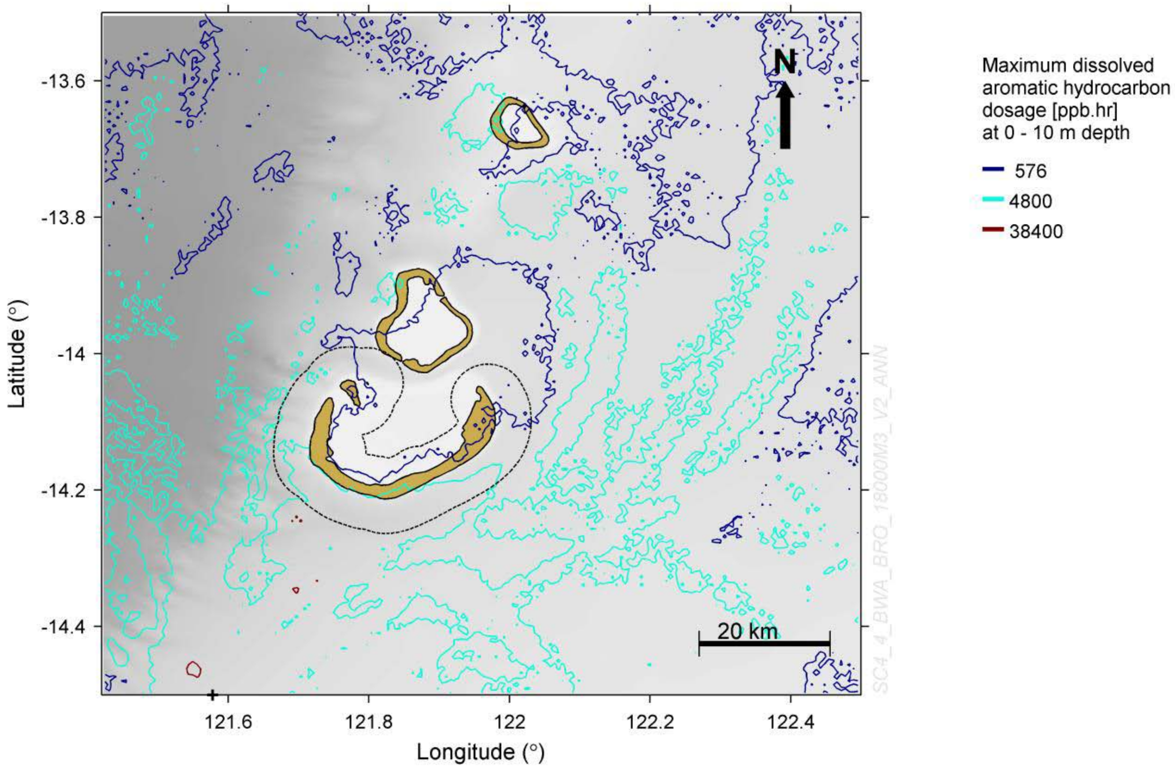


Figure 9 Scenario 4B - Maximum dissolved aromatic hydrocarbon dosage in shallow waters (0-10m depth)

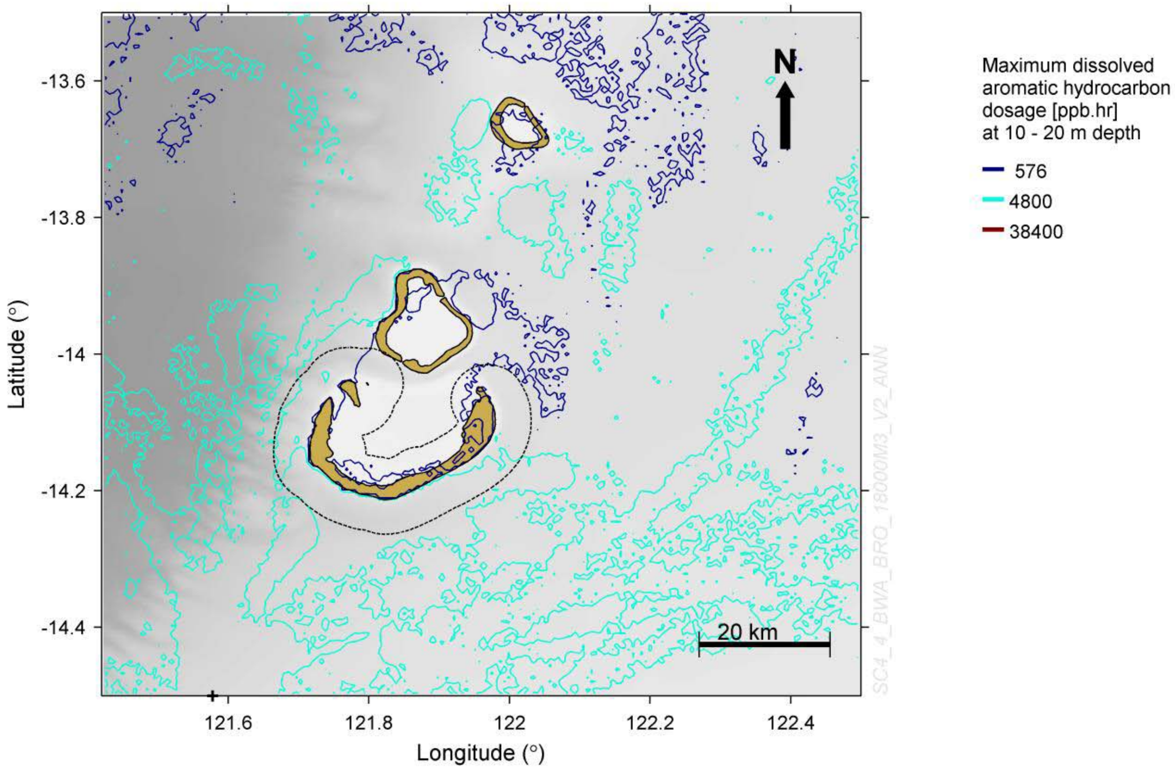


Figure 10 Scenario 4B - Maximum dissolved aromatic hydrocarbon dosage in shallow waters (10-20 m depth)

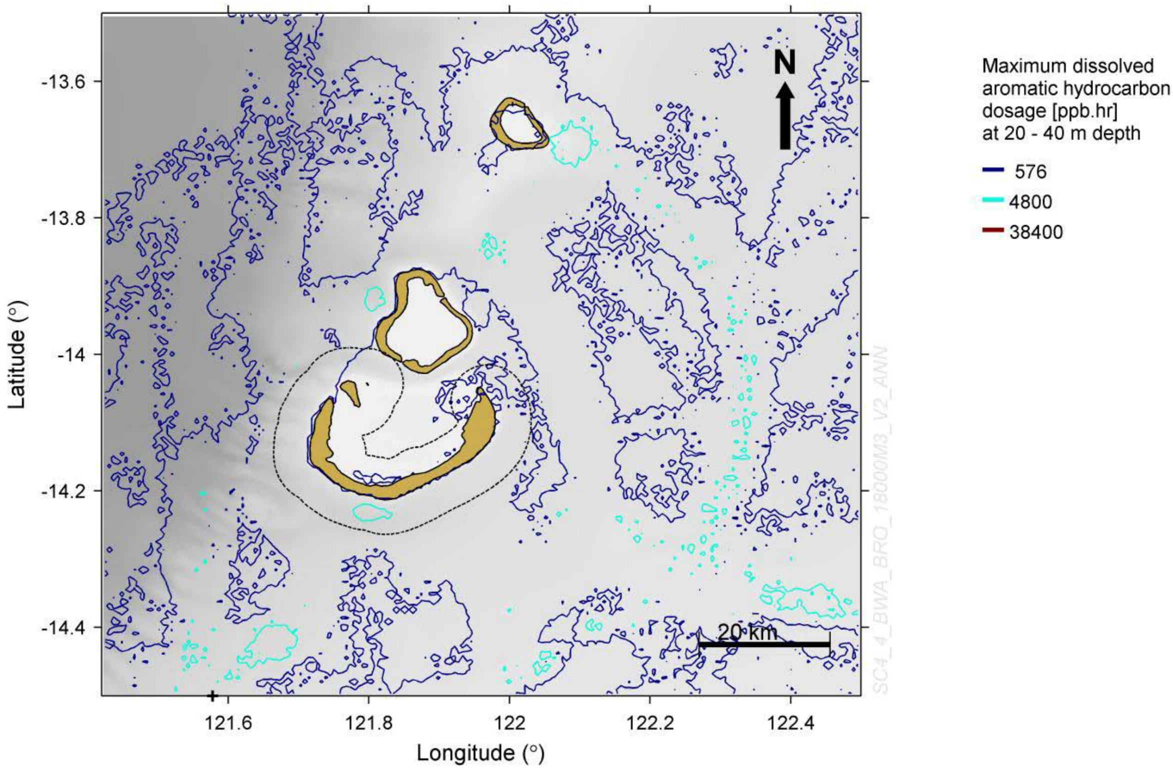


Figure 11 Scenario 4B - Maximum dissolved aromatic hydrocarbon dosage in deeper waters (20-40m depth)

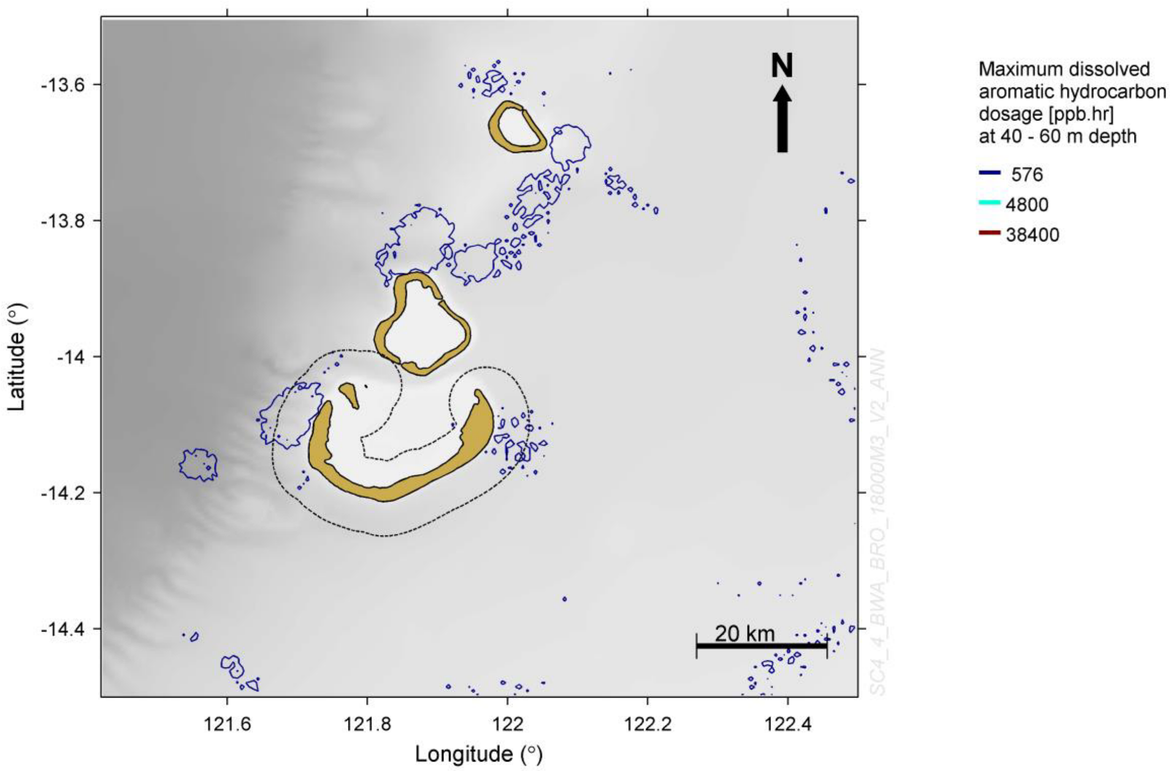


Figure 12 Scenario 4B - Maximum dissolved aromatic hydrocarbon dosage in deep waters (40-60m depth)

Scenario 6 – Loss of containment during offtake from FLNG facility due to marine breakaway coupling failure resulting in 5 minute 461.5m^3 condensate spill

Table 4: Description of plausible worst-case impacts to Scott Reef habitats for Scenario 6

Reef Location	Habitats	Dissolved Aromatic Hydrocarbon Dosage Threshold (ppb hr)	Impact Magnitude	Where	Spatial Extent
South Reef	Deep lagoonal	38,400	Major mortality	None	None
		4,800	Significant mortality	None	None
		576	Sublethal stress/ low mortality	None	None
	Shallow water	38,400	Major mortality	None	None
		4,800	Significant mortality	None	None
		576	Sublethal stress/ low mortality	Outer margin of the east side of the reef	~1% of shallow water habitats of South Reef
North Reef	Deep lagoonal	38,400	Major mortality	none	None
		4,800	Significant mortality	none	None
		576	Sublethal stress/ low mortality	Central lagoon	~5% of deep lagoonal habitats of North Reef
	Shallow water	38,400	Major mortality	none	None
		4,800	Significant mortality	none	None
		576	Sublethal stress/ low mortality	Northeast and east side of the reef	~40% of shallow water habitats of North Reef

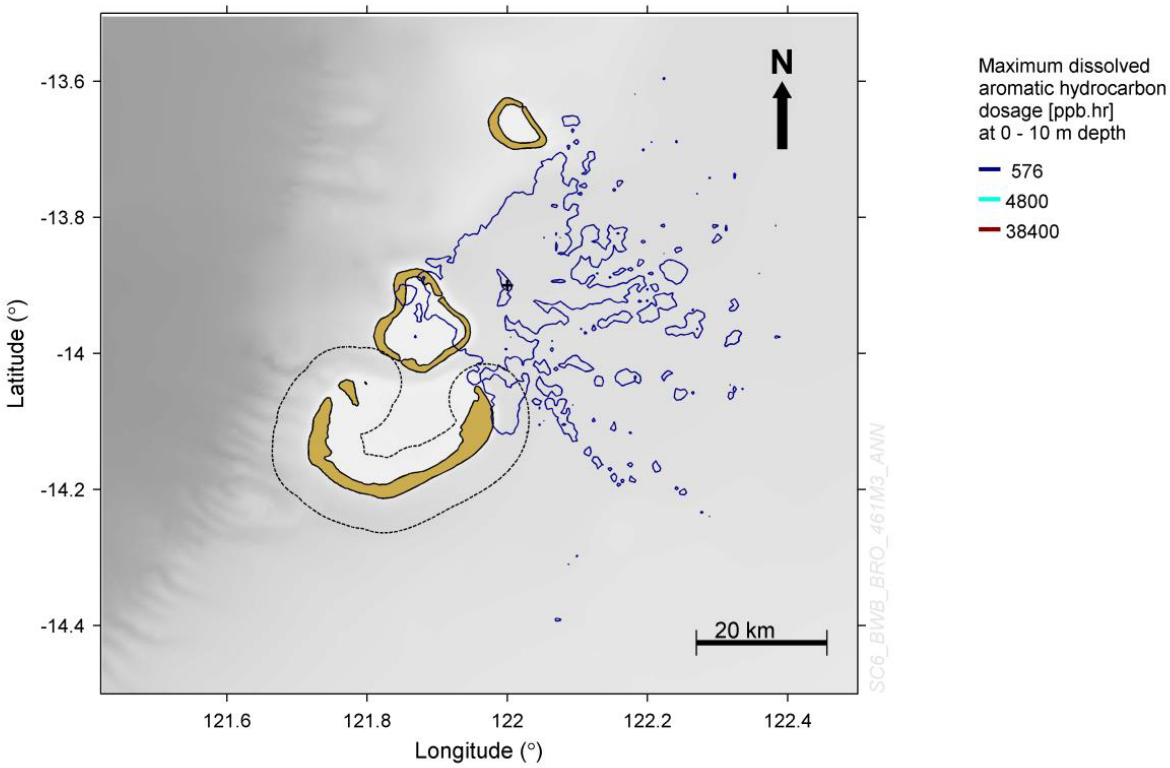


Figure 13 Scenario 6 - Maximum dissolved aromatic hydrocarbon dosage in shallow waters (0-10m depth)

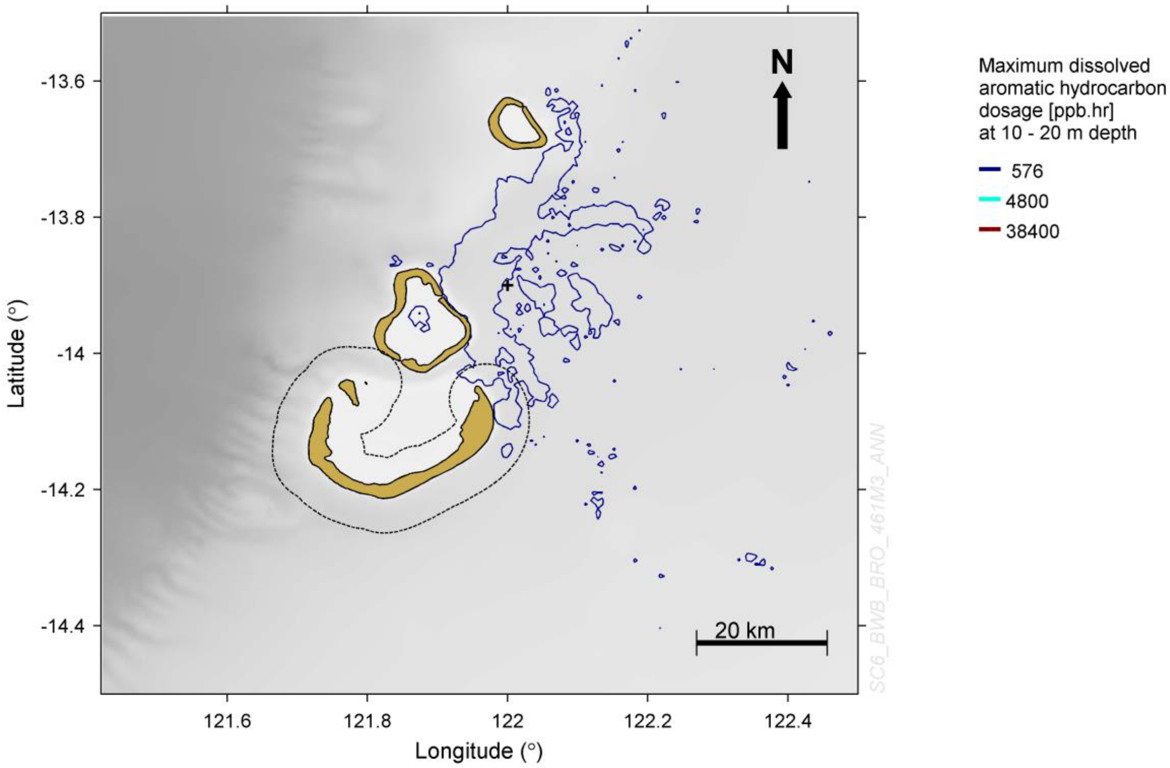


Figure 14 Scenario 6 - Maximum dissolved aromatic hydrocarbon dosage in shallow waters (10-20 m depth)

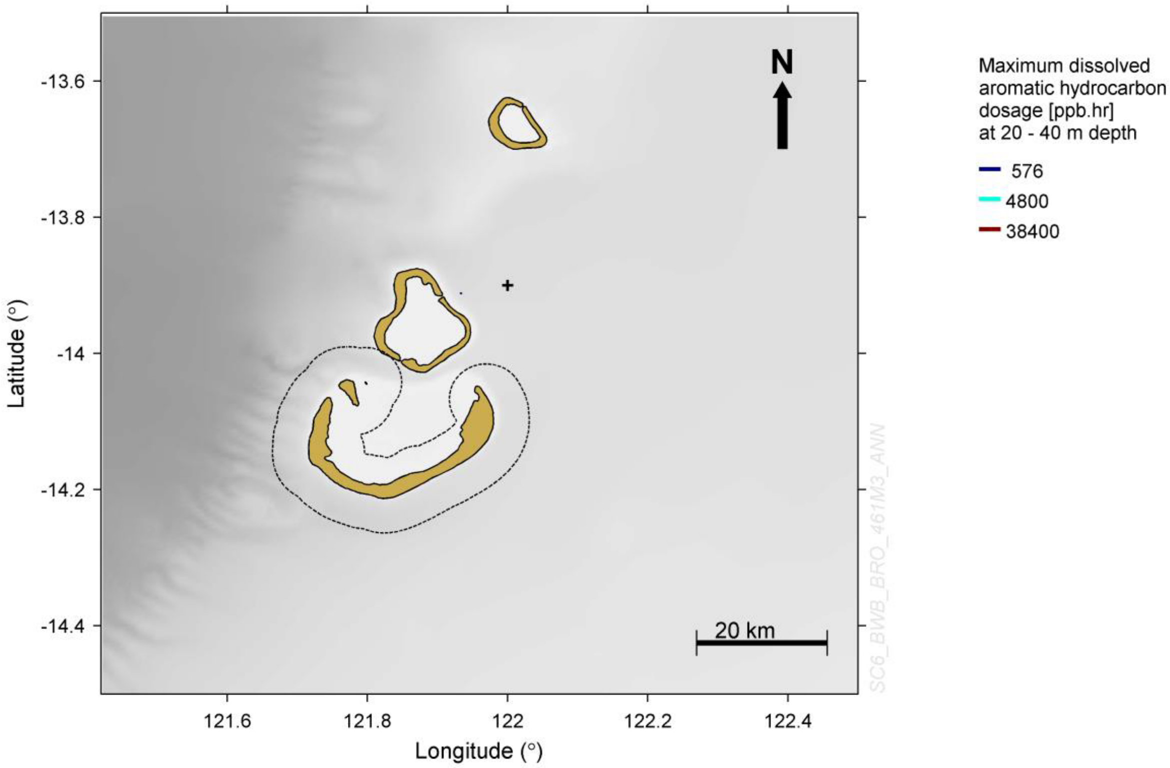
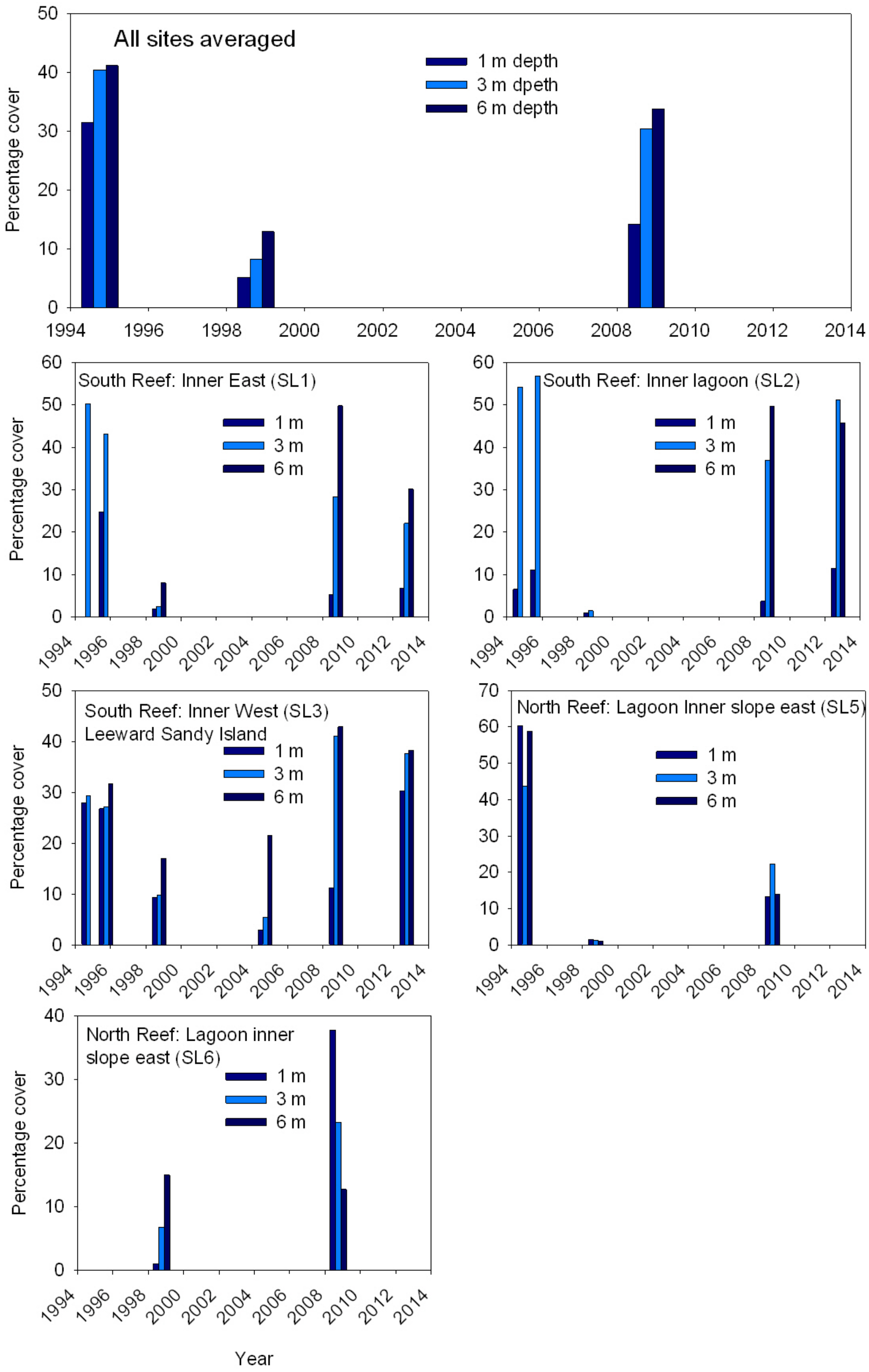


Figure 15 Scenario 6 - Maximum dissolved aromatic hydrocarbon dosage in deeper waters (20-40m depth)

Appendix 3. Impact and recovery of total coral cover at shallow (<9 m) reef slope communities at Scott Reef. Mass-bleaching occurred in 1998 and category 5 Cyclone Fay in 2004. Surveys were conducted at most locations in 1994, 1998 and 2008, but not in many other years. The gaps in data reflect the years in which surveys were not conducted.

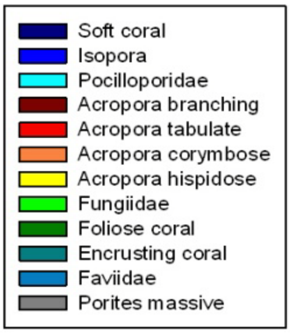


Appendix 4. Impact (1998) and recovery (2010) of cover of hard and soft corals at reef slope sites (9 m) at Scott Reef following the mass-bleaching. Red indicates high impact, processes that slow recovery, and low recovery; orange indicates moderate impact, processes that have moderate influence on recovery, and moderate recovery; yellow indicates low impact, processes that aid recovery, and high recovery.

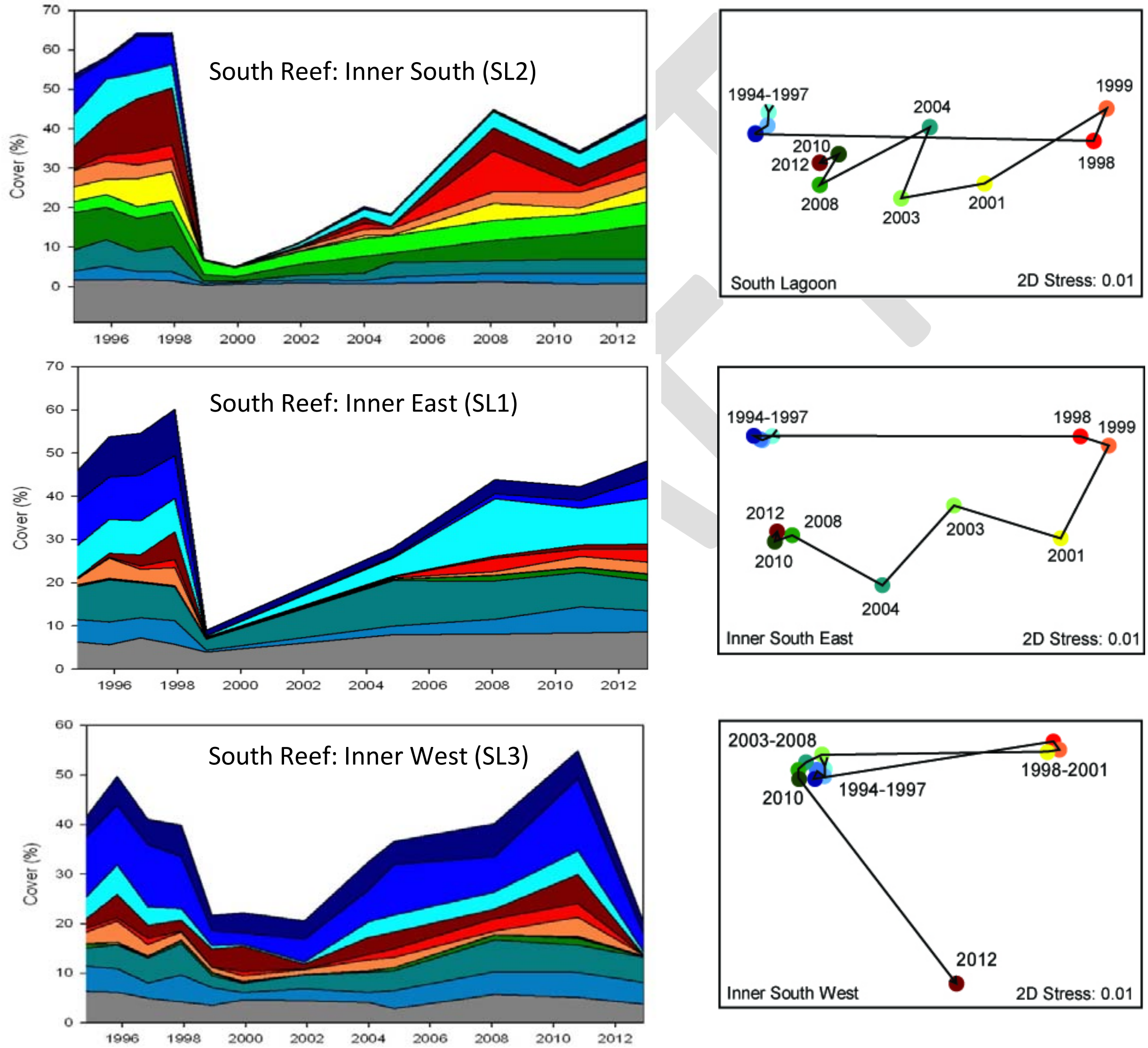
	IMPACT					RECOVERY				
Study Location	Bleaching impact	% impact hard coral	% impact soft coral	Subsequent disturbances		Spawned larval supply	Brooded larval supply	% hard coral recovery	% soft coral recovery	PROCESSES
SL2	High	92	95	Bleaching, disease,		Moderate	Low	53	11	Community had mostly recovered from severe impacts, but for branching, brooding and soft corals. Lower cover in 2010 due to an outbreak of disease and moderate bleaching.
SS2	High	91	92	Cyclone, bleaching		High	Low	92	43	Community had recovered from severe impacts, but for branching, brooding and soft corals. Recovery slowed by additional disturbances and low recruitment of brooding corals.
SS1	High	90	91	Moderate cyclones, bleaching		Low	Low	69	10	Community had mostly recovered from severe impacts, but for branching, brooding, soft corals and massive *Porites*. Recovery slowed by additional disturbances and low recruitment of spawning and brooding corals.
SL1	Moderate	82	87	Moderate bleaching, disease, storms, cyclones		High	High	105	48	Community had recovered from moderate bleaching impacts, but for soft corals and massive *Porites*. Recovery aided by lack of disturbances and high recruitment of spawning corals.
SL4	Moderate	52	67	Storms, cyclones		Low	Moderate	119	74	Community had recovered from moderate bleaching impacts, but for soft corals. Recovery aided by high recruitment of brooded corals, but slowed by low recruitment of spawning corals and exposure to cyclones.
SL3	Low	47	36	Storms,		Moderat	High	138	29	Community had recovered from low bleaching

				cyclones		e				impacts. Recovery aided by high recruitment of brooded corals, but slowed by low recruitment of spawning corals and exposure to cyclones.

Appendix 5. Impact and recovery of coral cover and community structure at the reef slope (9 m) locations at Scott Reef.



The mass-bleaching in 1998 affected all reef-slope (9 m) communities, after which they had varying exposures to subsequent disturbances and impacts to different coral groups (left column). Consequently, the extent of recovery differed among locations (right column; non-metric multidimensional scaling of changes in community structure).



Appendix 5 (continued)